

# Chapter 2

## Incentives to Innovate: Reference Prices vs. Copayments

### 2.1 Introduction.

Recently, there has been much debate about the likely consequences of implementing a reference price system in the market for ethical drugs. Much has been said from a descriptive point of view, but little has been done from a theoretical one. The aim of this paper is to provide insights on firms' long run decisions (R&D decisions) under the implementation of a reference price system. This approach complements Mestre-Ferrándiz (2001) where short-run decisions (prices, quantities) were analysed.

Reference price systems have been implemented in various developed countries, such as Germany, Sweden, Denmark and Holland. Furthermore, in each country, this system has been implemented in a different way. For example, in Germany if the price set by pharmaceutical firms exceeds the reference price, the consumer pays the difference, while the patient does not need to copay otherwise (Pavcnik 2000). In Spain, the following mechanism has been enforced: when a physician prescribes a drug with a price higher than the reference price, the consumer has two options: either (s)he buys a generic or a branded (more expensive) version. In the former case, the consumer pays the same copayment that was paid before the implementation of the reference price system. In the latter, the total payment results from the sum of the difference in price between the branded good and the reference price and the copayment associated to the *reference price* (El País, 21 July 2000).

The difference between this system with the previously enforced is that the patient used to pay only a (fixed) copayment of the price, irrespectively of the good purchased. For obvious reasons, we will use the Spanish way of implementing reference prices throughout this paper. Hence, this setting is implicitly assuming that the reference price is set below the price of the branded good, but equal or higher than the price of the generic drug. One of the main purposes of implementing reference prices is to try to achieve more intense price competition between branded and generic producers; Health Authorities hope that branded good producers actually reduce their prices. Pavcnik (2000) shows the effects of implementing reference prices in Germany empirically, and her results confirm that implementing such system affect the pricing decision of firms. The interested reader can find a more detailed explanation on the objectives of reference prices in Mestre-Ferrándiz (2001). There exist two opposing views with respect to the effects that such system will have on the R&D decision of pharmaceutical firms. On the one hand, it is argued that the introduction of this system will reduce profits which will lead to decreased revenues to finance the R&D costs necessary to develop new drugs. On the other, it is assumed that the R&D decision of these firms depend on total sales. Pharmaceutical enterprises are usually multiproduct firms, so even though sales for the drugs which are subject to reference prices might be reduced, total sales may not necessarily be so.

Most literature on R&D races in oligopoly deals with the evaluation of incentives to undertake cost reducing investments. However, this kind of setting would be inappropriate in our context, since the R&D undertaken in this industry aims at discovering new drugs, or improving versions of older ones (Sola-Sola (2000)). Hence we will assume that according

to the level of investment in R&D, the firm will be able to produce completely new drugs (so-called *breakthrough drugs*), or alternatively, improved versions of an existing one (*me-too drugs*). Hence, the R&D undertaken affects the degree of differentiation between the drugs available, rather than reducing costs of producing the existing goods. This is appropriate in this industry because we observe that firms compete through product innovation, either in new drugs, or in innovations of existing drugs.

We will have a “mature” market in the sense that the patent for a branded drug has expired, so that a generic alternative has entered the market. The degree of product differentiation between these two will be exogenous. The producer of the branded drug then faces a decision: whether to produce a second branded drug, and if this is so, to determine the degree of product differentiation between this new drug and the existing goods. If the firm decides to produce a new drug, then this firm can, by spending enough resources in R&D, obtain a revolutionary, or breakthrough drug. This allows the firm to create a new market, acting as a monopolist. However, if the firm spends less on R&D, then a me-too drug will be produced, entering the already established market and competing vis-a-vis with the older branded drug and its generic alternative. Moreover, we also have to take into account the possibility of substituting the older branded drug by the new one. The fact that it is the branded drug that undertakes the R&D investment is consistent with reality, since generic firms do not need to spend huge amounts of money on R&D, as they just have to carry out tests of bioequivalence<sup>7</sup> in order to enter the market. For this purpose, we will treat the branded producer as a Stackelberg leader, leadership that arises because it is this firm that

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<sup>7</sup> Bioequivalent implies being statistically indistinguishable from the established product in key aspects of therapeutic use.

carries out R&D and can achieve a patent. Hence, the generic producer acts as a follower, in the sense that this firm depends on what the incumbent puts into the market.

More precisely, the timing of the game will be as follows. Suppose we have a mature duopoly market where a branded and a generic drug are already in the market. The degree of product differentiation between these two goods is exogenous. The incumbent firm now faces the following decision: produce another good and determine the degree of substitutability between this new drug and the existing ones (branded/generic) and become multiproduct, or produce the second drug but substitute the older branded version by the new one, remaining singled-product. When the incumbent decides to produce this new drug, it has two possible options: either spend a large amount in R&D to obtain a breakthrough drug (and markets between the existing drugs and the new one will be separate and independent) or alternatively, spend less to obtain just a me-too drug so that the market structure becomes a triopoly, with the incumbent competing in the mature market with two goods. When the breakthrough drug is produced, and under certain assumptions, the incumbent firm will never have incentives to substitute the old drug by the new one, since the two goods produced by this firm compete in different markets. However, with the me-too drug the analysis is not that straightforward: will the leader prefer to have both goods in the same market, cannibalising part of the demand for the older branded drug, or will profits be higher by removing the old version from the market? As shown later, one crucial parameter for this comparison is the potential market sizes for each good produced.

What we want to analyse is whether the leader will have higher incentives to produce the breakthrough drug and the me-too drug under reference prices or copayments. Moreover,

on more general terms, we will also focus on when will the incumbent firm have incentives to produce the breakthrough drug or the me-too, given that either reference prices or copayments are enforced.

The paper is organised as follows. Section 2 presents the model, both the demand and the supply side, and will explain in detail the relationship between the level of R&D investment and the type of new drug produced. Section 3 describes the equilibrium that arises when a breakthrough drug is produced, and compares the situation obtained with reference prices with the one obtained under copayments. Section 4 shows the same comparisons, but this time given that a me-too drug is produced. Section 5 analyses when will the firm have incentives to substitute the old drug by new one, while Section 6 gives conditions for the incumbent firm to produce the breakthrough drug rather than the me-too, both under reference prices and copayments. Section 7 concludes and presents future research.

## **2.2 The Model.**

We have a duopoly setting where firms act noncooperatively. In the first stage, the leader chooses the level of R&D investment, which determines the degree of product differentiation between the new branded good, if produced, and the old branded/generic good. Once this variable has been determined, firms will compete in prices à la Stackelberg i.e. the incumbent chooses first the prices of both goods.

The demand side is a simplified version of Singh and Vives (1984), but taking into account that under copayments and reference prices, the consumer does not pay the whole

price. There is a continuum of consumers of the same type. The representative consumer maximises

$$U(q_{B1}, q_{B2}, q_G) - \sum_i^{B1, B2, G} \hat{p}_i, \quad (53)$$

where  $i = B1, B2, G$ , denotes the old branded good, the new branded good and the generic respectively,  $q_i$  is the amount of good  $i$  and  $\hat{p}_i$  is the net price paid by the consumer for this good.  $U(q_{B1}, q_{B2}, q_G)$  is assumed to be quadratic and strictly concave as

$$U(q_{B1}, q_{B2}, q_G) = a_{B1}q_{B1} + a_{B2}q_{B2} + a_Gq_G - \frac{1}{2}(q_{B1}^2 + q_{B2}^2 + q_G^2) - \frac{1}{2}(2\gamma_1q_{B1}q_G + 2\gamma_2q_{B1}q_{B2} + 2\gamma_2q_{B2}q_G). \quad (54)$$

The degree of product differentiation between the old branded and the generic good is exogenous and equal to  $\gamma_1 \in (0, 1)$ . The parameter  $\gamma_2$  represents the degree of differentiation between the new drug (if it is produced) and the old branded/generic good. This is the variable that the incumbent chooses after observing a period where only the old branded version and its generic alternative co-exist in the market. As shown in equation (2.54), the lower the value of  $\gamma_2$  (implying higher product differentiation between the existing goods and the new product), the higher the utility function of the representative consumer. Hence, that is why we have that Health Authorities should try to promote highly innovative ethical drugs.

