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PRICE LINKAGES IN PHARMACEUTICAL MARKETS

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Abstract

This paper studies the existing price linkage between generics and branded pharmaceuticals, in which the generic price must be a fraction of the latter. Using a vertical differentiation model, we look at the market equilibrium, the effects on the incentives for the brand producer to develop new products, and the possibility of predation by the brand producer over the generic firm. We find that the price linkage increases prices compared to no indexation and it may increase the incentives for the brand producer to expand its set of products. When prices are freely set, the branded firm may also want to expand a new product with a higher quality, but will prefer to remove the original one from the market. Predation may equally occur in both schemes but the price linkage may give fewer incentives for the branded firm to predate while compensating losses with a new drug.

Keywords: Pharmaceutical competition; Generics; Price regulation; Predatory pricing

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1 Introduction

In Portugal, as in other countries[1], the price of generic pharmaceuticals is legislated to be, at most, a given percentage of their branded counterpart – a type of regulation known as *price linkage*. In the particular case of Portugal, the price of generics cannot exceed 50% of the branded originator price[2] (75%, if the generic wholesale price is lower than 10€). While its aim is to give consumers a cheaper alternative to obtain a similar treatment, generic producers have been complaining that brand-name sellers are engaging in predatory pricing. Namely, by setting their prices too low, branded-drug producers can decrease the profit margin of generic producers, since the share they are allowed to charge has an upper limit, thus forcing their exit from the market[3].

This paper studies the consequences of the price linkage on the market for pharmaceuticals. In particular, we look at three questions. First, we study the consequences on the market equilibrium: how prices, profits and consumer surplus change with this price-setting scheme. Second, we look at the incentives for the brand-name firm to expand its set of products. Finally, we look at the question of predation. Producers of brand-name drugs may set their prices low enough so that, at a given maximum share, the allowed generic price may not cover its costs and producers would be forced to exit the market – the so-called *limit price*. Firms may do so to avoid price competition arisen by the existence of other products in the market. In case they are successful, they would enjoy a monopoly position, while consumers would be hurt due to higher prices and the lower number of products from which to choose from. Using

[1] See EGA (2009) for a description of the type of regulation used in generic prices in several countries.
[2] The Ordinance 4/2012, published in January 2nd, 2012, established this limit. Until then, the value was established at 65%.
[3] See Alves and Ramos (2011) for the development of the branded and generic price in a particular drug.

the first two above-mentioned questions, we look at predation from two points of view. First, how does the prospect of predation change with the price linkage. Second, how the possibility of predation changes with the expansion of the set of products.

This paper is primarily a theoretical analysis of the pharmaceuticals market. We use a vertical differentiation model, that is, a model in which products are differentiated by quality, to study the above-mentioned issues affecting these markets. No empirical application is performed, though policy implications are discussed.

Our results show that the price linkage increases pharmaceutical prices compared to the situation in which they are freely set, thus making consumers worse off. Moreover the increase in the generic price is lower than in the branded one, which means that the generic producer steals demand from the branded producer. Therefore, profits for the generic seller increase, while for the branded producer the effect is ambiguous, since demand decreases and at the same time price increases.

The incentives to develop a new brand-name product may be different with price linkage. Indeed, in this case it is not clear whether the firm should continue with the two products in the market, or to move the original brand out of the market, in order to avoid competition between its own products. When prices are freely set, though, our results show that the firm should not remain supplying the market with the two products but rather keep only the new one.

Regarding the possibility of predation, we find that the benefits and costs of predation are the same, regardless of the pricing scheme in place, thus making predation determined only by how attractive it is to be in the duopoly, the alternative strategy to predation. Therefore, predation under the price linkage depends only on the extent to which it increases (decreases) the duopoly profits for the branded producer, making its occurrence less (more) likely. We also find that developing a new product may increase the possibility of predation. In fact, having two products may increase the prospect of predation because the increase in the duopoly profits may be smaller than the increase in benefits of a successful predation. This happens because when in a monopoly, competition between the two goods is internalized and therefore the firm can use them to exploit both low- and high-valuation consumers, greatly increasing profits.

This paper is organized as follows. We start by briefly summarizing the existent relevant literature in Section 2. In Section 3 we present the model and its implications to our analysis while in Section 4 we focus in the discussion of the predation issue. Finally, we conclude in Section 5 by discussing the main policy implications.

2 Literature Review

The initial idea of what became to be known as *vertical product differentiation models* was developed by Gabszewicz and Thisse (1979). In their work, they explored the idea that consumers viewed certain products as of different qualities, with all consumers agreeing on one of the goods to be of higher quality than the others. The crucial point is that consumers have different incomes and that allows for firms with low-quality goods to coexist with the high-quality ones. However, the notion of quality in their work was taken exogenously, without allowing firms to set and compete in qualities. Later, Shaked and Sutton (1982) further developed these types of models to allow for endogenous quality choice[4] and entry, in a dynamic game.

Perhaps the most important breakthrough as far as these models are concerned was the *finiteness property*, a term coined by Shaked and Sutton (1983)[5]. Accordingly, the income distribution creates an upper-limit on the number of firms than can exist in

[4] Motta (1993) further studied the endogenous quality choice.
[5] Previously shown to exist by Gabszewicz and Thisse (1980), but not fully studied.

the market with positive market shares. The extent of this result gives an alternative reasoning to why there are industries where only a small number of firms exist, instead of the argument of scale economies.

The use of vertical product differentiation models, or with a vertical differentiation component, for the study of policies in pharmaceutical markets has become typical. In the pharmaceutical case however, quality has not been modelled as *real*, but rather as *perceived*, since generic drugs must serve for the same therapeutic purpose as the branded drugs. Nevertheless, consumers do have the misperception that branded drugs are of better quality than generics, either due to the brand behind them or for being in the market for longer. Cabrales (2003), for example, studies the impact of a price ceiling in the market equilibrium (allowing for an endogenous quality choice) using a pure vertical differentiation model. Ren (2011) uses, instead, a both vertically and horizontally[6] differentiation model to study the effects of the price linkage system, taking quality as exogenous. In our paper we do not intend to study the effects of each differentiation type in our issues and, as such, we only use vertical differentiation, as it seems to be the most relevant type. Moreover, we use exogenous qualities since, by construction of our model, firms will choose to have products as differentiated as possible, in order to avoid price competition arising from homogenous products.[7]

The notion of *limit price* was first developed by Bain (1949). There, he acknowledge the possibility of a firm charging a price such that it would deter entry into the market, that is, it would make the entrant have zero profits. Though Bain (1949)

[6] In this case, some consumers prefer the brand-name drug while others prefer generic drugs, even at the same price.

[7] See Shaked & Sutton (1982) for this result. In fact, we can show that the generic firm will hit the lower bound available for quality, while the quality chosen by the branded firm will be limited by its cost function.

exclusively uses the limit pricing in an entry deterrence problem, its role in predation in order to drive a competitor out of the market is similar.

The major contribution on the notion of limit price was later developed by both Bain (1956) and Sylos-Labini (1957). Their main ideas were summarized by Modigliani (1958): "… the far more interesting case where fewness [of firms] is the result of purely economic forces, entry being prevented by – and within the limits of – certain price-output policies of existing producers. This is precisely the essence of homogeneous oligopoly analyzed by both Sylos and Bain."

3 The model

To address the problem, we use a vertical differentiation model. Products are ranked by quality, agreed upon by all consumers. Consumers *perceive* the branded drug as having a higher quality than its generic counterpart. We do not use the term *perceive* loosely. As, by definition, the generic drug is similar to the branded one in terms of therapeutic purpose, the difference in quality modelled only exists from the viewpoint of consumers.

We follow Tirole (1988, pp. 96-97). The consumer utility function, U, is equal to $\theta s_k - p_k$ if the consumer buys one unit of good k, and 0 otherwise, where s_k represents the quality and p_k the price of good k, while θ is a taste parameter. Each consumer either buys one unit of one product, or does not buy any. All consumers prefer a higher-quality good, but those with a higher θ are more willing to pay for the increasing quality, as its impact on utility is higher. Therefore, θ represents consumer valuation of the good but can also be thought of as income[8]. Throughout our analysis we make the same assumptions that Tirole (1988, pp 296-297) does, that is, (i) Tastes will be

[8] See Tirole (1988, pp 296-297)

considered uniformly distributed, between $\underline{\theta} \geq 0$ and $\overline{\theta}$. (ii) The market is covered, everyone buys one unit of the good. This requires that $\underline{\theta} s_1 - p_1^* \geq 0$ or $\underline{\theta} \geq \frac{p_1^*}{s_1}$; (iii) Consumer heterogeneity is high enough so that different qualities of the good may coexist. More specifically, $\overline{\theta} > 2\underline{\theta}$; (iv) Constant marginal cost of production, c, equal to all firms; and (v) Firms independently and simultaneously choose prices.

Consider first the case in which two goods are sold in the market, the branded drug, good 2, whose patent already expired, and its generic competitor, good 1. They are ranked in quality as $s_2 > s_1 > 0$. Obviously, $p_2 > p_1$, otherwise consumers would always buy only good 2.

Demands are found by using the notion of indifferent consumer, called $\theta_{2,1}$ and given by $\theta_{2,1} s_2 - p_2 = \theta_{2,1} s_1 - p_1$ or $\theta_{2,1} = \frac{p_2 - p_1}{s_2 - s_1}$. Then, the demand for the branded drug is given by all consumers with taste parameter higher than $\theta_{2,1}$ while the demand for the generic drug is given by all consumers with a smaller taste parameter.

Denote as B the firm selling good 2, the branded one, and as G the firm selling the generic drug, good 1. Profits are given by $\pi_G = (p_1 - c)\left(\frac{p_2 - p_1}{s_2 - s_1} - \underline{\theta}\right)$ and $\pi_B = (p_2 - c)\left(\overline{\theta} - \frac{p_2 - p_1}{s_2 - s_1}\right)$. Solving for the equilibrium yields:

$$p_1^* = c + \frac{\overline{\theta} - 2\underline{\theta}}{3}(s_2 - s_1) \text{ and } p_2^* = c + \frac{2\overline{\theta} - \underline{\theta}}{3}(s_2 - s_1) \qquad (1)$$

$$\pi_G^* = (s_2 - s_1)\frac{\left(\overline{\theta} - 2\underline{\theta}\right)^2}{9} \text{ and } \pi_B^* = (s_2 - s_1)\frac{\left(2\overline{\theta} - \underline{\theta}\right)^2}{9} \qquad (2)$$

3.1 Product expansion without price linkage

Firm B has now the option to adopt a new drug (good 3), newly patented at cost F, which serves for the same therapeutic purpose but it is of higher perceived quality than the original brand drug, $s_3 > s_2$. Recall that this new product is not necessarily better in medicinal terms. Consumers may simple attribute it a higher quality because it is a novelty, has a brand associated to its name or due to the firm's investment in marketing to increase its perceived quality. Nevertheless, it may in fact have a higher quality as it may be better in therapeutic terms, innovation does not need to be ruled out of our model. The firm selling the branded drugs will have two options of expansion: either it launches a new product and keeps the old one or it doesn't and remains only with the new product. In the first option, the original brand will compete with the newer drug and the generic, whereas the latter two will not compete directly among themselves, because of the original brand with an intermediate quality. Demand allocation between firms depends only on the competition between the generic and the original brand, while the competition between the two brands is internalized by the firm.