The next step is to define explicitly the net price paid by the consumer, denoted as  $\hat{p}_i$ . As mentioned in the introduction, we will use the Spanish reference price system. Hence, we obtain that under *copayments*,

$$\hat{p}_i = \rho p_i, \quad i = B1, B2, G, \quad (55)$$

while under *reference prices*,

$$\hat{p}_i = \begin{cases} \rho p_G & \text{if consumer buys generic,} \\ \rho r + (p_{Bj} - r) & \text{if consumer buys branded, } j = 1, 2, \end{cases} \quad (56)$$

with  $\rho \in (0, 1)$  being the copayment and  $r > 0$  is the reference price set<sup>8</sup>. Moreover, we need that  $p_G \leq r < p_B$  for the system to be well defined.

The decision the leader firm faces is whether to produce or not to produce a new drug. Moreover, if this firm decides to become a multiproduct firm, there is a second decision to be taken: the degree of differentiation between the existing branded and generic and this new drug. The firm has two options: either produce a breakthrough drug, or alternatively, produce a me-too. Obviously, the R&D cost associated with the former is higher than the cost associated to the latter, although with the breakthrough drug, this firm is able to create a new market for this drug due to the high degree of innovation. On the other hand, with the me-too drug, if it is produced, the market becomes a triopoly, so it is as if the incumbent firm is cannibalising part of its demand of the older drug with this (marginal)

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<sup>8</sup> These two parameters are chosen by Health Authorities, and will be treated as exogenous throughout the whole analysis. However, we will carry out comparative static analysis to see how firms' decision variables are affected by the choice of these two parameters.

improved version of the drug. Another possibility that has to be taken into account is giving the incumbent firm the possibility of substituting the old drug by the new one, remaining singled-product.

Relating this line of argument to the value that  $\gamma_2$  will take for each particular situation, it implies that this parameter will take two values depending on the type of new drug produced. When  $\gamma_2 = 0$ , the incumbent firm produces a breakthrough drug, so that two separate markets exist. The incumbent competes in these two markets; in the old market the situation is unchanged, but now, this firm becomes a monopolist in the market for the breakthrough drug (the new market). In this case it is trivial to show that this firm will never have incentives to remove the old drug from the market, since the old and new drug do not directly compete, so that it is profitable for the incumbent firm to keep both goods in the market<sup>9</sup>. If  $\gamma_2 = \gamma_1$ , this is the case when a me-too drug is produced. The new drug in the market is not innovative enough, so that there exists only one market. This market is now a triopoly, with two branded drugs and one generic. Under this situation, it is also possible for the incumbent firm to substitute the old drug by the new one, so that there are still two goods in the old market.

The questions we want to answer are twofold: the first thing we want to know is given that the branded good producer has decided to spend the amount of investment required to obtain a breakthrough drug, will this firm be better off under copayments or reference prices? Secondly, we are interested to see when the incumbent firm will have incentives

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<sup>9</sup> As shown later, we will assume that the cost of production of the new drug is sufficiently low so that there are always incentives to produce it, so that the profits obtained by producing this drug are never negative.



to produce just a me-too drug rather than producing a very innovative drug, or substituting the older drug by the new one.

The utility function expressed in (2.54) gives rise to a linear demand system. The inverse demands are

$$\hat{p}_{B1} = a_{B1} - q_{B1} - \gamma_1 q_G - \gamma_2 q_{B2},$$

$$\hat{p}_{B2} = a_{B2} - q_{B2} - \gamma_2 (q_{B1} + q_G),$$

$$\hat{p}_G = a_G - q_G - \gamma_1 q_{B1} - \gamma_2 q_{B2}.$$

Notice that  $\hat{p}_i$ , with  $i = B1, B2, G$ , denotes the net price paid by the consumer if (s)he decides to buy the old branded drug, the new branded drug, or the generic good respectively. The exact definition of this net price is identical to expressions (2.55) and (2.56) if copayments or reference prices exist respectively.

Inverting these inverse demand functions, we obtain the following demand functions:

$$q_{B1} = \frac{(1 - \gamma_2^2)(a_{B1} - \hat{p}_{B1}) - \gamma_2(1 - \gamma_1)(a_{B2} - \hat{p}_{B2}) - (\gamma_1 - \gamma_2^2)(a_G - \hat{p}_G)}{1 + 2\gamma_1\gamma_2^2 - \gamma_1^2 - 2\gamma_2^2},$$

$$q_{B2} = \frac{(1 + \gamma_1)(a_{B2} - \hat{p}_{B2}) - \gamma_2(a_{B1} + a_G) + \gamma_2(\hat{p}_G + \hat{p}_{B1})}{1 + \gamma_1 - 2\gamma_2^2},$$

$$q_G = \frac{(1 - \gamma_2^2)(a_G - \hat{p}_G) - (\gamma_1 - \gamma_2^2)(a_{B1} - \hat{p}_{B1}) - \gamma_2(1 - \gamma_1)(a_{B2} - \hat{p}_{B2})}{1 + 2\gamma_1\gamma_2^2 - \gamma_1^2 - 2\gamma_2^2}.$$

Notice that the parameters  $a_{B1}$ ,  $a_{B2}$  and  $a_G$  will determine the (potential) size of the market for the three goods. For example, the larger is  $a_{B1}$ , the bigger the market size for the old branded good, *ceteris paribus*. The same reasoning applies for the relationship between  $a_{B2}$  and  $a_G$  and the market size for the new branded good and the generic respectively.

This relationship between these three parameters and market sizes will be shown to be very important for the results obtained later. Hence, the total (potential) market size is  $\frac{a_{B1}(1 - \gamma_2) + a_{B2}(1 + \gamma_1 - 2\gamma_2) + a_G(1 - \gamma_2)}{1 + \gamma_1 - 2\gamma_2^2}$ , which is (monotonically) increasing in  $a_{B1}$ ,  $a_{B2}$  and  $a_G$ .

For computational reasons, we will make additional assumptions on the values of some parameters. We assume that  $a_{B1} = a_G = 1$ , and we let  $a_{B2} > 0$ . Moreover,  $\rho = 0.4$ , which is the average copayment paid in Spain.

The idea behind the R&D technology is similar to Lambertini and Rossini (1998). The incumbent can spend  $k_B \in [0, k_{\max}]$ , where  $k_B$  represents the R&D investment of this firm. Hence, obtaining a breakthrough drug ( $\gamma_2 = 0$ ) in this case implies spending  $k_{\max}$ , while obtaining a me-too drug ( $\gamma_2 = \gamma_1$ ) implies spending  $k^* \in (0, k_{\max})$ . Alternatively, no new drug is produced whenever the incumbent firm does not spend any resources on R&D i.e.  $k = 0$ . This framework is implicitly assuming that the higher the level of investment, the higher the degree of product differentiation between the new drug produced and the already existing ones, so the lower the value of  $\gamma_2$ . Of course, the R&D effort has a cost associated, denoted as  $C(k_B)$ . We assume that this cost function is convex, and  $C(0) = 0$ . Furthermore, since we are not considering entry conditions, we will assume that the highest possible cost,  $C(k_{\max})$  is not too high. This implies that profits obtained for the new product by the incumbent are non-negative for all values of  $k_B$ . We assume a separable cost function for innovation and production.

The production costs are assumed to be linear, with no fixed costs. Hence,

$$C(q_i) = c_i q_i, \quad i = B1, B2, G.$$

Moreover, we will have constant marginal costs of production for the three goods, and for computational reasons, these costs are set equal to zero ( $c_{B1} = c_{B2} = c_G = 0$ )<sup>10</sup>.

## 2.3 Breakthrough Drug.

Suppose that the conditions that give rise to a breakthrough drug are met, so that the incumbent firm becomes multiproduct and there exist two separate markets. This implies that  $\gamma_2 = 0$ . Assume first that copayments are enforced. With  $\gamma_2 = 0$ , and including the assumptions on the parameter values, demand functions reduce to:

$$\begin{aligned} q_{B1}^C(\gamma_2 = 0) &= \frac{(1 - 0.4p_{B1}^C) - \gamma_1(1 - 0.4p_G^C)}{1 - \gamma_1^2}, \\ q_{B2}^C(\gamma_2 = 0) &= a_{B2} - 0.4p_{B2}^C, \\ q_G^C(\gamma_2 = 0) &= \frac{(1 - 0.4p_G^C) - \gamma_1(1 - 0.4p_{B1}^C)}{1 - \gamma_1^2}. \end{aligned}$$

Solving by backward induction, the problem for the generic producer becomes

$$\max_{p_G^C} \pi_G^C(p_{B1}^C, p_G^C) = p_G^C q_G^C(p_{B1}^C, p_G^C),$$

yielding

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<sup>10</sup> This assumption will have some consequences when we compare equilibrium values, as shown later. However, it does not change qualitative the results and intuitions obtained.

$$p_G^C(p_{B1}^C) = 1.25(1 - \gamma_1) + 0.5\gamma_1 p_{B1}^C. \quad (57)$$

The leader then chooses  $p_{B1}^C$  and  $p_{B2}^C$  to maximise profits, taking (2.57) into account. The maximisation program for the incumbent then becomes:

$$\max_{p_{B1}^C, p_{B2}^C} \pi_B^C(p_{B1}^C, p_{B2}^C, p_G^C(p_{B1}^C)) = p_{B1}^C q_{B1}^C(p_{B1}^C, p_G^C(p_{B1}^C)) + p_{B2}^C q_{B2}^C(p_{B2}^C) - C(k_{\max}).$$

This maximisation program yields

$$p_{B1}^C = 1.25 \frac{2 - \gamma_1 - \gamma_1^2}{2 - \gamma_1^2}, \quad (58)$$

$$p_{B2}^C = 1.25 a_{B2}. \quad (59)$$

Note that the price of the new branded drug does not depend on  $\gamma_1$ . This is because the leader acts as a monopolist in the market created for the new drug, and the new drug does not compete with the already existing drugs. Evaluating (2.57) results in

$$p_G^C = 0.625 \left[ \frac{4 - 2\gamma_1 - 3\gamma_1^2 + \gamma_1^3}{2 - \gamma_1^2} \right]. \quad (60)$$

Evaluating quantities, the associated equilibrium values are

$$q_{B1}^C = \frac{1}{4} \left[ \frac{2 + \gamma_1}{1 + \gamma_1} \right], \quad (61)$$

$$q_{B2}^C = 0.5 a_{B2}, \quad (62)$$

$$q_G^C = \frac{1}{4} \left[ \frac{4 - 2\gamma_1 - 3\gamma_1^2 + \gamma_1^3}{(2 - \gamma_1^2)(1 - \gamma_1^2)} \right]. \quad (63)$$

We can evaluate profits to obtain

$$\pi_B^C = p_{B1}^C q_{B1}^C + p_{B2}^C q_{B2}^C =$$

$$0.3125 (2 - \gamma_1 - \gamma_1^2) \frac{2 + \gamma_1}{(2 - \gamma_1^2)(1 + \gamma_1)} + 0.625 a_{2B}^2 - C(k_{\max}),$$

$$\pi_G^C = p_G^C q_G^C =$$

$$0.15625 (4 + 2\gamma_1 - \gamma_1^2) \frac{4 - 2\gamma_1 - 3\gamma_1^2 + \gamma_1^3}{(1 + \gamma_1)(2 - \gamma_1^2)^2}.$$

When reference prices are enforced, demand functions become:

$$q_{B1}^{RP}(\gamma_2 = 0) = \frac{(1 + 0.6r - p_{B1}^{RP}) - \gamma_1 (1 - 0.4p_G^{RP})}{1 - \gamma_1^2},$$

$$q_{B2}^{RP}(\gamma_2 = 0) = a_{B2} + 0.6r - p_{B2}^{RP},$$

$$q_G^{RP}(\gamma_2 = 0) = \frac{(1 - 0.4p_G^{RP}) - \gamma_1 (1 + 0.6r - p_{B1}^{RP})}{1 - \gamma_1^2}.$$

Before solving the model, it is interesting to note that when all prices are zero, we can compare the maximum market size for the three goods between copayments and reference prices. For both branded goods, implementing a reference price system can act as a subsidy compared to the situation with copayments, since  $q_{B1}^{RP}(p_{B1}^{RP} = p_{B2}^{RP} = p_G^{RP} = 0) = \frac{1 - \gamma_1 + 0.6r}{1 - \gamma_1^2}$  and  $q_{B1}^C(p_{B1}^C = p_{B2}^C = p_G^C = 0) = \frac{1 - \gamma_1}{1 - \gamma_1^2}$ . However, for the generic producer this result is reversed, since  $q_G^{RP}(p_{B1}^{RP} = p_{B2}^{RP} = p_G^{RP} = 0) = \frac{1 - \gamma_1 (1 + 0.6r)}{1 - \gamma_1^2}$  while  $q_G^C(p_{B1}^C = p_{B2}^C = p_G^C = 0) = \frac{1 - \gamma_1}{1 - \gamma_1^2}$ . This result will provide a nice explanation for some of the results presented later.

Using the same approach as with copayments, the generic producer maximises profits by

$$\max_{p_G^{RP}} \pi_G^{RP}(p_{B1}^{RP}, p_G^{RP}) = p_G^{RP} q_G^{RP}(p_{B1}^{RP}, p_G^{RP}) \text{ s.t. } p_G^{RP} \leq r.$$

The restriction on  $p_G^{RP}$  arises because the reference price has to be equal or higher than the generic price for the system to be well defined. Hence, the generic producer has two options; either set a price below the reference price or choose the corner solution whereby  $p_G^{RP} = r$ . For the interior solution to be a feasible solution, we obtain negative quantities for the relevant range of  $r$ . Hence, this possible solution is disregarded. A well defined equilibrium only exists when the generic producer chooses the highest possible price:  $p_G^{RP} = r$ . Taking this result into account, the problem for the branded producer is the same as with copayments. The prices that maximises profits are hence:

$$p_{B1}^{RP} = 0.5(1 - \gamma_1) + (0.3 + 0.2\gamma_1)r, \quad (64)$$

$$p_{B2}^{RP} = 0.5a_{B2} + 0.3r. \quad (65)$$

Notice that all three prices are increasing with the level of the reference price. However, the response of a change in  $r$  is different for all prices. Formally,

$$\frac{\partial p_G^{RP}}{\partial r} \geq \frac{\partial p_{B1}^{RP}}{\partial r} \geq \frac{\partial p_{B2}^{RP}}{\partial r} > 0.$$

In words, the generic producer will have incentives to increase its price the most when the reference price increases. Evaluating quantities,

$$\begin{aligned}
q_{B1}^{RP} &= 0.1 \left[ \frac{5(1 - \gamma_1) + (3 + 2\gamma_1)r}{(\gamma_1 + 1)(1 - \gamma_1)} \right], \\
q_{B2}^{RP} &= 0.5a_{B2} + 0.3r, \\
q_G^{RP} &= 0.1 \left[ \frac{10 - 5\gamma_1 - 5\gamma_1^2 - (4 + 3\gamma_1 - 2\gamma_1^2)r}{(\gamma_1 + 1)(1 - \gamma_1)} \right].
\end{aligned}$$

However, when we analyse what is the relationship between quantities and the level of the reference price, we see that the responses for the branded goods and the generic drug not only are quantitatively different, but also qualitatively. Formally, we have that

$$\frac{\partial q_G^{RP}}{\partial r} \leq 0, \quad \frac{\partial q_{B1}^{RP}}{\partial r} \geq 0, \quad \frac{\partial q_{B2}^{RP}}{\partial r} \geq 0.$$

When comparing the absolute value of these derivatives in order to rank them, we obtain that

$$\left| \frac{\partial q_G^{RP}}{\partial r} \right| \geq \left| \frac{\partial q_{B1}^{RP}}{\partial r} \right| \geq \left| \frac{\partial q_{B2}^{RP}}{\partial r} \right|.$$

In words, an increase in  $r$  results in an increase in demand for both branded drugs, but a decrease in the demand for the generic drug. Again, it is for the generic producer that an increase in the level of the reference price causes the biggest change, this time in quantity, in absolute value. This set of inequalities will prove to be crucial when we compare equilibrium values between copayments and reference prices. Evaluating profits, we obtain

$$\begin{aligned}
\pi_B^{RP} &= p_{B1}^{RP} q_{B1}^{RP} + p_{B2}^{RP} q_{B2}^{RP} - C(k_{\max}) = \\
&= 0.01 \frac{(5(1 - \gamma_1) + (3 + 2\gamma_1)r)^2}{(1 + \gamma_1)(1 - \gamma_1)} + (0.5a_{B2} + 0.3r)^2 - C(k_{\max}),
\end{aligned}$$

$$\begin{aligned}\pi_G^{RP} &= p_G^{RP} q_G^{RP} = \\ &= 0.1 \left[ \frac{10 - 5\gamma_1 - 5\gamma_1^2 - (4 + 3\gamma_1 - 2\gamma_1^2)r}{(\gamma_1 + 1)(1 - \gamma_1)} \right] r.\end{aligned}$$