The second option would be to completely drop the production of the original brand and focus only on the new product. One of the advantages of proceeding in this last manner would be to deviate part of the demand from product 2 to the new one, even if the other part is lost to the generic drug, since the margin would be higher. If the original brand is not available anymore, part of consumers that were buying it will buy the new drug while the others will purchase the generic. The other advantage of removing the original brand lies in increasing the quality differential of the products available in the market, making products less homogeneous, thus increasing prices and profits. Remember that firms are interested in being in each endpoint of quality spectrum in order to decrease price competition.

The first option of expansion is not relevant in this price setting scheme (see the Technical Appendix), as the second option dominates it. The rational decision for the firm is to remove the original brand from the market and sell only the new one. The equilibrium will be given by

$$p_1^* = c + \frac{\overline{\theta}-2\underline{\theta}}{3}(s_3 - s_1) \text{ and } p_2^* = c + \frac{2\overline{\theta}-\underline{\theta}}{3}(s_3 - s_1) \tag{3}$$

$$\pi_G^* = (s_3 - s_1)\frac{(\overline{\theta}-2\underline{\theta})^2}{9} \text{ and } \pi_B^* = (s_3 - s_1)\frac{(2\overline{\theta}-\underline{\theta})^2}{9} \tag{4}$$

Proposition 1 (Consumer surplus) *With a new, higher-quality, product in the market, and the original brand removed, consumer surplus increases only if consumers do not value the good high enough, that is, if* $\overline{\theta}$ *is low.*

Proof. Given the utility function, the consumer surplus (CS) is given by aggregating the utility of individual consumers. Therefore, in the case where there are only goods 1 and 2 in the market, we have: $CS = \int_{\underline{\theta}}^{\theta_{2,1}}\left(\theta s_1 - \left(c + \frac{\overline{\theta}-2\underline{\theta}}{3}(s_2 - s_1)\right)\right)d\theta + \int_{\theta_{2,1}}^{\overline{\theta}}\left(\theta s_2 - \left(c + \frac{2\overline{\theta}-\underline{\theta}}{3}(s_2 - s_1)\right)\right)d\theta$, where $\theta_{2,1} = \frac{c+\frac{2\overline{\theta}-\underline{\theta}}{3}(s_2-s_1)-\left(c+\frac{\overline{\theta}-2\underline{\theta}}{3}(s_2-s_1)\right)}{s_2-s_1}$ is the taste parameter of the consumer indifferent between buying good 1 or 2. After expansion, with goods 1 and 3 in the market, we have $CS = \int_{\underline{\theta}}^{\theta_{3,1}}\left(\theta s_1 - \left(c + \frac{\overline{\theta}-2\underline{\theta}}{3}(s_3 - s_1)\right)\right)d\theta + \int_{\theta_{3,1}}^{\overline{\theta}}\left(\theta s_3 - \left(c + \frac{2\overline{\theta}-\underline{\theta}}{3}(s_3 - s_1)\right)\right)d\theta$, where $\theta_{3,1} = \frac{c+\frac{2\overline{\theta}-\underline{\theta}}{3}(s_3-s_1)-\left(c+\frac{\overline{\theta}-2\underline{\theta}}{3}(s_3-s_1)\right)}{s_3-s_1}$. The difference between the last case and the first gives $\Delta CS = \frac{1}{18}(s_3 - s_2)\left(14\overline{\theta}\underline{\theta} - 11\underline{\theta}^2 - 2\overline{\theta}^2\right)$. It is positive, that is, CS is higher after expansion if $\Delta CS > 0 \Leftrightarrow \overline{\theta} < \frac{7+\sqrt{27}}{2}\underline{\theta}$.■

The new product has both a higher quality and price. As such, the effect on consumer surplus is not straightforward. On the one hand, higher quality brings higher utility. On the other hand, higher price generates lower utility. The crucial point, however, is that the quality of the generic drug remains the same, but its price increases as well due to the lower price competition generated by the product differentiation. If there are consumers that value the good high enough, that is, the top valuation $\overline{\theta}$ is high, it would translate into further increases in both prices to take advantage of these consumers. If there are no such consumers, prices will not be able to increase as much, for the same perceived qualities.

3.2 Price linkage

Generic prices are regulated to be at most a given fraction, call it $\overline{m}$, of the branded drug. The brand producer takes it into account when setting its own prices, since it can more easily influence the generic price.

Consider now the case with two goods, in which $p_1 = mp_2$. Firm B maximizes its profits by choosing p_2 while firm G's decision variable is $m \in]0, \overline{m}]$:

$$\max_m \left\{\pi_G = (mp_2 - c)\left(\frac{p_2(1-m)}{s_2 - s_1} - \underline{\theta}\right)\right\}; \max_{p_2}\left\{\pi_B = (p_2 - c)\left(\overline{\theta} - \frac{p_2(1-m)}{s_2 - s_1}\right)\right\} \quad (5)$$

The market outcome will depend on whether the restriction is binding or not and the results are reported in Table 1, in appendix.

Lemma 1 (Prices) *If the restriction is not binding, generic price indexation to the branded drug will increase equilibrium prices relative to no linkage. Furthermore, the increase in the generic price is lower than that in the branded product.*

Proof. The price variations are given by: $\Delta p_1 = \frac{1}{8}\left[7c + \Omega + 2(s_2 - s_1)(\overline{\theta} - 3\underline{\theta})\right] - \left(c + \frac{\overline{\theta} - 2\underline{\theta}}{3}(s_2 - s_1)\right) = \frac{1}{24}\left(3\Omega - 3\mathrm{c} - 2(s_2 - s_1)\left(\overline{\theta} + \underline{\theta}\right)\right)$ and $\Delta p_2 = \frac{1}{4}\left[3c + \Omega + 2(s_2 - s_1)(\overline{\theta} - \underline{\theta})\right] - \left(c + \frac{2\overline{\theta} - \underline{\theta}}{3}(s_2 - s_1)\right) = \frac{1}{12}\left(3\Omega - 3\mathrm{c} - 2(s_2 - s_1)\left(\overline{\theta} + \underline{\theta}\right)\right)$.

Notice now that $3\Omega - 3\mathrm{c} - 2(s_2 - s_1)\left(\overline{\theta} + \underline{\theta}\right) > 0 \Leftrightarrow$

$$\Leftrightarrow \sqrt{4(s_2-s_1)^2\left(\overline{\theta}-\underline{\theta}\right)^2+c\left(c+4(s_2-s_1)\left(3\overline{\theta}-\underline{\theta}\right)\right)} > c+\frac{2}{3}(s_2-s_1)\left(\overline{\theta}+\underline{\theta}\right)$$

$\Rightarrow \frac{16}{9}(s_2-s_1)\left(2\overline{\theta}-\underline{\theta}\right)\left(3c+(s_2-s_1)\left(\overline{\theta}-2\underline{\theta}\right)\right) > 0$. Therefore, $\Delta p_2 > \Delta p_1 > 0$.■

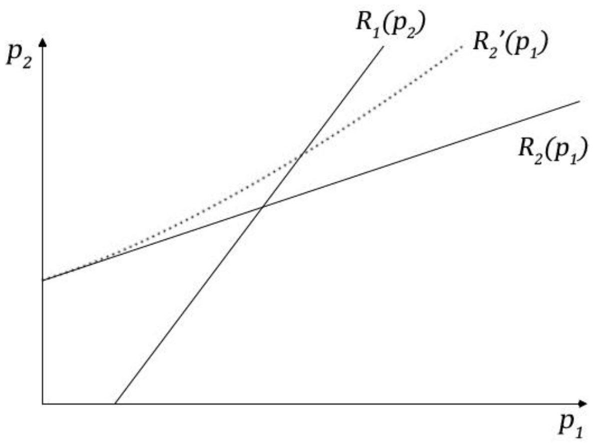

Figure 1 Firm's reaction functions. R_1 is the reaction function of the generic producer while R_2 is the one regarding the brand producer.

In the case of no price linkage, the movement in one's price is chased by the other's since they work as strategic complements. However, when prices are linked, the same movement is reinforced due to the price linkage. Therefore, equilibrium prices increase. Note that this effect comes solely from the change in the branded firm's behaviour. The behaviour of the generic firm remains the same – if it wants to choose a share instead of the price, it will simply decide it as the optimal price divided by the branded price – that is, the generic firm is only affected by the strategic effect. This is easily seen through the reaction functions in Figure 1. In the Technical Appendix we show the conditions that $\overline{m}$ has to meet in order for prices to be lower than without indexation.

Proposition 2 (Profits) *If the restriction is not binding, the generic firm's profits increase with price indexation compared to the no-indexation case. The branded firm's profits increase only if marginal costs are low.*

Proof. Profits of the generic firm increase if $\frac{1}{64}\frac{\left(2(s_2-s_1)\left(\overline{\theta}-3\underline{\theta}\right)+\Omega-c\right)^2}{(s_2-s_1)} > (s_2-s_1)\frac{\left(\overline{\theta}-2\underline{\theta}\right)^2}{9}$ or $\Omega > c+\frac{2}{3}(s_2-s_1)\left(\overline{\theta}+\underline{\theta}\right)$, which is already proven to hold in Lemma 1.

The branded firm's profits increase if $\frac{1}{32(s_2-s_1)}\left(c+2(s_2-s_1)(3\overline{\theta}-\underline{\theta})-\Omega\right)\left(2(s_2-s_1)(\overline{\theta}-\underline{\theta})+\Omega-\mathrm{c}\right)>(s_2-s_1)\frac{(2\overline{\theta}-\underline{\theta})^2}{9}$, which simplifies to $\left(3\Omega-3\mathrm{c}-2(s_2-s_1)(\overline{\theta}+\underline{\theta})\right)\left(3c+2(s_2-s_1)(5\overline{\theta}-\underline{\theta})-3\Omega\right)>0$. The first part was shown to be positive in Lemma 1. The second part is positive if $c<\frac{4}{3}(\mathrm{s}_2-\mathrm{s}_1)(\overline{\theta}+\underline{\theta})$. ∎

To gain some insight, notice that demand allocation in equilibrium changes in favour of generics, since the increase in the generic price is smaller. In fact, this will make some consumers prefer to switch from the branded drug to the generic, which will decrease demand for the former and at the same time it increases for the latter.

Since both the generic demand and price increase, firm's profits unambiguously increase. However, for the branded product, price increases whereas demand decreases, which creates an ambiguous effect. The overall effect on profits depends on whether the profit margin is high or low, which will be determined by the (constant) marginal cost.

Proposition 3 (Consumer Surplus) *The price linkage scheme, without making the restriction binding, will decrease consumer surplus. If the restriction binds, consumer surplus increases only if it makes prices lower than without the linkage system.*

Note that the utility for each consumer suffers only a change in price, not in benefits. Therefore, all consumers face a loss in surplus compared to no linkage.

3.3 Product expansion with price linkage

Again, the brand producer has the option to introduce a second branded product, with higher perceived quality by the consumer than the others, at cost F.

The maximization problem for the generic firm does not change whereas the firm selling the branded drug has, now, two options, just as in the case without price regulation. If it chooses to keep both products, the firms' maximization problems become $\max_m \pi_G = \left\{(mp_2 - c)\left(\frac{p_2(1-m)}{s_2-s_1} - \underline{\theta}\right)\right\}$ and $\max_{p_2,p_3}\left\{\pi_B = (p_2 - c)\left(\frac{p_3-p_2}{s_3-s_2} - \frac{p_2(1-m)}{s_2-s_1}\right) + (p_3 - c)\left(\overline{\theta} - \frac{p_3-p_2}{s_3-s_2}\right)\right\}$. The market outcome is reported in Table 2:

Lemma 2 (Prices) *If the brand-name firm sells two products and the linkage restriction is not binding, equilibrium prices of the original branded and generic products do not change with the expansion of a new branded drug.*

Remember that demand allocation will be decided only the competition between the two original products in the market. Therefore, firms will still be setting the same prices in these two goods in order to reach the optimal demand allocation. The competition between the branded drugs will be internalized by the seller and it will be used not to enlarge demand, but as a mean to extract additional revenue from the consumers that value the most high-quality goods.

The second option would be to remove the original brand from the market due to the reasons already mentioned. In this case, one aspect is important. Since the original brand drug leaves the market, the generic drug can no longer be indexed to it. Moreover, the new drug is patented, meaning that it will not belong to the same homogeneous group as the generic. Therefore, we assume that the generic price will be indexed to the last known price of the original drug, call it $\overline{p_2} = \frac{1}{4}\left[3c + \Omega + 2(s_2 - s_1)(\overline{\theta} - \underline{\theta})\right]$.

In this case, the problems of the firms become $\max_m\left\{\pi_G = (m\overline{p_2} - c)\left(\frac{p_3-m\overline{p_2}}{s_3-s_1} - \underline{\theta}\right)\right\}$ and $\max_{p_3}\left\{\pi_B = (p_3 - c)\left(\overline{\theta} - \frac{p_3-m\overline{p_2}}{s_3-s_1}\right)\right\}$. The market outcome is reported in Table 3. Note that the equilibrium share is simply the non-regulated optimal price divided by the last known price of the drug (which turns the variable into a percentage). Therefore, the equilibrium prices are the non-regulation optimal ones.

The price regulation loses its meaning if the original branded drug leaves the market and the restriction does not bind.

Considering these two possible choices, the optimal one for the brand-name producer is the one giving higher profits. The following proposition is derived.

Proposition 4 (Expansion) W*ith the price linkage scheme and if the firm chooses to expand a new product with a higher perceived quality, then:*

a) *If* $s_3 > \frac{4(s_2-s_1)\left(\overline{\theta}^2((5s_1+9s_2))-\underline{\theta}(9s_2-s_1)(4\overline{\theta}-\underline{\theta})\right)-(\Omega-c)\left(9(\Omega-c)-36\overline{\theta}(s_2-s_1)\right)}{8(s_2-s_1)(7\overline{\theta}-2\underline{\theta})(\overline{\theta}-2\underline{\theta})}$ *profits are higher if the original brand is dropped out of the market and the resulting equilibrium has only two products being sold in the market. The profits of both firms increase due to the higher quality differential.*

b) *If* $s_3 < \frac{4(s_2-s_1)\left(\overline{\theta}^2((5s_1+9s_2))-\underline{\theta}(9s_2-s_1)(4\overline{\theta}-\underline{\theta})\right)-(\Omega-c)\left(9(\Omega-c)-36\overline{\theta}(s_2-s_1)\right)}{8(s_2-s_1)(7\overline{\theta}-2\underline{\theta})(\overline{\theta}-2\underline{\theta})}$ *profits are higher if the brand producer sells two products. The market will be comprised of three different drugs. The profits of the generic seller do not change, while the branded producer's profits increase.*

Proof. Comparing profits between having one product and having two gives $(s_3 - s_1)\frac{(2\overline{\theta}-\underline{\theta})^2}{9} - \left(\frac{4\overline{\theta}(s_2-s_1)\left(\Omega-c+\overline{\theta}(2s_3+s_2-3s_1)\right)-(s_2-s_1)^2\left(4\underline{\theta}(4\overline{\theta}-\underline{\theta})\right)-(\Omega-c)^2}{32(s_2-s_1)}\right) =$

$$\frac{4(s_2-s_1)\left(\underline{\theta}^2(s_1-9s_2+8s_3)-\overline{\theta}^2(5s_1+9s_2-14s_3)-4\overline{\theta}\underline{\theta}(s_1-9s_2+8s_3)\right)+(\Omega-c)\left(9(\Omega-c)-36\overline{\theta}(s_2-s_1)\right)}{288(s_2-s_1)}$$

It is positive when $s_3 > \frac{4(s_2-s_1)\left(b^2((5s_2+9s_1))-a(9s_2-s_1)(4b-a)\right)-(D-c)\left(9(D-c)-36b(s_2-s_1)\right)}{8(s_2-s_1)(7b-2a)(b-2a)}$ and negative otherwise. ■

Intuitively, if the perceived quality of the new good is high enough, then the firm wants to avoid having a product with a quality between the others in order to decrease price competition. However, if the quality of the new good is low (but still higher than in any existing product), price competition will be higher and so the brand producer can use the original brand-name product to manipulate demand allocation between firms and use the new drug to extract higher revenue. In this case, the price of the two original goods does not change. The generic producer maintains the same price and profits while the brand producer's profits increases. This is achieved not by stealing the other firm's clients, but by cannibalising its own consumers from the original brand. Nevertheless, consumers diverted to the new drug pay a higher price, whereas consumers from the original brand pay the same as before.

Proposition 5 (Consumer surplus) *If the producer of the branded product keeps the original product in the market when expanding its set of products, then consumer surplus unambiguously increases. If it chooses to drop the original brand from the market, then consumer surplus increases only if the perceived quality of the good is high enough and consumer's top valuation is low.*

Proof. Using the same method for computing CS as in the case without regulation, the CS with goods 1 and 2 in the market is $CS = \int_{\underline{\theta}}^{\theta_{2,1}} \left(\theta s_1 - \left(\frac{1}{8}\left[7c + \Omega + 2(s_2 - s_1)(\overline{\theta} - 3\underline{\theta})\right]\right)\right) d\theta + \int_{\theta_{2,1}}^{\overline{\theta}} \left(\theta s_2 - \left(\frac{1}{4}\left[3c + \Omega + 2(s_2 - s_1)(\overline{\theta} - \underline{\theta})\right]\right)\right) d\theta$, Where $\theta_{2,1} = \frac{\frac{1}{4}[3c+\Omega+2(s_2-s_1)(\overline{\theta}-\underline{\theta})]-\left(\frac{1}{8}[7c+\Omega+2(s_2-s_1)(\overline{\theta}-3\underline{\theta})]\right)}{s_2-s_1}$. After expansion, with only goods 1 and 3 in the market, we have $CS = \int_{\underline{\theta}}^{\theta_{3,1}} \left(\theta s_1 - \left(c + \frac{\overline{\theta}-2\underline{\theta}}{3}(s_3 - s_1)\right)\right) d\theta + \int_{\theta_{3,1}}^{\overline{\theta}} \left(\theta s_3 - \left(c + \frac{2\overline{\theta}-\underline{\theta}}{3}(s_3 - s_1)\right)\right) d\theta$, where $\theta_{3,1} = \frac{c+\frac{2\overline{\theta}-\underline{\theta}}{3}(s_3-s_1)-\left(c+\frac{\overline{\theta}-2\underline{\theta}}{3}(s_3-s_1)\right)}{s_3-s_1}$.The difference between the second and first case gives $\Delta CS =$

$$\frac{(36(7\overline{\theta}-5\underline{\theta})(\Omega-c)-4(\underline{\theta}^2(176s_3-207s_2+31s_1)+2\overline{\theta}\underline{\theta}(117s_2-5s_1-112s_3)+\overline{\theta}^2(32s_3+9s_2-41s_1)))(s_2-s_1)-9(\Omega-c)^2}{1152(s_2-s_1)}$$

It is positive, that is, consumer surplus is higher after expansion if $\Delta CS > 0$ if:

1. $s_3 > \frac{(s_2-s_1)(4(\overline{\theta}^2(9s_2-41s_1)-\underline{\theta}^2(207s_2-31s_1)+2\overline{\theta}\underline{\theta}(117s_2-5s_1))-36(7\overline{\theta}-5\underline{\theta})(\Omega-c))+9(\Omega-c)^2}{64((s_2-s_1))(-11\underline{\theta}^2+14\overline{\theta}\underline{\theta}-2\overline{\theta}^2)}$

2. The effect of the new perceived quality on the difference in consumer surplus is not straightforward since $\frac{\delta}{\delta s_3}\Delta CS = -\frac{1}{9}(\frac{11}{2}\underline{\theta}^2 + \overline{\theta}^2 - 7\underline{\theta}\overline{\theta})$. Therefore, in order for $\Delta CS > 0$, that is, for consumer surplus after expansion to be higher, we need as well that $\frac{\delta}{\delta s_3}\Delta CS > 0$ so that the difference in consumer surplus increases with s_3. This happens if $\overline{\theta} < \frac{7+\sqrt{27}}{2}\underline{\theta}$.■

To see why consumer surplus unambiguously increases if both brand-name products remain in the market, remember that the price of the two initial products does not change. Consumers still buying these products will not have their surplus changed. Nevertheless, some consumers switch to the new drug. In order for them to prefer it, their surplus will have to increase.