The next step is to give the conditions under which the model is well defined. This implies giving conditions under which quantities are non-negative and prices for the branded goods are higher than the reference price. These amount to

$$\begin{aligned}q_G^{RP} > 0 &\Leftrightarrow r < \frac{5(2 - \gamma_1 - \gamma_1^2)}{(4 + 3\gamma_1 - 2\gamma_1^2)} \equiv G', \\ p_{B1}^{RP} - r > 0 &\Leftrightarrow r < \frac{0.5(1 - \gamma_1)}{0.7 - 0.2\gamma_1} \equiv H', \\ p_{B2}^{RP} - r > 0 &\Leftrightarrow r < \frac{0.5a_{B2}}{0.7} \equiv I' .\end{aligned}$$

The first thing we need to do is to compare the three critical values for  $r$  shown in the inequalities above ( $G'$ ,  $H'$ ,  $I'$ ) and see which one is the most restrictive. Simple algebra shows that  $\frac{5(2 - \gamma_1 - \gamma_1^2)}{(4 + 3\gamma_1 - 2\gamma_1^2)} > \frac{0.5(1 - \gamma_1)}{0.7 - 0.2\gamma_1}$  for the relevant range of  $\gamma_1$ . Hence,  $G' > H'$ , so that we require that  $r < \min \{H', I'\}$ . Direct comparison between these critical values ( $H'$ ,  $I'$ ) gives us the following inequality:

$$H' > I' \Leftrightarrow a_{B2} < \frac{7(1 - \gamma_1)}{7 - 2\gamma_1}.$$

Notice that  $\frac{\partial \left( \frac{7(1 - \gamma_1)}{7 - 2\gamma_1} \right)}{\partial \gamma_1} \leq 0$ . The following lemma summarises the conditions under which the equilibrium that gives rise to a breakthrough drug is well defined.



**Lemma 15** When  $\gamma_2 = 0$ ,  $a_{B1} = a_G = 1$ ,  $\rho = 0.4$  there exists an equilibrium both

under reference prices and copayments, characterised by equations (2.58)-(2.65), when

$$\begin{cases} r < \frac{0.5a_{B2}}{0.7} \equiv I' \text{ if } a_{B2} \in \left(0, \frac{7(1-\gamma_1)}{7-2\gamma_1}\right), \text{ or} \\ r < \frac{0.5(1-\gamma_1)}{0.7-0.2\gamma_1} \equiv H' \text{ if } a_{B2} > \frac{7(1-\gamma_1)}{7-2\gamma_1}. \end{cases}$$

It is important to mention at this point how these critical values depend on  $a_{B2}$ . When  $a_{B2}$  takes low values, implying not only small (potential) demand for the new branded drug, but also low price and demand for this drug, then it is more difficult that the price of this drug is higher than the reference price, so that the inequality that dominates is actually  $p_{B2}^{RP} - r > 0$  i.e. the reference price cannot be set too high because the price that this firm can charge for the new branded drug is low, due to the small (potential) market. However, as the parameter  $a_{B2}$  starts to take higher values, implying higher prices set for the new branded drug by the leader, then the condition that starts to dominate is  $p_{B1}^{RP} - r > 0$ . This is because the higher is  $a_{B2}$ , the lower the difference  $(p_{B1}^{RP} - p_{B2}^{RP})$ , so that the price of the new branded drug can actually be much higher than the price of the old branded drug.

The next step is to compare equilibrium values obtained under copayments and reference prices. We can first evaluate how the difference in prices vary as the parameters of the model vary. More precisely, we obtain that

$$\begin{aligned} \frac{\partial(p_{B1}^{RP} - p_{B1}^C)}{\partial r} &= 0.3 + 0.2\gamma_1 > 0, \text{ and} \\ \frac{\partial(p_{B1}^{RP} - p_{B1}^C)}{\partial \gamma_1} &= 0.05 \frac{10 + 65\gamma_1^2 - 10\gamma_1^4 + 16(1-\gamma_1^2)r + 4r\gamma_1^4}{(-2 + \gamma_1^2)^2} > 0. \end{aligned}$$

This implies that the difference between the price set for the old branded drug under reference price and under copayments increases as the reference prices increases, and as the degree of product differentiation between this old branded drug and its generic version decreases ( $\gamma_1$  increases). With respect to the prices of the old branded drug, direct comparison yields that

$$p_{B1}^{RP} - p_{B1}^C > 0 \Leftrightarrow r > \frac{5(3 - \gamma_1)}{2(3 + 2\gamma_1)} \equiv A'.$$

We need to compare  $A'$  with  $H'$  and  $I'$  to see whether under the feasible range for the reference price, the price of the old branded good is higher under reference prices. We obtain that

$$A' - H' = 2.5 \frac{15 - 11\gamma_1 + 6\gamma_1^2}{(3 + 2\gamma_1)(7.0 - 2\gamma_1)} > 0, \forall \gamma_1 \in (0, 1),$$

$$A' - I' > 0 \Leftrightarrow a_{B2} < 3.5 \frac{3 - \gamma_1}{3 + 2\gamma_1},$$

where  $3.5 \frac{3 - \gamma_1}{3 + 2\gamma_1} > \frac{7(1 - \gamma_1)}{7 - 2\gamma_1}$ . This implies that when  $a_{B2}$  is low enough,  $A' > I'$ , and for higher values of  $a_{B2}$ , we also have that  $A' > H'$ . Hence, for the relevant range of  $r$  for the model to be well defined,  $p_{B1}^{RP} < p_{B1}^C$ . Using a similar procedure for demands for the old branded drug, we have that

$$q_{B1}^{RP} - q_{B1}^C = 0.05 \frac{2r(3 + 2\gamma_1) - 5\gamma_1(1 - \gamma_1)}{(\gamma_1 + 1)(1 - \gamma_1)} > 0 \Leftrightarrow$$

$$r > \frac{5\gamma_1(1 - \gamma_1)}{2(3 + 2\gamma_1)} \equiv B'.$$

Notice first that the difference ( $q_{B1}^{RP} - q_{B1}^C$ ) is increasing in  $r$ . Comparing  $B'$  with the relevant critical values for  $r$ , we obtain that  $B' < H'$ , and  $B' < I'$  when  $a_{B2} > 3.5\gamma_1 \frac{1 - \gamma_1}{3 + 2\gamma_1}$  ( $< \frac{7(1 - \gamma_1)}{7 - 2\gamma_1}$ ). Therefore, when comparing quantities for the old branded good, we need to consider three intervals for  $a_{B2}$ . When

$$a_{B2} \in \left( 0, 3.5\gamma_1 \frac{1 - \gamma_1}{3 + 2\gamma_1} \right),$$

$B' > \min \{H', I'\} = I'$ . Hence for these values of  $a_{B2}$ , demand under reference prices will always be lower under the relevant range of  $r$ . When

$$a_{B2} \in \left( 3.5\gamma_1 \frac{1 - \gamma_1}{3 + 2\gamma_1}, \frac{7(1 - \gamma_1)}{7 - 2\gamma_1} \right),$$

$B' < \min \{H', I'\} = I'$ . This implies that for the lower (higher) values of the reference price  $\left( r < (>) \frac{5\gamma_1(1 - \gamma_1)}{2(3 + 2\gamma_1)} \right)$ , demand under copayments will be higher (lower) than under reference prices for this old branded drug. For high values of  $a_{B2}$   $\left( \text{higher than } \frac{7(1 - \gamma_1)}{7 - 2\gamma_1} \right)$ ,  $B' < \min \{H', I'\} = H'$ . Hence, when  $r \in (0, B')$ ,  $q_{B1}^{RP} < q_{B1}^C$ , but when  $r > B'$ ,  $q_{B1}^{RP} > q_{B1}^C$ . Summarising then, when  $a_{B2}$  is sufficiently low, demand under reference prices for this good will always be lower (under the relevant range for  $r$ ). However, as this parameter increases, implying a higher market size for the new branded good, demand for the old branded drug can be higher under reference prices. For this to be the case, we need that  $r$  is set sufficiently high.