In the latter case, however, prices increase and there is a new product with higher perceived quality, creating an ambiguous effect on the consumer surplus. Moreover, as in the case in which prices were freely set, the quality of the generic does not change, though its price increases. Consumer surplus increases only if the new quality is high, which increases the benefits of consuming it. Nevertheless, it increases both prices as well. Therefore, we also need that consumers do not value the good too much, in order to put a brake in the increase in prices, so firms will not be able to exploit high-valuation consumers.

4 Predation

Generic producers have been claiming that the branded-drug firms are engaging in predatory pricing, that is, a pricing strategy aimed at forcing them to leave the market. More specifically, if the branded-drug producers set a price “low enough”, it may not be profitable for the generic sellers to be in the market, since their prices will have to be lower, and the generic producer will eventually be driven out of the market. Note that this may occur in any pricing scheme since the difference in perceived qualities force generic prices to be lower than their branded counterpart, even if prices are not linked. The main question is if it is more likely to happen in a certain scheme.

A predatory-pricing strategy involves a short-run loss in order to obtain some advantage in a future period. In case predation is successful and the generic firm is driven out of the market, the branded-drug producer would enjoy the monopoly profits.

However, in order to be successful in predation, it needs to lower its price from the profit-maximizing one, which will result on a lower profit while predation lasts.

We consider a time horizon of 2 periods. The condition that makes predatory pricing worthwhile for the branded producer is $\pi^{LP} + \pi^{M} > 2\pi^{D}$. This condition states that the profits in the first period from charging the limit price combined with the monopoly position in the second period is higher than the alternative of being in a duopoly in both periods[9]. We ignore discounting.

4.1 Monopoly price

When the brand-name firm holds a patent, it faces no competition since, by law, no other drug can be sold in the market if it possesses the same therapeutic purpose. Therefore, the firm enjoys its monopoly profits, regardless of the price-setting scheme.

[9] Superscript LP stands for Limit Price, M for Monopoly and D for Duopoly.

We show, in a separate attached Technical Appendix, the computations for the monopoly price and profit. We also show that the branded price under monopoly can actually be lower than under the duopoly, that is, vertical differentiation may explain the so-called generic paradox.

4.2 Limit price

In order for predation to be successful, the brand producer must charge a price "low enough" in order to force the generic firm out of the market. Note that it entails charging a price different than the profit-maximizing one and so it means that the firm is reducing its own profits. The magnitude of the price fall is given by the limit pricing, that is, the price that makes the other firm just indifferent between being, or not, in the market. That point occurs when its profits are zero.

The limit pricing is computed by choosing the branded price such that, upon best responding, the generic producer gets zero profits. Graphically, in Figure 1, the branded firm has to choose a point in the generic firm's reaction function $R_1(p_2)$ such that its profits are zero. However, the reaction function is the same whether prices are indexed or not. Thus, the limit price and profits for the branded firm are the same regardless of the price-setting scheme. Full computations are shown in the Technical Appendix.

4.3 Price-scheme comparison

Predation depends on the branded-firm's profits in three situations: the limit pricing, the monopoly and the duopoly. As already seen, the limit pricing and monopoly profits are the same regardless of the pricing scheme in place. Therefore, the costs and benefits of engaging in predatory pricing are the same. The only difference must come, then, from the alternative to this strategy, the duopoly profits. The higher they are, the less likely it is that predation occurs, since the benefits of not engaging into predation are higher. The relation between the duopoly profits in the two pricing schemes was already analysed.

Proposition 6 (Predation) *The possibility of predation depends only on the duopoly profits. In particular, if the marginal cost of production is low, predation is more likely to occur under an unregulated pricing scheme. If the marginal cost is high, predation is more likely to occur under price linkage.*

Proof. If $c < \frac{4}{3}(\mathrm{s}_2 - \mathrm{s}_1)(\overline{\theta} + \underline{\theta})$, then by Proposition 2 profits for the branded firm are higher under price linkage compared to no indexation. Therefore, the alternative to predation is more appealing and thus it is less likely to occur with price linkage. Note that if $\mathrm{s}_2 = \mathrm{s}_1$ then for sure predation is more likely to occur under price linkage. ■

Another way of looking at this condition is to write it as $c < \frac{8}{3}(\mathrm{s}_2 - \mathrm{s}_1)\mathrm{E}(\theta)$, where $\mathrm{E}(\theta) = \frac{(\overline{\theta}+\underline{\theta})}{2}$ is the expected value of θ. Thus, marginal cost must be lower than $\frac{8}{3}$ of the difference in qualities measured at the mean consumer valuation for predation to be more likely without price indexation.

4.4 The effect of product expansion on predation

One of the complaints of generic producers is that the branded firms are lowering the price of the original brand, thus engaging in predatory strategies, while compensating the losses with a new product with higher quality. In this section we explore this possibility comparing it with the use of only the original product to predate.

Consider the case in which the firm selling the branded product puts a new one in the market, with a higher perceived quality than the original. Due to the nature of vertical product differentiation, the new product will not compete directly with the generic. In order to engage into predatory pricing, the firm has to use only the original brand, by setting its price equal to the limit price while it can set the profit-maximizing price in the new drug. Therefore, the limit price is the same as before[10]. However, profits for the branded firm increase compared to having only one product since it has a new product with higher quality, thus obtaining a bigger profit margin on those sales.

The limit price argument refers only to the costs of engaging in predation. In order to study the complete impact of using two products to predate, we need to see as well the effect of having an additional product in the monopoly profits. The firm will have two products that compete with each other, but this competition will be internalized. The new product will serve only to collect part of the sales that were directed towards the original brand, but for a higher profit. Thus, profits increase.

Finally, in order to check whether predation is more easily incurred with two goods, we need to compare the alternative of predation, the duopoly, when having two products against one. As already studied, expanding a new product does increase profits. Therefore, having two products makes predation easier, but at the same time makes the alternative more attractive. It is not clear, *a priori,* if one firm is simply expanding its operations and benefiting from the higher profits or if it is expanding operations in order to more easily engage in predation. The final effect depends on the relation between the conditions for predation in the two situations.

Proposition 7 (Predation with product expansion) *When prices are not linked, predation is more likely if the firm launches a new product with higher quality. If prices are linked, then the possibility of predation may either remain at the same level or be higher due to the expansion.*

[10] We assume that the branded firm does not exert effort to transfer sales from the original to the new drug. This could happen because the consumption pattern of pharmaceuticals depends not only on consumer behaviour but also on prescription decision by physicians and on pharmaceutical workers recommendation. Firms could also influence these two last agents to predate more easily.

Proof. Recall that, in the case in which prices are not linked, the branded seller would never want to have both products in the market. Therefore, the firm would never use the two products as the alternative strategy to predation, but would only use the new one, high-quality product. The difference between the condition for predation with the new drug with the one given by predation with the original product[11] gives $-\frac{1}{18}\left(\overline{\theta}-2\underline{\theta}\right)\left(7\overline{\theta}-2\underline{\theta}\right)(s_3-s_2)<0$. If prices are linked, the analysis becomes less straightforward. Remember that in this case the firm may prefer, or not, to keep both products as the duopoly alternative to predation. In the case the firm does prefer to drop out the original brand from the market, thus remaining only with the novel product, the analysis is just the same as in the instance prices are not linked because the equilibrium that arises is the "unregulated" equilibrium, as previously shown. The second possibility is to have both products in the market. In this case, the duopoly profits increase by the same amount as the increase in the monopoly and limit price profits. Predation and the alternative become more appealing by the same amount. Therefore, the likelihood of predation is just the same as in the one-product case. Full computations can be found in the Technical Appendix. ■

5 Conclusion

Pharmaceutical prices are regulated in many countries. One type of regulation, applied in Portugal, is the *price linkage*, in which the generic price (of the first one introduced in the market) cannot exceed a given share of its branded counterpart. The main goal of this price regulation is to ensure that the generic prices are low, thus allowing consumers to obtain the same treatment at a lower cost. Nevertheless, generic producers have been arguing that the price linkage scheme allows the branded-drug

[11] The conditions can be found in the Technical Appendix.

firms to more easily engage in predatory pricing, that is, to lower the branded prices in order to obligate the generic price to decrease and force them out of the market.

Our analysis concludes that the price linkage scheme may actually increase pharmaceutical prices, since the branded firm becomes more sensitive to the other's price variations. Allowing for prices to be freely set would increase competition, thus lowering prices.

The type of price-definition scheme that is set is also a matter of concern to product expansion. Indeed, a pricing scheme in which prices are freely set does seem to make branded producers willing to introduce a new product, with higher quality, but at the cost of removing the original brand from the market. In the case of the price linkage, this does not necessarily happen: the branded firm *may* prefer to keep both products.

The concern of generic producers that price linkage may facilitate predation against them is not as straightforward as it may look. The price that the branded firm has to set in order to force the generic firm out of the market is the same in both pricing schemes because the latter chooses the share of the branded product to charge in an analogous way to the case in which prices are freely set. Therefore, the real concern to predation comes from the duopoly profits, because they provide an alternative to the predatory strategy. Decreasing the prospect of predatory pricing, then, implies using the pricing system that gives the highest duopoly profits.

Regarding the use of a new product in order to more easily engage in predation, it appears that the complaints from generic producers may be justified. When using two branded products, the increase in the benefits of predation may be higher, in some situations, than the increase in the duopoly profits, making predation more likely. Still, in some cases, the relation between the predation and the duopoly does not change. In this particular case predation is just as likely with one or two branded products.

All in all, the type of policy that should be adopted depends on two factors. First, the most adequate type of policy depends on the primary objective of the regulator. Indeed, none of the analysed policies improves all the areas a regulator would consider beneficial and that were studied. Second, the results change according to the parameters. Therefore, a proper analysis of the market in which the regulator operates must be conducted, in order to better determine the correct policy to adopt.

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7 Appendix

Let $\Omega = \sqrt{4(s_2 - s_1)^2(\overline{\theta} - \underline{\theta})^2 + c(c + 4(s_2 - s_1)(3\overline{\theta} - \underline{\theta}))}$ in the following tables.

Table 1: Market equilibrium with the two original goods under price regulation

	$\boldsymbol{m^*} \leq \boldsymbol{\overline{m}}$	$\boldsymbol{m^*} > \boldsymbol{\overline{m}}$
m^*	$\frac{1}{4}\left[5 - \frac{\Omega}{c} + 2(s_2 - s_1)(\frac{\overline{\theta} - \theta}{c})\right]$	
p_1^*	$\frac{1}{8}\left[7c + \Omega + 2(s_2 - s_1)(\overline{\theta} - 3\underline{\theta})\right]$	$\overline{m}\left[\frac{c}{2} + \frac{\overline{\theta}(s_2 - s_1)}{2(1 - \overline{m})}\right]$
p_2^*	$\frac{1}{4}\left[3c + \Omega + 2(s_2 - s_1)(\overline{\theta} - \underline{\theta})\right]$	$\frac{c}{2} + \frac{\overline{\theta}(s_2 - s_1)}{2(1 - \overline{m})}$
π_G^*	$\frac{1}{64}\frac{\left(2(s_2 - s_1)\left(\overline{\theta} - 3\underline{\theta}\right) + \Omega - c\right)^2}{(s_2 - s_1)}$	$\frac{\left(\overline{\theta}\overline{m}(s_2 - s_1) - c(1 - \overline{m})(2 - \overline{m})\right)\left(c(1 - \overline{m}) + (s_2 - s_1)(\overline{\theta} - 2\underline{\theta})\right)}{4(s_2 - s_1)(1 - \overline{m})}$
π_B^*	$\frac{\left(c + 2(s_2 - s_1)\left(3\overline{\theta} - \underline{\theta}\right) - \Omega\right)\left(2(s_2 - s_1)\left(\overline{\theta} - \underline{\theta}\right) + \Omega - c\right)}{32(s_2 - s_1)}$	$\frac{\left(c(1 - \overline{m}) - \overline{\theta}(s_2 - s_1)\right)^2}{4(s_2 - s_1)(1 - \overline{m})}$

Table 2: Market equilibrium with three goods under price regulation

	$\boldsymbol{m^*} \leq \boldsymbol{\overline{m}}$	$\boldsymbol{m^*} > \boldsymbol{\overline{m}}$
m^*	$\frac{1}{4}\left[5 - \frac{\Omega}{c} + 2(s_2 - s_1)(\overline{\theta} - \underline{\theta})\right]$	

p_1^*	$\frac{1}{8}\left[7c+\Omega+2(s_2-s_1)(\overline{\theta}-3\underline{\theta})\right]$	$\overline{m}\left[\frac{c}{2}+\frac{\overline{\theta}(s_2-s_1)}{2(1-\overline{m})}\right]$
p_2^*	$\frac{1}{4}\left[3c+\Omega+2(s_2-s_1)(\overline{\theta}-\underline{\theta})\right]$	$\frac{c}{2}+\frac{\overline{\theta}(s_2-s_1)}{2(1-\overline{m})}$
p_3^*	$\frac{1}{4}\left[3c+\Omega+2(\overline{\theta}(s_3-s_1)-\underline{\theta}(s_2-s_1))\right]$	$\frac{c}{2}+\frac{\overline{\theta}(s_3(1-\overline{m})+\overline{m}s_2-s_1)}{2(1-\overline{m})}$
π_G^*	$\frac{1}{64}\frac{\left(2(s_2-s_1)(\overline{\theta}-3\underline{\theta})+\Omega-c\right)^2}{(s_2-s_1)}$	$\frac{\left(\overline{\theta}\overline{m}(s_2-s_1)-c(1-\overline{m})(2-\overline{m})\right)(c(1-\overline{m})+(s_2-s_1)(\overline{\theta}-2\underline{\theta}))}{4(s_2-s_1)(1-\overline{m})}$
π_B^*	$\frac{4\overline{\theta}(s_2-s_1)\left(\Omega-c+\overline{\theta}(2s_3+s_2-3s_1)\right)-(s_2-s_1)^2\left(4\underline{\theta}(4\overline{\theta}-\underline{\theta})\right)-(\Omega-c)^2}{32(s_2-s_1)}-F$	$\frac{\overline{\theta}^2(s_2-s_1)(s_3(1-\overline{m})+\overline{m}s_2-s_1)+c(1-\overline{m})\left(c(1-\overline{m})-2\overline{\theta}(s_2-s_1)\right)}{4(s_2-s_1)(1-\overline{m})}-F$

Table 3: Market equilibrium with two goods under price regulation after expansion if the original brand product is dropped out of the market

	$\boldsymbol{m^* \leq \overline{m}}$	$\boldsymbol{m^* > \overline{m}}$
m^*	$\frac{1}{\overline{\overline{p_2}}}\left(c+\frac{\overline{\theta}-2\underline{\theta}}{3}(s_3-s_1)\right)$	
p_1^*	$c+\frac{\overline{\theta}-2\underline{\theta}}{3}(s_3-s_1)$	$\overline{m}\left(\frac{1}{4}\left[3c+\Omega+2(s_2-s_1)(\overline{\theta}-\underline{\theta})\right]\right)$
p_3^*	$c+\frac{2\overline{\theta}-\underline{\theta}}{3}(s_3-s_1)$	$\frac{c+\overline{\theta}(s_2-s_1)+\overline{m}\left(\frac{1}{4}\left[3c+\Omega+2(s_2-s_1)(\overline{\theta}-\underline{\theta})\right]\right)}{2}$
π_G^*	$(s_3-s_1)\frac{\left(\overline{\theta}-2\underline{\theta}\right)^2}{9}$	$\frac{(\overline{m}(2(s_2-s_1)(\overline{\theta}-\underline{\theta})+\Omega+3c)-4c)\left(4c+4(s_3-s_1)(\overline{\theta}-2\underline{\theta})-\overline{m}(2(s_2-s_1)(\overline{\theta}-\underline{\theta})+\Omega+3c)\right)}{32(s_3-s_1)}$
π_B^*	$(s_3-s_1)\frac{\left(2\overline{\theta}-\underline{\theta}\right)^2}{9}-F$	$\frac{\left(4\overline{\theta}(s_3-s_1)+\overline{m}\left(\Omega+3c+2(s_2-s_1)(\overline{\theta}-\underline{\theta})\right)-4c\right)^2}{64(s_3-s_1)}$

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PRICE LINKAGES IN PHARMACEUTICAL MARKETS - TECHNICAL APPENDIX -

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1 Product expansion without price linkage

The firm selling the branded drugs will have two options of expansion: either it launches a new product and keeps the old one or it doesn't and remains only with one product. In the first option the two products will compete among themselves and with the generic. More specifically, the original brand will compete with the newer drug and the generic, while the latter two will not compete directly among themselves. This can be clearly seen by the new demand functions, which were obtained in an analogous way to the standard case

$$D_3(p_3, p_2) = \overline{\theta} - \frac{p_3 - p_2}{s_3 - s_2};\ D_2(p_3, p_2, p_1) = \frac{p_3 - p_2}{s_3 - s_2} - \frac{p_2 - p_1}{s_2 - s_1};\ D_1(p_2, p_1) = \frac{p_2 - p_1}{s_2 - s_1} - \underline{\theta} \qquad (1)$$

In any case, demand allocation between firms depends only in the competition between the generic and the original brand, whereas the competition between the two brands is internalized by the firm. This means that the sources of competitive constraints are different for each branded pharmaceutical. The original one faces a constraint posed by another firm's product (as well as by the newer product) and increases in price will lead to losses in demand in favour of the other firm. However, a high price in the new product will not lead to demand losses to the other firm. Consumers will choose to buy the original brand instead, leaving the newer product with lower demand but the overall demand for the firm remains the same. Nevertheless, a deviation from the new to the original drug would translate into a loss of the profit margin, a situation the firm would like to avoid.

The maximization problem for the firm selling the generic remains the same, $\max_{p_1} \left\{\pi_G = (p_1 - c)\left(\frac{p_2 - p_1}{s_2 - s_1} - \underline{\theta}\right)\right\}$, while the firm selling the branded product faces a new one, $\max_{p_2, p_3} \left\{\pi_B = (p_2 - c)\left(\frac{p_3 - p_2}{s_3 - s_2} - \frac{p_2 - p_1}{s_2 - s_1}\right) + (p_3 - c)\left(\overline{\theta} - \frac{p_3 - p_2}{s_3 - s_2}\right) - F\right\}$.

The new equilibrium is:

$$p_1^* = c + \frac{\overline{\theta} - 2\underline{\theta}}{3}(s_2 - s_1);\ p_2^* = c + \frac{2\overline{\theta} - \underline{\theta}}{3}(s_2 - s_1);$$
$$p_3^* = c + \overline{\theta}\left(\frac{s_3}{2} + \frac{s_2}{6} - 2\frac{s_1}{3}\right) - \underline{\theta}\frac{(s_2 - s_1)}{3} \tag{2}$$

$$\pi_G^* = (s_2 - s_1)\frac{\left(\overline{\theta} - 2\underline{\theta}\right)^2}{9}$$
$$\pi_B^* = \frac{1}{36}\left[s_3 9\overline{\theta}^2 + s_2\left(7\overline{\theta} - 2\underline{\theta}\right)\left(\overline{\theta} - 2\underline{\theta}\right) - s_1 4\left(2\overline{\theta} - \underline{\theta}\right)^2\right] - F \tag{3}$$

Note that $p_3^* > p_2^*$ and that the price of the two initial products did not change. All the competitive pressure associated with the new product is internalized in the joint maximization by the branded producer.

The second option would be to completely drop the production of the original brand and focus only in the new product. In this case the firms' problem would revert to the initial one, but with a new, higher quality: $\max_{p_1}\left\{\pi_G = (p_1 - c)\left(\frac{p_3 - p_1}{s_3 - s_1} - \underline{\theta}\right)\right\}$ and $\max_{p_3}\left\{\pi_B = (p_3 - c)\left(\overline{\theta} - \frac{p_3 - p_1}{s_3 - s_1}\right) - F\right\}$. The solution yields equilibrium prices

$$p_1^* = c + \frac{\overline{\theta} - 2\underline{\theta}}{3}(s_3 - s_1) \text{ and } p_3^* = c + \frac{2\overline{\theta} - \underline{\theta}}{3}(s_3 - s_1) \tag{4}$$

And equilibrium profits

$$\pi_G^* = (s_3 - s_1)\frac{\left(\overline{\theta} - 2\underline{\theta}\right)^2}{9} \text{ and } \pi_B^* = (s_3 - s_1)\frac{\left(2\overline{\theta} - \underline{\theta}\right)^2}{9} - \mathrm{F} \tag{5}$$

Lemma 1 (Prices) *If the firm launches a new product with higher perceived quality and drops the other, prices increase compared to the original two-product situation.*

The difference in perceived quality between the two products is higher, which allows firms to decrease price competition, resulting in higher prices.

The comparison between these two options allows us to derive the following proposition.

Proposition 1 (Expansion) *Under an unrestricted price-setting scheme, if the brand-name firm offers a new product with a higher perceived quality than the others, it is better off by removing the original drug from the market.*

Proof. Taking the difference in profits between having one product and two, (5) – (3), gives $(s_3 - s_1)\frac{(2\overline{\theta}-\underline{\theta})^2}{9} - \mathrm{F} - \left(\frac{1}{36}\left[s_3 9\overline{\theta}^2 + s_2(7\overline{\theta} - 2\underline{\theta})(\overline{\theta} - 2\underline{\theta}) - s_1 4(2\overline{\theta} - \underline{\theta})^2\right] - \mathrm{F}\right)1 = \frac{1}{36}(7\overline{\theta} - 2\underline{\theta})(\overline{\theta} - 2\underline{\theta})(s_3 - s_2) > 0.$ ■

The decision to expand must also be contingent on the fixed cost of expansion.