With respect to the generic producer, the difference ( $p_G^{RP} - p_G^C$ ) is increasing in  $r$  and in  $\gamma_1$ . This difference is positive or negative, depending on the values of  $r$ , as shown below

$$p_G^{RP} - p_G^C > 0 \Leftrightarrow r > \frac{5(4 - 2\gamma_1 - 3\gamma_1^2 + \gamma_1^3)}{8(2 - \gamma_1^2)} \equiv C'.$$

Following the same approach as before, we need to compare the critical value  $C'$  with  $\min \{H', I'\}$  to see if the former lies in the interval that the reference price must satisfy for the model to be well defined. Comparing these critical values yields that

$$C' - H' = 0.625 \frac{+12 - 6\gamma_1 - 9\gamma_1^2 + 5\gamma_1^3 - 2\gamma_1^4}{(\gamma_1^2 - 2)(-7 + 2\gamma_1)} > 0, \forall \gamma_1 \in (0, 1),$$

$$C' - I' > 0 \Leftrightarrow a_{B2} < 0.875 \frac{4 - 2\gamma_1 - 3\gamma_1^2 + \gamma_1^3}{2 - \gamma_1^2},$$

where  $0.875 \frac{4 - 2\gamma_1 - 3\gamma_1^2 + \gamma_1^3}{2 - \gamma_1^2} > \frac{7(1 - \gamma_1)}{7 - 2\gamma_1}, \forall \gamma_1 \in (0, 1)$ . These inequalities imply that under the range for  $a_{B2}$  that  $\min \{H', I'\} = I', C' > I'$ , and when  $\min \{H', I'\} = H', C' > H'$ . Hence, under the relevant range for  $r$ , we have that  $p_G^{RP} < p_G^C$ .

Comparing quantities for the generic drug,

$$q_G^{RP} - q_G^C = 0.05 \frac{20 - 10\gamma_1 - 25\gamma_1^2 + 5\gamma_1^3 + 10\gamma_1^4 - 2(8 + 6\gamma_1 - 8\gamma_1^2 - 3\gamma_1^3 + 2\gamma_1^4)r}{(2 - \gamma_1^2)(1 - \gamma_1^2)} > 0$$

$$\Leftrightarrow r < \frac{20 - 10\gamma_1 - 25\gamma_1^2 + 5\gamma_1^3 + 10\gamma_1^4}{2(8 + 6\gamma_1 - 8\gamma_1^2 - 3\gamma_1^3 + 2\gamma_1^4)} \equiv D'.$$

From the expression shown above for the difference  $(q_G^{RP} - q_G^C)$ , we can see that this difference is decreasing in  $r$ . The next step is to compare this critical value,  $D'$ , with  $H'$  and  $I'$ . We have that

$$D' > H' \Leftrightarrow 0 < \gamma_1 < 0.82,$$

$$D' > I' \Leftrightarrow a_{B2} < 3.5 \frac{4 - 2\gamma_1 - 5\gamma_1^2 + \gamma_1^3 + 2\gamma_1^4}{8 + 6\gamma_1 - 8\gamma_1^2 - 3\gamma_1^3 + 2\gamma_1^4},$$

where  $3.5 \frac{4 - 2\gamma_1 - 5\gamma_1^2 + \gamma_1^3 + 2\gamma_1^4}{8 + 6\gamma_1 - 8\gamma_1^2 - 3\gamma_1^3 + 2\gamma_1^4} > \frac{7(1 - \gamma_1)}{7 - 2\gamma_1}$  when  $0 < \gamma_1 < 0.82$ . Hence, when comparing demands for the generic good, we need to consider different intervals for the parameters. Suppose first that  $0 < \gamma_1 < 0.82$ . Then,  $D'$  is always greater than  $\min\{H', I'\}$ . This implies that when  $\gamma_1$  is sufficiently small (less than 0.82), under the relevant range for  $r$ , demand will be higher for the generic good under reference prices. Consider now the case when  $\gamma_1 > 0.82$ . Assume that  $a_{B2} \in \left(0, \frac{7(1 - \gamma_1)}{7 - 2\gamma_1}\right)$ . When

$$a_{B2} < 3.5 \frac{4 - 2\gamma_1 - 5\gamma_1^2 + \gamma_1^3 + 2\gamma_1^4}{8 + 6\gamma_1 - 8\gamma_1^2 - 3\gamma_1^3 + 2\gamma_1^4} \left( < \frac{7(1 - \gamma_1)}{7 - 2\gamma_1} \right),$$

$D' > \min\{H', I'\} = I'$ . However, when  $a_{B2}$  increases such that

$$a_{B2} \in \left( 3.5 \frac{4 - 2\gamma_1 - 5\gamma_1^2 + \gamma_1^3 + 2\gamma_1^4}{8 + 6\gamma_1 - 8\gamma_1^2 - 3\gamma_1^3 + 2\gamma_1^4}, \frac{7(1 - \gamma_1)}{7 - 2\gamma_1} \right),$$

$D' < \min\{H', I'\} = I'$ .

Hence, we can say that for sufficiently low levels of  $a_{B2}$ , demand for the generic drug is higher under reference prices for the values that  $r$  must satisfy for the model to be well defined, for all levels of  $\gamma_1$ . However, as  $a_{B2}$  increases, and is higher than

$$3.5 \frac{4 - 2\gamma_1 - 5\gamma_1^2 + \gamma_1^3 + 2\gamma_1^4}{8 + 6\gamma_1 - 8\gamma_1^2 - 3\gamma_1^3 + 2\gamma_1^4},$$

if  $r$  is set high enough, demand for this drug will be higher under copayments. As  $a_{B2}$  increases further, so that  $\min\{H', I'\} = H'$ , and with  $\gamma_1 > 0.82$ ,  $D' < H'$ . This implies

that when  $r \in (0, D')$ ,  $q_G^{RP} > q_G^C$ , but when the reference price is set higher and above  $D'$  (but lower than  $H'$ ), then the sign of the last inequality is reversed and hence  $q_G^{RP} < q_G^C$ . Summarising then, for low levels of  $\gamma_1$  (implying less substitutability between the old branded and the generic drug), under the relevant range for  $r$ , demand for the generic drug will be higher under reference prices. This result is maintained for low values of  $a_{B2}$  when  $\gamma_1$  increases. However, when the value of  $a_{B2}$  is sufficiently high, then depending on the value of the reference price set, demand for the generic drug will be higher or lower under reference prices. If the reference price is set low enough, then demand will still be higher under reference prices. However, if such reference price is set sufficiently high, then demand will be higher under copayments.

Before going into direct comparisons between prices for the new branded drug, it is interesting to compare how the price for this drug varies as the parameter  $a_{B2}$  varies. Both under copayments and reference prices, an increase in  $a_{B2}$  increases the price of this drug, but when comparing these changes, we obtain that

$$\frac{\partial p_{B2}^C}{\partial a_{2B}} = 1.25 > 0.5 = \frac{\partial p_{B2}^{RP}}{\partial a_{2B}}, \text{ and}$$

$$\frac{\partial (p_{B2}^{RP} - p_{B2}^C)}{\partial a_{2B}} < 0, \text{ and moreover,}$$

$$\frac{\partial (p_{B2}^{RP} - p_{B2}^C)}{\partial r} > 0.$$

In words, these inequalities show that the higher the value of  $a_{2B}$ , (implying a higher (potential) market for this new drug), the difference between the prices set under reference prices and copayments is decreased, but that as the level of the reference price is increased,

this difference will actually increase. Moreover, an increase in  $a_{2B}$  makes  $p_{B2}^C$  increase more than  $p_{B2}^{RP}$ . For the new branded drug, where a market has been created due to its high degree of innovation, we get that

$$\begin{aligned} p_{B2}^{RP} - p_{B2}^C &= 0.3r - 0.75a_{2B} > 0 \Leftrightarrow \\ r &> \frac{0.75a_{2B}}{0.3} \equiv E'. \end{aligned}$$

When we compare this critical value,  $E'$ , with  $\min\{H', I'\}$ , we get the following inequalities:

$$\begin{aligned} E' &> I', \forall a_{2B} > 0, \text{ and} \\ E' &> H' \text{ for } a_{2B} > \frac{2(1 - \gamma_1)}{7 - 2\gamma_1}. \end{aligned}$$

Since  $\frac{7(1 - \gamma_1)}{7 - 2\gamma_1} > \frac{2(1 - \gamma_1)}{7 - 2\gamma_1}$ , for the smaller values of  $a_{B2}$ , so that  $\min\{H', I'\} = I'$ ,  $E' > I'$ , and for the larger values,  $E' > H'$ . This result implies that for the relevant range of the reference price, the price of the innovative drug will be higher under copayments than under reference prices.