Proposition 2 (Profits) *The firm producing the branded drug increases its profits with the introduction of a new product, provided the patent cost is not too high. The profits of the generic seller increase as well.*

Proof. The condition that ensures profits of having one higher-quality product are larger than having the original product is the difference between (5) and profits under the duopoly: $(s_3 - s_1)\frac{(2\overline{\theta}-\underline{\theta})^2}{9} - \mathrm{F} > (s_2 - s_1)\frac{(2\overline{\theta}-\underline{\theta})^2}{9}$ or $\mathrm{F} < \frac{(2\overline{\theta}-\underline{\theta})^2}{9}(s_3 - s_2)$. ■

2 Product expansion with price linkage

Remember that under price linkage:

a) If the branded producer does not expand:

$$\pi_B^* = \frac{(c+2(s_2-s_1)(3\overline{\theta}-\underline{\theta})-\Omega)(2(s_2-s_1)(\overline{\theta}-\underline{\theta})+\Omega-\mathrm{c})}{32(s_2-s_1)} \tag{6}$$

b) If the firm expands but drops off the original product from the market:

$$\pi_B^* = (s_3 - s_1)\frac{(2\overline{\theta}-\underline{\theta})^2}{9} - F \tag{7}$$

c) If the firm expands and keeps both products in the market,

$$\pi_B^* = \frac{4\overline{\theta}(s_2-s_1)\left(\Omega-c+\overline{\theta}(2s_3+s_2-3s_1)\right)-(s_2-s_1)^2\left(4\underline{\theta}(4\overline{\theta}-\underline{\theta})\right)-(\Omega-c)^2}{32(s_2-s_1)} - F \qquad (8)$$

It was proven that, depending on the parameters, the firm would either keep, or not, the original drug in the market, after developing a new product. Thus, we need to compare both situations to the fixed cost of expansion.

Proposition 3 (Profits) *The firm producing the branded drug increases its profits with the introduction of a new product, provided the patent cost is not too high.*

Proof. If the firm sells only one product, the condition that ensures profits of having one higher-quality product are larger than having the original product is (7) > (6):

$$(s_3-s_1)\frac{(2\overline{\theta}-\underline{\theta})^2}{9} - \mathrm{F} > \frac{\left(c+2(s_2-s_1)\left(3\overline{\theta}-\underline{\theta}\right)-\Omega\right)\left(2(s_2-s_1)\left(\overline{\theta}-\underline{\theta}\right)+\Omega-c\right)}{32(s_2-s_1)}$$ or

$$\mathrm{F} < \frac{32}{9}\frac{(s_3-s_1)(s_2-s_1)(2\overline{\theta}-\underline{\theta})^2}{\left(c+2(s_2-s_1)\left(3\overline{\theta}-\underline{\theta}\right)-\Omega\right)\left(2(s_2-s_1)\left(\overline{\theta}-\underline{\theta}\right)+\Omega-c\right)}.$$

If it is better for the firm to keep the two products, it is willing to expand if (8) > (6):

$$\frac{4\overline{\theta}(s_2-s_1)\left(\Omega-c+\overline{\theta}(2s_3+s_2-3s_1)\right)-(s_2-s_1)^2\left(4\underline{\theta}(4\overline{\theta}-\underline{\theta})\right)-(\Omega-c)^2}{32(s_2-s_1)} - F >$$

$$\frac{(c+2(s_2-s_1)(3\overline{\theta}-\underline{\theta})-\Omega)(2(s_2-s_1)(\overline{\theta}-\underline{\theta})+\Omega-c)}{32(s_2-s_1)}$$, which solves for $\frac{\overline{\theta}^2(s_3-s_2)}{4} > F$ ■

3 Equilibrium prices under linkage with a binding restriction

If the share of the branded-product price is regulated properly, prices can be lower than without regulation. Particularly, if $\overline{\mathrm{m}}$ is low enough both the generic and branded prices will be lower than the original. Nevertheless, there are values for $\overline{\mathrm{m}}$ in which the generic price is lower than the initial situation while the branded prices are higher.

To see why, note that in order for the regulated generic price to be lower than the unregulated we need $\overline{m}\left[\frac{c}{2}+\frac{\overline{\theta}(s_2-s_1)}{2(1-\overline{m})}\right]<c+\frac{\overline{\theta}-2\underline{\theta}}{3}(s_2-s_1)$ or $\overline{\mathrm{m}}<\frac{3}{2}+\frac{(s_2-s_1)(5\overline{\theta}-4\underline{\theta})-\sqrt{(s_2-s_1)^2(5\overline{\theta}-4\underline{\theta})^2+3c(3c+(s_2-s_1)(22\overline{\theta}-8\underline{\theta}))}}{6c}$.

For the price of good 2 to be lower than the unregulated we need $\frac{c}{2}+\frac{\overline{\theta}(s_2-s_1)}{2(1-\overline{m})}<c+\frac{2\overline{\theta}-\underline{\theta}}{3}(s_2-s_1)$, which, solving for $\overline{m}$ gives $\overline{m}<\frac{3c+(s_2-s_1)(\overline{\theta}-2\underline{\theta})}{3c+(s_2-s_1)(4\overline{\theta}-2\underline{\theta})}$.

When $\overline{m}=\frac{3c+(s_2-s_1)(\overline{\theta}-2\underline{\theta})}{3c+(s_2-s_1)(4\overline{\theta}-2\underline{\theta})}$, we have that $p_1=\left[c+\frac{2\overline{\theta}-\underline{\theta}}{3}(s_2-s_1)\right]\frac{3c+(s_2-s_1)(\overline{\theta}-2\underline{\theta})}{3c+(s_2-s_1)(4\overline{\theta}-2\underline{\theta})}$. At this particular value, the regulated generic price is lower than the unregulated, since $\left[c+\frac{2\overline{\theta}-\underline{\theta}}{3}(s_2-s_1)\right]\frac{3c+(s_2-s_1)(\overline{\theta}-2\underline{\theta})}{3c+(s_2-s_1)(4\overline{\theta}-2\underline{\theta})}-\left(c+\frac{\overline{\theta}-2\underline{\theta}}{3}(s_2-s_1)\right)=\frac{1}{3}(s_2-s_1)\left(\underline{\theta}-2\overline{\theta}\right)\frac{3c+(s_2-s_1)(\overline{\theta}-2\underline{\theta})}{3c+(s_2-s_1)(4\overline{\theta}-2\underline{\theta})}<0.$ Therefore, $\frac{3}{2}+\frac{(s_2-s_1)(5\overline{\theta}-4\underline{\theta})-\sqrt{(s_2-s_1)^2(5\overline{\theta}-4\underline{\theta})^2+3c(3c+(s_2-s_1)(22\overline{\theta}-8\underline{\theta}))}}{6c}>\frac{3c+(s_2-s_1)(\overline{\theta}-2\underline{\theta})}{3c+(s_2-s_1)(4\overline{\theta}-2\underline{\theta})}$

Concluding, when $\overline{\mathrm{m}}<\frac{3c+(s_2-s_1)(\overline{\theta}-2\underline{\theta})}{3c+(s_2-s_1)(4\overline{\theta}-2\underline{\theta})}$ both the generic price and the branded price are lower than the original. When $\frac{3c+(s_2-s_1)(\overline{\theta}-2\underline{\theta})}{3c+(s_2-s_1)(4\overline{\theta}-2\underline{\theta})}<\overline{\mathrm{m}}<\frac{3}{2}+\frac{(s_2-s_1)(5\overline{\theta}-4\underline{\theta})-\sqrt{(s_2-s_1)^2(5\overline{\theta}-4\underline{\theta})^2+3c(3c+(s_2-s_1)(22\overline{\theta}-8\underline{\theta}))}}{6c}$ the generic price is lower while the branded prices are higher than the initial situation.

When decreasing the value of the binding restriction, the point at which the regulated price is lower than the unregulated occurs first for the generic because of two reasons. First, the increase in its price is lower. Second, the decrease in price is quicker because for each cut in the maximum share, the generic price decreases by that additional amount.

4 The importance of product differentiation

Brand-name pharmaceuticals and their generic counterpart are defined to be therapeutically the same. Even so, the different quality that consumers attribute to each product, though not a real quality but rather a perceived one, has implications to the price setting. Firms want their products to be differentiated (even if only in a simulated way) to decrease the price competition triggered by homogeneous product. If firms were to choose their perceived quality, they would choose it to be the furthest from each other as possible. Consumers are, then, worsening their own position by stigmatizing generic products and inducing firms to increase prices. In this model, we considered as exogenous, not chosen by firms, the quality of each product. Nevertheless, more informed consumers, i.e., consumers aware that, in therapeutic terms, the pharmaceuticals are the same, would make the difference in quality lower and trigger fiercer price competition, lowering prices and improving consumer surplus.

Define $s = \mathrm{s}_2 - \mathrm{s}_1$, the difference in perceived quality. Then, we can compute how equilibrium prices change with s. Without indexation, prices are given by $p_1^* = c + \frac{\overline{\theta}-2\underline{\theta}}{3}(s_2 - s_1)$ and $p_2^* = c + \frac{2\overline{\theta}-\underline{\theta}}{3}(s_2 - s_1)$. Thus, $\frac{\partial p_1^*}{\partial s} = \frac{\overline{\theta}-2\underline{\theta}}{3} > 0$ and $\frac{\partial p_2^*}{\partial s} = \frac{2\overline{\theta}-\underline{\theta}}{3} > 0$. We can see that, as expected, a lower s decreases equilibrium prices. Lower product differentiation will trigger price competition and bring equilibrium prices closer to marginal costs. In the limit, if consumers gave the same quality to the goods, competition would revert to the Bertrand game with homogeneous goods and prices would be equal to marginal costs. Moreover, the branded drug price falls more quickly than the generic. Note that they both reach the same price (marginal cost) when the difference in perceived quality is the same. Therefore, as the initial price of the branded drug is higher, it naturally has to decrease at a higher rate. The generic price is always lower, that is, closer to marginal costs, which make its price movements more restricted and as such, less affected by decreases in the quality difference.

If prices are regulated, and admitting that the restriction is not binding, we have $p_1^* = \frac{1}{8}\left[7c + \Omega + 2(s_2 - s_1)\left(\overline{\theta} - 3\underline{\theta}\right)\right]$ and $p_2^* = \frac{1}{4}\left[3c + \Omega + 2(s_2 - s_1)(\overline{\theta} - \underline{\theta})\right]$, where $\Omega = \sqrt{4(s_2 - s_1)^2(\overline{\theta} - \underline{\theta})^2 + c(c + 4(s_2 - s_1)(3\overline{\theta} - \underline{\theta}))}$. The response of equilibrium prices to changes in the perceived-quality differential is different in magnitude, but not in the direction. Note again that if qualities are the same, prices will be the same and equal to marginal costs. Products become homogeneous and the generic seller decides to charge 100% of the branded product. The partial derivatives of the equilibrium prices in respect to s yields: $\frac{\partial p_1^*}{\partial s} = \frac{2s(\overline{\theta}-\underline{\theta})^2 + c(3\overline{\theta}-\underline{\theta})}{4\sqrt{4s^2(\overline{\theta}-\underline{\theta})^2 + c(c+s(12\overline{\theta}-4\underline{\theta}))}} + \frac{\overline{\theta}-3\underline{\theta}}{4} > 0$ and $\frac{\partial p_2^*}{\partial s} = \frac{2s(\overline{\theta}-\underline{\theta})^2 + c(3\overline{\theta}-\underline{\theta})}{2\sqrt{4s^2(\overline{\theta}-\underline{\theta})^2 + c(c+s(12\overline{\theta}-4\underline{\theta}))}} + \frac{\overline{\theta}-\underline{\theta}}{2} > 0$. As in the previous case, the branded-name product reacts more strongly to changes in the difference of qualities than the generic, and for the same reason as before.

The final case is the one in which prices are regulated and the restriction is binding, given by $p_1^* = \overline{m}\left[\frac{c}{2} + \frac{\overline{\theta}(s_2 - s_1)}{2(1-\overline{m})}\right]$ and $p_2^* = \frac{c}{2} + \frac{\overline{\theta}(s_2 - s_1)}{2(1-\overline{m})}$. In this situation, the prices in equilibrium response to changes in quality difference are $\frac{\partial p_1^*}{\partial s} = \frac{\overline{m}\overline{\theta}}{2(1-\overline{m})}$ and $\frac{\partial p_2^*}{\partial s} = \frac{\overline{\theta}}{2(1-\overline{m})}$. The conclusion is the same as before: the equilibrium price of the branded product reacts strongly to changes in the qualities discrepancy than the generic price. In fact, the reaction of the generic price will be a percentage of the branded product, which is defined by the regulator. However, there is an important difference when the share of the branded-name product that the generic producer can charge is set by the regulator. If perceived quality reaches the same value for the two products, prices will be given by $p_1 \ = \overline{m}\frac{c}{2}$ and $p_2 \ = \frac{c}{2}$, as seen by the equations. However, this cannot be an equilibrium as both firms are having losses (prices are lower than marginal cost) and the brand producer will want to correct its behaviour (the generic cannot unilaterally adjust since it has no decision variable). Assuming that while a firm is having negative profits it will not produce, the brand producer will set the highest price it can while leaving the generic seller with negative profits, at the given price indexation level[1]. At the limit, this point occurs just before $p_2^* = \frac{c}{\overline{m}}$ and so $p_1^* = c$. Thus, when the restrictions binds, erasing the stigma imposed by consumers on generics will lead to positive profits for the branded firm while giving losses for the generic firm, eventually forcing it out of the market.

5 The generic paradox

When the brand-name firm holds a patent, it faces no competition since, by law, no other drug can be sold in the market if it possesses the same therapeutic purpose. Therefore, the firm enjoys its monopoly profits, regardless of the price-setting scheme.

In this case, the market will not be covered. By having a lower perceived quality and price, the generic provides the safeguard for consumers with a lower valuation (due to lower income, for example) that ensures the market is covered. Then, while the brand product is the only available, the market may not be covered. The demand of the firm (we keep the same notation of calling good 2 to the only one in the market in this subsection), then, will be given by $\mathrm{D}(p_2) = 1 - F\left(\frac{p_2}{s_2}\right) = \overline{\theta} - \frac{p_2}{s_2}$. Firm 2's

[1] Assuming that this value is lower than the monopoly price.

maximization problem becomes $\max_{p_2}\left\{\pi_B = (p_2 - c)\left(\overline{\theta} - \frac{p_2}{s_2}\right)\right\}$. Solving for the price equilibrium yields $p_2^* = \frac{c+\overline{\theta}s_2}{2}$ and $\pi_B^* = \frac{\left(\overline{\theta}s_2 - c\right)^2}{4s_2}$.

How does the monopoly price compares to equilibrium price after the generic seller enters the market – the duopoly price? In the case where price are not linked, taking the difference between prices $\frac{c+\overline{\theta}s_2}{2} - \left(c + \frac{2\overline{\theta}-\underline{\theta}}{3}(s_2 - s_1)\right)$ gives $\frac{1}{6}\left(2\underline{\theta}(s_2 - s_1) - \overline{\theta}(s_2 - 4s_1) - 3c\right)$. Therefore, the monopoly price is higher if $s_1 > \frac{1}{2(2\overline{\theta}-\underline{\theta})}\left(3c + s_2(\overline{\theta} - 2\underline{\theta})\right)$. If the quality that consumers attribute to the generic is high enough (it gets closer to the perceived quality of the brand-name product), the two products will not be too different in terms of quality and, therefore, will compete fiercely in prices, lowering them close to marginal cost. Remember that product differentiation acts as a way to decrease price competition: the smaller the degree of differentiation is, the more intensive price competition is.

If the perceived quality of the generic is low, $s_1 < \frac{1}{2(2\overline{\theta}-\underline{\theta})}\left(3c + s_2(\overline{\theta} - 2\underline{\theta})\right)$, then the product differentiation is high and price competition will not be intense. Prices can be comfortably higher than marginal cost, and the price of the branded product is clearly higher than the generic. In fact, the existence of a competitor will make the branded good seller increase its price compared to the monopoly position. To see why, consider first the monopoly case. Then, any price increase immediately translates into a loss in demand. Profit margin increases but demand decreases. In the duopoly case, however, any brand price increase will also induce an increase in the generic price (since they are strategic complements), undermining the losses in demand compared to the monopoly case, but still increasing the profit margin. It creates room for the branded-good price to increase more easily[2], above even the monopoly price.

If the perceived qualities are different enough, the well-known generic paradox occurs. The entry of a generic drug in the market will encourage an increase in the price of the brand-name product instead of making it lower through more intense competition. According to the results, if the generic enters the market and consumers are aware that they are the same in therapeutic terms, the generic paradox will not occur.

With a price indexation scheme, the generic paradox may occur as well. Particularly, the difference between the monopoly price and duopoly is given by $\frac{c+\overline{\theta}s_2}{2} - \left(\frac{1}{4}\left[3c + \Omega + 2(s_2 - s_1)(\overline{\theta} - \underline{\theta})\right]\right) = \frac{1}{4}(2s_1 b + 2a(s_2 - s_1) - c - \Omega)$. The expression is negative, that is, the generic paradox occurs when $s_1 < s_2 \frac{s_2(\overline{\theta}-2\underline{\theta})+3c}{2s_2(\overline{\theta}-\underline{\theta})+2c}$. The intuition is the same as in the case prices are not regulated.

Proposition 4 (Generic paradox) *The set of qualities for the generic quality that generates the generic paradox is larger with price indexation. Therefore, the generic paradox is more easily occurred when prices are linked under an indexed scheme.*

Proof. Taking the difference for the generic paradox between price linkage and no indexation gives $s_2 \frac{s_2(\overline{\theta}-2\underline{\theta})+3c}{2s_2(\overline{\theta}-\underline{\theta})+2c} - \frac{1}{2(2\overline{\theta}-\underline{\theta})}\left(3c + s_2(\overline{\theta} - 2\underline{\theta})\right) = \frac{\left(3c+s_2(\overline{\theta}-2\underline{\theta})\right)(\overline{\theta}s_2-c)}{2\left(s_2(\overline{\theta}-\underline{\theta})+c\right)(2\overline{\theta}-\underline{\theta})} > 0$. Thus, the condition is less restrictive under price linkage. ■

6 Limit price

In order for predation to be successful, the brand producer must charge a price "low enough" in order to force the generic firm out of the market. The magnitude to

[2] The same reasoning applies to the case where the perceived quality of the generic is "high". However, the intense price competition created by similar qualities will drive prices closer to marginal cost, which will not allow the price to increase above the monopoly price.

how low price would have to be is given by the limit pricing, that is, the price that makes the other firm just indifferent between being, or not, in the market. That point occurs when its profits equal zero. Note that any other price below the limit pricing also forces the generic producer out of the market, but it is not a rational decision by the branded firm because its profits would be even lower (since it is moving away from the monopoly price).

In this section we follow Church and Ware (2000, pp. 473-476)[3]. The limit pricing is computed by setting to zero the profits of the generic seller, $(p_1 - c)\left(\frac{p_2-p_1}{s_2-s_1} - \underline{\theta}\right) - F = 0$, where F is the fixed cost from operating in the market . The generic producer sets its price according to the reaction function, $p_1 = R_1(p_2)$ and, therefore, the branded product seller can set its price in order to make the generic firm's profits equal to zero.

When prices are not linked, the reaction function is given by $p_1 = \frac{p_2+c-\underline{\theta}(s_2-s_1)}{2}$ and, thus, the limit price is computed by setting p_2 such that $\left(\left(\frac{p_2+c-\underline{\theta}(s_2-s_1)}{2}\right) - c\right)\left(\frac{p_2-\left(\frac{p_2+c-\underline{\theta}(s_2-s_1)}{2}\right)}{s_2-s_1} - \underline{\theta}\right) - F = 0$ or $p_2 = \mathrm{c} + \underline{\theta}(\mathrm{s}_2 - \mathrm{s}_1) + 2\sqrt{F(s_2 - s_1)}$. Note that when F increases, the branded product seller can charge a higher price and still force the generic producer out of the market because its costs will be higher. At this brand-name drug's price, the generic price is $p_1 = \mathrm{c} + \sqrt{F(s_2 - s_1)}$.

If prices are linked, the reaction function is given by $m = \frac{p_2+c-\underline{\theta}(s_2-s_1)}{2p_2}$, and the limit price sets $(mp_2 - c)\left(\frac{p_2(1-m)}{s_2-s_1} - \underline{\theta}\right) - F = 0$ or $\left(\left(\frac{p_2+c-\underline{\theta}(s_2-s_1)}{2p_2}\right)p_2 -\right.$

[3] **Church, Jeffrey and Roger Ware.** 2000. *Industrial Organization: A Strategic Approach*. New York: Irwin/McGraw-Hill.