Comparing quantities is straightforward, and yields that  $q_{B2}^{RP} > q_{B2}^C, \forall r > 0$ .

The following proposition summarises the results obtained when the incumbent firm produces a breakthrough drug.

**Proposition 16** *When  $\gamma_2 = 0$ ,  $a_{B1} = a_G = 1$ ,  $a_{B2} > 0$ ,  $\rho = 0.4$ , and  $r < \min\{H', I'\}$ , prices for the old branded, the new branded and the generic drugs are higher under copayments than under reference prices. Moreover, demand for the new branded drug is higher*

*under reference prices. Demand for the old branded drug can be higher under reference prices, depending on the value of the parameters. For small values of  $a_{B2}$ , demand for this drug will be higher under copayments. For intermediate and high values of  $a_{B2}$ , when the reference price is set sufficiently high, demand for the old branded drug will be higher under reference prices. For  $0 < \gamma_1 < 0.82$ , demand for the generic drug will be higher under reference prices. For values of  $\gamma_1 > 0.82$ , for sufficiently low levels of  $a_{B2}$ , this result is maintained. However, as  $a_{B2}$  becomes high enough, this result depends on the value of the reference price. For low levels of  $r$ , demand is still higher for the generic drug under reference prices, but if it is set above a certain threshold, demand will be higher under copayments.*

The intuition behind this proposition comes from analysing the variables' response to a change in the parameters. Let us concentrate first on the new branded drug. We know that under the relevant range for the reference price, the price for this drug will be set higher under copayments. This is due first to the higher positive effect that the parameter  $a_{2B}$  has on  $p_{B2}^C$  compared to its effect on  $p_{B2}^{RP}$ . Secondly, even though there is positive effect on the difference between the price set under reference prices and under copayments, since the reference price cannot be set too high, the negative effect that  $a_{2B}$  has on this difference is sufficient to offset the positive effect caused by the level of  $r$ . Hence, the positive relationship between  $a_{2B}$  and  $p_{B2}^C$  is higher than the positive effect of  $a_{2B}$  and  $r$  on  $p_{B2}^{RP}$  because for the model to be well defined, the reference price must not be too high. With respect to the quantities demanded for this drug, the effect is reversed, however. The effect of the parameter  $a_{2B}$  is identical for the equilibrium quantity under reference prices and under



copayments; nonetheless, there is a positive effect of  $r$  on  $q_{B2}^{RP}$  that does not exist on  $q_{B2}^C$ , hence the result obtained.

For the old branded drug, the price of this drug will be higher under copayments because the positive effect of  $r$  on  $p_{B1}^{RP}$  is not high enough, again because there is an upper bound for the reference price by the Authorities. With respect to quantities for this drug, the result depends on the value of  $a_{2B}$  because this parameter determines the upper bound that the reference price can take. When this parameter ( $a_{2B}$ ) is sufficiently low, decreasing the upper bound for  $r$ , then the positive effect that  $r$  has on  $q_{B1}^{RP}$  cannot be sufficiently high, so that quantity demanded for this drug will actually be higher under copayments. However, as  $a_{2B}$  takes higher values, increasing the upper bound for  $r$ , then the critical value of  $r$  that determines whether the difference ( $q_{B1}^{RP} - q_{B1}^C$ ) is positive lies in the interval that  $r$  can take; hence, if  $a_{2B}$  increases (and thereby the potential total market size increases), there is a possibility that demand for this good will be higher under reference price. For this to occur, the reference price has to be set high enough so that the positive effect that  $r$  has on demand for this product actually dominates.

Prices for the generic good under copayments are higher due to a similar reasoning that causes that under the relevant range for  $r$  the prices of both branded goods are higher under copayments: since there is an upper bound for  $r$ , the positive effect that  $r$  has on  $p_G^{RP}$  is not sufficiently strong. The analysis for demands for this drug is somewhat more complex. We know that for sufficiently low levels of  $r$ , demand for the generic alternative will be higher under reference prices. This is because the negative effect that  $r$  has on  $q_G^{RP}$  is not too high. However, the critical value of  $r$  that gives rise to a negative difference ( $q_G^{RP} - q_G^C$ )

actually depends on  $a_{2B}$ , because as mentioned before,  $a_{2B}$  determines the upper bound for  $r$ . Hence, when  $a_{2B}$  is low enough, the upper bound for  $r$  is low enough, so that the negative effect of  $r$  on  $q_G^{RP}$  is never too strong. However, as  $a_{2B}$  starts to increase, the upper bound for  $r$  starts to increase also, so that there is room that for sufficient high levels of  $r$ , the negative effect of  $a_{2B}$  on generic demand under reference prices can start to dominate, and actually becomes dominant. Hence, under this circumstances, we obtain that the quantity for this good under copayments is higher.

## 2.4 Me-too drug.

Assume that the conditions that give rise to a me-too drug are satisfied, so that  $\gamma_2 = \gamma_1$ . There are three goods in the same market, two branded and one generic. Suppose first that copayments are enforced<sup>11</sup>. Demand functions become

$$\begin{aligned} q_{B1}^C(\gamma_2 = \gamma_1) &= 0.2 \frac{5(1 - \gamma_1 a_{B2}) - 2(1 + \gamma_1)p_{B1} + 2\gamma_1(p_{B2} + p_G)}{1 + \gamma_1 - 2\gamma_1^2}, \\ q_{B2}^C(\gamma_2 = \gamma_1) &= 0.2 \frac{5a_{B2}(1 + \gamma_1) - 10\gamma_1 - 2(1 + \gamma_1)p_{B2} + 2\gamma_1(p_{B1} + p_G)}{1 + \gamma_1 - 2\gamma_1^2}, \\ q_G^C(\gamma_2 = \gamma_1) &= 0.2 \frac{5(1 - \gamma_1 a_{B2}) - 2(1 + \gamma_1)p_G + 2\gamma_1(p_{B1} + p_{B2})}{1 + \gamma_1 - 2\gamma_1^2}. \end{aligned}$$

In this case, since the new drug is a me-too, it will directly compete with the old branded drug and the generic version. Proceeding by backward induction again, equilibrium prices

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<sup>11</sup> Recall that we are assuming that  $a_{B1} = a_G = 1$ , and  $\rho = 0.4$ .

are:

$$p_G^C = 0.625 \frac{2 + 3\gamma_1 - 2\gamma_1^2 - 2\gamma_1^3 - \gamma_1(1 + \gamma_1 - \gamma_1^2)a_{B2}}{(\gamma_1 + 1)(1 + \gamma_1 - \gamma_1^2)}, \quad (2.66)$$

$$p_{B1}^C = 0.625 \frac{2 + \gamma_1 - 3\gamma_1^2}{1 + \gamma_1 - \gamma_1^2}, \quad (2.67)$$

$$p_{B2}^C = 0.625 \frac{2(1 + \gamma_1 - \gamma_1^2)a_{B2} - \gamma_1(1 + \gamma_1)}{1 + \gamma_1 - \gamma_1^2}, \quad (2.68)$$

yielding the associated equilibrium quantities:

$$q_G^C = 0.25 \frac{2 + 3\gamma_1 - 2\gamma_1^2 - 2\gamma_1^3 - \gamma_1 a_{B2}(1 + \gamma_1 - \gamma_1^2)}{(2\gamma_1^2 - 1\gamma_1 - 1)(\gamma_1^2 - \gamma_1 - 1)}, \quad (2.69)$$

$$q_{B1}^C = 0.25 \frac{2 + 3\gamma_1 - \gamma_1 a_{B2}(2 + 3\gamma_1)}{(1 + \gamma_1 - 2\gamma_1^2)(\gamma_1 + 1)}, \quad (2.70)$$

$$q_{B2}^C = 0.25 \frac{(2 + 4\gamma_1 + \gamma_1^2)a_{B2} - 3\gamma_1 - 4\gamma_1^2}{(1 + \gamma_1 - 2\gamma_1^2)(\gamma_1 + 1)}. \quad (2.71)$$

Notice that the price and quantity of the new drug depend positively on the parameter  $a_{B2}$ , while the generic's price, its demand and the old branded's demand depend negatively. Hence, an increase in the (potential) size of the market for the new drug has two opposing effects for the leader: on the one hand, it increases profits earned by the new branded drug; on the other, it decreases the profits obtained with the old one. Moreover, as shown later, the size of this parameter will actually affect the decision whether or not to actually substitute the old drug by the new one. For the generic producer, an increase in this parameter has an unambiguous effect: higher  $a_{B2}$  implies lower profits, *ceteris paribus*.