$c)\left(\frac{p_2\left(1-\frac{p_2+c-\underline{\theta}(s_2-s_1)}{2p_2}\right)}{s_2-s_1}-\underline{\theta}\right)-F=0$. Notice that when plugging the reaction function into the profits, nothing changes related to the no-indexation case. The branded price for which the generic seller has zero profits remains at $p_2 = \mathrm{c}+\underline{\theta}(\mathrm{s}_2-\mathrm{s}_1)+2\sqrt{F(s_2-s_1)}$.

At this particular pair of prices, what matters for predation assessment is the profit that the branded producer can extract while forcing the generic firm out of the market. It is given by $\pi_B^{LP} = (s_2-s_1)(\underline{\theta}(\overline{\theta}-\underline{\theta}))+(2\overline{\theta}-3\underline{\theta})\sqrt{F(s_2-s_1)}-2F$.

7 Specific conditions for predation

We use the following condition for predation to occur: $\pi^{LP}+\pi^{M}>2\pi^{D}$. This condition states that the profits in the first period from charging the limit price combined with the monopoly position in the second period is higher than the alternative of being in a duopoly in both periods[4]. We ignore discounting.

When prices are not linked by legislation, the condition that makes predation a rational strategy is given by $(s_2-s_1)\left(\underline{\theta}\left(\overline{\theta}-\underline{\theta}\right)\right)+\left(2\overline{\theta}-3\underline{\theta}\right)\sqrt{F(s_2-s_1)}-2F+\frac{\left(\overline{\theta}s_2-c\right)^2}{4s_2}>2(s_2-s_1)\frac{\left(2\overline{\theta}-\underline{\theta}\right)^2}{9}$ or

$$F>\frac{\frac{1}{4}\left(s_2\left(72\overline{\theta}-108\underline{\theta}\right)(s_2-s_1)+12\Psi\right)\left(2\overline{\theta}-3\underline{\theta}\right)-9c\left(2\overline{\theta}s_2-c\right)+s_2\left(68\underline{\theta}\overline{\theta}-44\underline{\theta}^2\right)(s_2-s_1)-s_2\overline{\theta}^2(23s_2-32s_2)}{72s_2},$$

where $\Psi=\sqrt{7{s_2}^2\underline{\theta}(s_2-s_1)^2(4\overline{\theta}-\underline{\theta})-2s_2(s_2-s_1)(s_2\overline{\theta}^2(5s_2-14s_1)+9c(2\overline{\theta}s_2-c)}$.

When prices are linked, the condition is given by $(s_2-s_1)\left(\underline{\theta}\left(\overline{\theta}-\underline{\theta}\right)\right)+\left(2\overline{\theta}-3\underline{\theta}\right)\sqrt{F(s_2-s_1)}-2F+\frac{\left(\overline{\theta}s_2-c\right)^2}{4s_2}>2\frac{1}{32(s_2-s_1)}\left(c+2(s_2-s_1)\left(3\overline{\theta}-\underline{\theta}\right)-\right.$

[4] Superscript LP stands for Limit Price, M for Monopoly and D for Duopoly.

$\Omega\Big)\left(2(s_2 - s_1)\left(\overline{\theta} - \underline{\theta}\right) + \Omega - \mathrm{c}\right)$ or $F > \frac{1}{32 s_2 (s_2 - s_1)}\Big(s_2 \Omega(\Omega - 2c) + c^2(5s_2 - 4s_1) - (s_2 - s_1)\left(2(2\overline{\theta} - 3\underline{\theta})\left((2s_2 s_1 - 2s_2^2)(2\overline{\theta} - 3\underline{\theta}) + \Upsilon\right) + 4s_2\overline{\theta}(c + \Omega)\right) - 4s_2\left(s_2^2\left(2\overline{\theta}^2 + 5\underline{\theta}^2\right) - 5s_1\left(s_2\overline{\theta}^2 - s_1\underline{\theta}^2\right) + 2s_1^2 s_2\underline{\theta}(8\overline{\theta} - 5\underline{\theta}) - 8\underline{\theta}\overline{\theta}(s_1^2 + s_2^2) + 3s_1^2\overline{\theta}^2\right)\Big)$, where $\Upsilon = \sqrt{2s_2(s_2\Omega(\Omega - 2c) - 4s_2\overline{\theta}(s_2 - s_1)(c + \Omega) + c^2(5s_2 - 4s_1)) - 4{s_2}^2(s_2 - s_1)(\underline{\theta}(s_2\underline{\theta} - 4\overline{\theta}(s_2 - s_1)) - s_1(2\overline{\theta}^2 + \underline{\theta}^2))}$

8 The effect of product expansion on predation

The limit price is the same as the one without the new product. Due to the nature of vertical product differentiation, the new product will not compete directly with the generic. Therefore, in order to engage into predatory pricing, the firm must use the original brand, by setting its price equal to the limit price while it can set the profit-maximizing price in the new drug.

Under the limit price, the best response regarding the new product is to set $p_3 = c + \underline{\theta}(s_2 - s_1) + \frac{1}{2}\overline{\theta}(s_3 - s_2) + 2\sqrt{F(s_2 - s_1)}$. Under these conditions, the profits of the branded firm with the two products and engaging in predatory pricing are $\pi_B^{LP} = \left(\underline{\theta}(\overline{\theta} - \underline{\theta})\right)(s_2 - s_1) + \frac{1}{4}\overline{\theta}^2(s_3 - s_2) + (2\overline{\theta} - 3\underline{\theta})\sqrt{F(s_2 - s_1)} - 2F.$

Remember that the limit price is the same regardless of the price scheme in use.

Lemma 2 (Limit Pricing Profits) *Predation is less costly with two products than with one only.*

Proof. Comparing the limit price profits of having two products with having one gives $\left(\underline{\theta}(\overline{\theta} - \underline{\theta})\right)(s_2 - s_1) + \frac{1}{4}\overline{\theta}^2(s_3 - s_2) + (2\overline{\theta} - 3\underline{\theta})\sqrt{F(s_2 - s_1)} - 2F - \left(\left(\underline{\theta}(\overline{\theta} - \underline{\theta})\right)(s_2 - s_1) + +(2\overline{\theta} - 3\underline{\theta})\sqrt{F(s_2 - s_1)} - 2F\right) = \frac{1}{4}\overline{\theta}^2(s_3 - s_2) > 0.$ ■

Regarding the new monopoly profits, the firm's problem with two products is $\max_{p_2,p_3}\left\{(p_2-c)\left(\frac{p_3-p_2}{s_3-s_2}-\frac{p_2}{s_2}\right)+(p_3-c)\left(\overline{\theta}-\frac{p_3-p_2}{s_3-s_2}\right)\right\}$, which yields, in equilibrium, $p_2^*=\frac{bs_2+c}{2}$, $p_3^*=\frac{bs_3+c}{2}$ and $\pi_B^*=\frac{c(c-2\overline{\theta}s_2)+\overline{\theta}^2 s_2 s_3}{4s_2}$. Note that this is also independent from the price scheme, since there is no generic product.

Lemma 3 (Monopoly Profits) *The benefits of predation, that is to say, the monopoly profits, are higher with two products rather than one.*

Proof. Comparing the monopoly profits of having two products with having one gives $\frac{c(c-2\overline{\theta}s_2)+\overline{\theta}^2 s_2 s_3}{4s_2}-\frac{\left(\overline{\theta}s_2-c\right)^2}{4s_2}=\frac{1}{4}\overline{\theta}^2(s_3-s_2)>0$. ■

Finally, in order to check whether predation is more easily incurred with two goods, we need to compare the alternative of predation, the duopoly, when having two products against one. As already studied, if the fixed cost of expansion is small enough, expanding a new product does increase profits. Therefore, having two products makes predation easier, but at the same time makes the alternative more attractive. It is not clear, *a priori*, if one firm is simply expanding its operations and benefit from the higher profits or if it is expanding operations in order to more easily engage in predation. The final effect depends on the relation between the conditions for predation in the two situations.

Proposition 5 (Predation with product expansion) *When prices are not linked, predation is more likely if the firm launches a new product with higher quality. If prices are linked, then the possibility of predation may either remain at the same level or be higher due to the expansion.*

Proof. In the case in which prices are not linked, remember that the branded seller would never want to have both products in the market. Therefore, the firm would never use the two products as the alternative strategy to predation, but would only use one, the new, high-quality product. Predation with the new drug occurs if $\left(\underline{\theta}\left(\overline{\theta}-\underline{\theta}\right)\right)(s_2 - s_1) + \frac{1}{4}\overline{\theta}^2(s_3 - s_2) + \left(2\overline{\theta} - 3\underline{\theta}\right)\sqrt{F(s_2 - s_1)} - 2F + \frac{c\left(c-2\overline{\theta}s^2\right)+\overline{\theta}^2 s^2 s^3}{4s_2} - 2(s_3 - s_1)\frac{\left(2\overline{\theta}-\underline{\theta}\right)^2}{9} > 0$. The difference of this condition with the one given by predation with the original product gives $-\frac{1}{18}\left(\overline{\theta} - 2\underline{\theta}\right)\left(7\overline{\theta} - 2\underline{\theta}\right)(s_3 - s_2) < 0$. Consequently, when prices are not linked, predation is more likely with the new brand product.

If prices are linked, the analysis becomes less straightforward. Remember that in this case, there were two possibilities of expansion, depending on the parameters. The firm may prefer, or not, to keep both products as the duopoly alternative to predation. In the case the firm does prefer to drop out the original brand from the market, thus remaining with the novel product, the analysis is just the same as in the instance prices are not linked. This happens because the equilibrium that arises is the “unregulated” equilibrium, as previously shown. Note again that the benefits of predation are independent of the price scheme, that is, the limit price and monopoly profits do not depend on the price scheme.

The second possibility is to have both products in the duopoly market. In this case, the duopoly profits increase by $\frac{4\overline{\theta}(s_2-s_1)\left(\Omega-c+\overline{\theta}(2s_3+s_2-3s_1)\right)-(s_2-s_1)^2\left(4\underline{\theta}\left(4\overline{\theta}-\underline{\theta}\right)\right)-(\Omega-c)^2}{32(s_2-s_1)} - \frac{\left(c+2(s_2-s_1)\left(3\overline{\theta}-\underline{\theta}\right)-\Omega\right)\left(2(s_2-s_1)\left(\overline{\theta}-\underline{\theta}\right)+\Omega-c\right)}{32(s_2-s_1)} = \frac{1}{4}\overline{\theta}^2(s_3 - s_2)$, making the alternative to predation more appealing. However, note that this increase is exactly the same as the increase of predation profits, which, in the end, makes the likelihood of predation just the same as in the one-product case. ■