Under reference prices, demand functions are as follows:

$$q_{B1}^C(\gamma_2 = \gamma_1) = 0.2 \frac{5(1 - \gamma_1 a_{B2}) + 3r - 5(1 + \gamma_1)p_{B1} + 5\gamma_1 p_{B2} + 2\gamma_1 p_G}{(1 - \gamma_1)(1 + 2\gamma_1)},$$

$$q_{B2}^C(\gamma_2 = \gamma_1) = 0.2 \frac{5a_{B2}(1 + \gamma_1) - 10\gamma_1 + 3r - 5(1 + \gamma_1)p_{B2} + 5\gamma_1 p_{B1} + 2\gamma_1 p_G}{(1 - \gamma_1)(1 + 2\gamma_1)},$$

$$q_G^C(\gamma_2 = \gamma_1) = 0.2 \frac{5(1 - \gamma_1 a_{B2}) - 6\gamma_1 r - 2(1 + \gamma_1)p_G + 5\gamma_1(p_{B1} + p_{B2})}{(1 - \gamma_1)(1 + 2\gamma_1)}.$$

As when a breakthrough drug is produced, comparing demand functions when copayments or reference prices are enforced shows that the reference price acts as a subsidy for both branded goods, while acts as a kind of tax for the generic good.

Solving first for the generic producer, we obtain a corner solution. Hence, we have that  $p_G^{RP} = r$ . The branded firm then chooses  $p_{B1}^{RP}$  and  $p_{B2}^{RP}$  so as to maximise profits, yielding

$$p_{B1}^{RP} = \frac{1}{2}(1 - \gamma_1) + (0.3 + 0.2\gamma_1)r, \quad (2.72)$$

$$p_{B2}^{RP} = \frac{1}{2}(a_{B2} - \gamma_1) + (0.3 + 0.2\gamma_1)r. \quad (2.73)$$

With these equilibrium prices, we obtain the associated equilibrium quantities:

$$q_{B1}^{RP} = 0.1 \frac{5(1 - \gamma_1 a_{B2}) + (2\gamma_1 + 3)r}{(1 - \gamma_1)(1 + 2\gamma_1)}, \quad (74)$$

$$q_{B2}^{RP} = 0.1 \frac{5(1 + \gamma_1)a_{B2} - 10\gamma_1 + (2\gamma_1 + 3)r}{(1 - \gamma_1)(1 + 2\gamma_1)}, \quad (75)$$

$$q_G^{RP} = 0.1 \frac{10 + 5\gamma_1 - 5\gamma_1 a_{B2} - (4 + 10\gamma_1 - 4\gamma_1^2)r}{(1 - \gamma_1)(1 + 2\gamma_1)}. \quad (76)$$

Carrying comparative static analysis will provide useful for later results. There is still a positive relationship between the level of the reference price and the prices for all three goods. With respect to the relationship between  $r$  and quantities, the positive relation-

ship still remains for both branded goods, but there is a negative relationship between the quantity demanded for the generic drug and the reference price. Moreover, we have that

$$\left| \frac{\partial p_G^{RP}}{\partial r} \right| > \left| \frac{\partial p_{B1}^{RP}}{\partial r} \right| = \left| \frac{\partial p_{B2}^{RP}}{\partial r} \right|, \text{ and}$$

$$\left| \frac{\partial q_G^{RP}}{\partial r} \right| > \left| \frac{\partial q_{B1}^{RP}}{\partial r} \right| = \left| \frac{\partial q_{B2}^{RP}}{\partial r} \right|$$

The relationship between the value of the parameter  $a_{B2}$  and these equilibrium values is the same qualitatively as when a breakthrough drug is produced: higher market size for the new drug implies higher prices and quantities for this new drug, but lower demand for the old branded and lower price and demand for the generic version.

Evaluating profits for both producers under copayments, we obtain

$$\pi_B^C = 0.16 \frac{(1 - \gamma_1 a_{2B}) (2 + 3\gamma_1)^2}{(1 + \gamma_1) (2\gamma_1 + 1) (1 + \gamma_1 - \gamma_1^2)} +$$

$$0.16 (2a_{2B}(1 + \gamma_1 - \gamma_1^2) - \gamma_1 - \gamma_1^2) \frac{a_{2B}(2 + 4\gamma_1\gamma_1^2) - 3\gamma_1 - 4\gamma_1^2}{(-1 - \gamma_1 + \gamma_1^2) (2\gamma_1^2 - \gamma_1 - 1) (1 + \gamma_1)} - C(k^*),$$

$$\pi_G^C = 0.625 \frac{(2 + 3\gamma_1 - 2\gamma_1^2 - 2\gamma_1^3 - \gamma_1 a_{2B} (1 + \gamma_1 - \gamma_1^2))^2}{(2\gamma_1^2 - \gamma_1 - 1) (-1 - \gamma_1 + \gamma_1^2)^2 (1 + \gamma_1)}.$$

Under reference prices, profits are:

$$\pi_B^{RP} = 0.01 \left[ (5(1 - \gamma_1) + (3 + 2\gamma_1)r) \frac{5(1 - \gamma_1 a_{B2}) + (2\gamma_1 + 3)r}{(1 - \gamma_1)(2\gamma_1 + 1)} \right] +$$

$$0.01 \left[ \frac{50a_{2B}(1 + \gamma_1 - 2\gamma_1^2) - 50\gamma_1(1 + \gamma_1 - 2\gamma_1^2) + 5ra_{2B}(3 + 5\gamma_1 + 2\gamma_1^2) - 10r\gamma_1(3 + 2\gamma_1) + r^2(9 + 12\gamma_1 + 4\gamma_1^2)}{1 + \gamma_1 - 2\gamma_1^2} \right] - C(k^*),$$

$$\pi_G^{RP} = 0.1 \left[ \frac{10 + 5\gamma_1 - 5\gamma_1 a_{B2} - (4 + 10\gamma_1 - 4\gamma_1^2)r}{(1 - \gamma_1)(2\gamma_1 + 1)} \right] r.$$

The next step is to define the conditions that ensure that this equilibrium is well-behaved.

The next lemma shows that under certain conditions, this equilibrium exists.

**Lemma 17** *When  $\gamma_2 = \gamma_1$ ,  $a_{B1} = a_G = 1$ ,  $\rho = 0.4$  and*

$$a_{B2} \in \left( \frac{\gamma_1(3 + 4\gamma_1)}{2 + \gamma_1^2 + 4\gamma_1}, \frac{1}{\gamma_1} \right),$$

*there exists an equilibrium both under reference prices and copayments, characterised by equations (2.66)-(2.76), and  $p_G^{RP} = r$ , when*

$$\left\{ \begin{array}{l} \text{CASES 1 and 2: } r < \frac{5(1 - \gamma_1)}{7 - 2\gamma_1} \equiv I \text{ if } a_{B2} \in \left( 1, \frac{1}{\gamma_1} \right), \text{ or} \\ \text{CASE 3: } r < \frac{5(a_{B2} - \gamma_1)}{7 - 2\gamma_1} \equiv H \text{ if } a_{B2} \in \left( \frac{\gamma_1(3 + 4\gamma_1)}{2 + \gamma_1^2 + 4\gamma_1}, 1 \right). \end{array} \right.$$

**Proof.** For the equilibrium to be well defined, we require non-negative equilibrium prices and quantities. Under copayments, we require that  $p_G^C, p_B^C, p_{B2}^C, q_G^C, q_{B1}^C, q_{B2}^C > 0$ . We obtain that  $p_{B1}^C$  is always non-negative when  $\gamma_1 \in (0, 1)$ . From straight algebraic manipulation, we obtain an upper and a lower bound for  $a_{B2}$  such that all equilibrium values are non-negative.

The lower bound is given by the last inequality, where  $q_{B2}^C > 0 \Leftrightarrow a_{B2} > \frac{\gamma_1(3 + 4\gamma_1)}{2 + \gamma_1^2 + 4\gamma_1}$ .

The upper bound is given from the inequality  $q_{B1}^C > 0$ , whereby for it to be satisfied, we

need that  $a_{B2} < \frac{1}{\gamma_1}$ . It can be easily shown that  $\frac{\gamma_1(3+4\gamma_1)}{2+\gamma_1^2+4\gamma_1} < 1 < \frac{1}{\gamma_1}$  for  $\gamma_1 \in (0, 1)$ ;

hence the interval is well defined. The first step of the proof is completed. Under reference

prices, we need the following inequalities to be satisfied:

$$q_G^{RP} > 0 \Leftrightarrow r < \frac{5}{2} \left[ \frac{2+2\gamma_1^2-\gamma_1+\gamma_1 a_{B2}}{2+5\gamma_1-2\gamma_1^2} \right] \equiv G.$$

$$p_{B2}^{RP} - r > 0 \Leftrightarrow r < \frac{5(a_{B2}-\gamma_1)}{7-2\gamma_1} \equiv H,$$

$$p_{B1}^{RP} - r > 0 \Leftrightarrow r < \frac{5(1-\gamma_1)}{7-2\gamma_1} \equiv I. \text{ The next step is to compare } G, H \text{ and } I \text{ in order}$$

to see which inequality is more restrictive. We have that  $H > I \Leftrightarrow a_{B2} > 1$ . More-

over, we have that  $H > G \Leftrightarrow a_{B2} > \frac{14+7\gamma_1-6\gamma_1^2}{4+17\gamma_1-6\gamma_1^2}$ , where  $\left( \frac{\gamma_1(3+4\gamma_1)}{2+\gamma_1^2+4\gamma_1} < \right) 1 < \frac{14+7\gamma_1-6\gamma_1^2}{4+17\gamma_1-6\gamma_1^2} < \frac{1}{\gamma_1}$  for  $\gamma_1 \in (0, 1)$ . We also have that  $I < G \Leftrightarrow a_{B2} < \frac{10-3\gamma_1-2\gamma_1^2}{\gamma_1(7-2\gamma_1)} \left( > \frac{1}{\gamma_1} \right)$ .

Hence, for the interval that the parameter  $a_{B2}$  must lie in,  $I < G$ . This set of inequalities

imply that we have three possible cases:

- Case 1. When  $\frac{14+7\gamma_1-6\gamma_1^2}{4+17\gamma_1-6\gamma_1^2} < a_{B2} < \frac{1}{\gamma_1}$ , then  $I < G < H$ .
- Case 2. When  $1 < a_{B2} < \frac{14+7\gamma_1-6\gamma_1^2}{4+17\gamma_1-6\gamma_1^2}$ , then  $I < H < G$ .
- Case 3. When  $\frac{\gamma_1(3+4\gamma_1)}{2+\gamma_1^2+4\gamma_1} < a_{B2} < 1$ , then  $H < I < G$ .

Therefore, Cases 1 and 2 imply that  $\min \{G, H, I\} = I$ , while Case 3 implies that  $\min \{G, H, I\} =$

$H$ .

■

The next step is to compare prices and quantities when a me-too drug is produced under reference prices and copayments. For the old branded good, we obtain that

$$p_{B1}^{RP} - p_{B1}^C > 0 \Leftrightarrow$$

$$r > \frac{5(6 + 5\gamma_1 - 7\gamma_1^2 - 4\gamma_1^3)}{4(3 + 5\gamma_1 - \gamma_1^2 - 2\gamma_1^3)} \equiv A.$$

We need to compare  $A$  with  $\min\{G, H, I\}$  to see if it is in the interval for the reference price  $r$ . Comparisons yield that  $A$  is always greater than the  $\min\{G, H, I\}$  so that under the relevant range of  $r$ ,  $p_{B1}^{RP} < p_{B1}^C$ . The next comparison is for quantities for the old branded good. We obtain that

$$q_{B1}^{RP} - q_{B1}^C > 0 \Leftrightarrow$$

$$r > \frac{5\gamma_1(1 - \gamma_1 a_{B2})}{6 + 10\gamma_1 + 4\gamma_1^2} \equiv D.$$

Analysing case by case as illustrated in the previous lemma, we have that under Case 1 and 2,  $D < I$ . Under Case 3, we have the following:

$$\left\{ \begin{array}{l} \text{when } a_{B2} \in \left( \frac{13\gamma_1 + 8\gamma_1^2 + 4\gamma_1^3}{6 + 10\gamma_1 + 11\gamma_1^2 - 2\gamma_1^3}, 1 \right), D < H, \\ \text{when } a_{B2} \in \left( \frac{\gamma_1(3 + 4\gamma_1)}{2 + \gamma_1^2 + 4\gamma_1}, \frac{13\gamma_1 + 8\gamma_1^2 + 4\gamma_1^3}{6 + 10\gamma_1 + 11\gamma_1^2 - 2\gamma_1^3} \right), D > H. \end{array} \right.$$

What this result is saying is that when the market size is bigger for the new branded drug than for the old branded and generic ( $a_{B2} > 1$ ), then for sufficiently high levels of the reference price, demand will be higher for this old branded drug under reference prices than under copayments. When the market size for the new branded drug is not sufficiently high, so that  $\min\{G, H, I\} = H$ , then we have two possible results. For values of  $a_{B2}$



higher than  $\frac{13\gamma_1 + 8\gamma_1^2 + 4\gamma_1^3}{6 + 10\gamma_1 + 11\gamma_1^2 - 2\gamma_1^3}$  (but lower than 1), so that  $D < H$ , then the same reasoning applies as when  $a_{B2} > 1$ : demand for the old branded drug will be higher under reference prices only when the reference price is set high enough. When  $a_{B2}$  decreases, so that  $D > H$ , demand for the branded drug will always be higher under copayments under the relevant range for  $r$ . In this subcase, the positive effect that the reference price has on  $q_{B1}^{RP}$  is not sufficiently high since the reference price cannot be set too high.

Let us compare now between the equilibrium values for the new branded drug. For prices, we obtain that

$$p_{B2}^{RP} - p_{B2}^C > 0 \Leftrightarrow r > \frac{30a_{B2}(1 + \gamma_1 + \gamma_1^2) - 5\gamma_1(1 + \gamma_1 + 4\gamma_1^2)}{12 + 20\gamma_1 - 4\gamma_1^2 - 8\gamma_1^3} \equiv C.$$

We need to compare this bound of  $r$ ,  $C$ , to see if it is placed in the interval for the reference price. Algebraic manipulation shows that  $C$  is always greater than  $\min\{G, H, I\}$ , so that under the relevant range for  $r$ ,  $p_{B2}^{RP} < p_{B2}^C$ . Hence, the price for the new branded drug will be higher under copayments than under reference prices, on the interval for the reference price that ensures that a well-behaved equilibrium exists. Comparison of quantities for the new branded drug yields exactly the same result as with the old branded drug, since

$$q_{B2}^{RP} - q_{B2}^C > 0 \Leftrightarrow r > \frac{5\gamma_1(1 - \gamma_1 a_{B2})}{6 + 10\gamma_1 + 4\gamma_1^2} \equiv D.$$

The next step is to do the same with the price and demand of the generic good. Price comparisons yield

$$p_G^{RP} - p_G^C > 0 \Leftrightarrow r > \frac{5(2 + 3\gamma_1 - 2\gamma_1^2 - 2\gamma_1^3) - 5\gamma_1 a_2(1 + \gamma_1 - \gamma_1^2)}{8(1 + 2\gamma_1 - \gamma_1^3)} \equiv E.$$

Under Cases 2 and 3, algebraic manipulation shows that  $E$  is higher than  $I$  and  $H$  respectively. This implies that in these two cases, under the relevant range for the reference price, the price of the generic good is higher under copayments. However, under Case 1, the analysis is not that straightforward. We have two possible subcases, depending on the values of  $\gamma_1$  and  $a_{B2}$ . When  $\gamma_1 \in (0.21, 1)$ , then for all relevant values of  $a_{B2}$ , we still have that  $p_G^{RP} < p_G^C$ . However, for sufficiently low levels of  $\gamma_1$ , and for sufficiently high values of  $a_{B2}$ , we can have that  $p_G^{RP} > p_G^C$ . Therefore, for the price of the generic good to be higher under reference prices, we require some degree of monopoly power (low value of  $\gamma_1$ ) and sufficient demand for the new branded drug (high value of  $a_{B2}$ ). Formally, we have that

$$\text{When (Case 1)} \left\{ \begin{array}{l} \left\{ \begin{array}{l} a_{B2} \in \left( \frac{6 + 9\gamma_1 - 4\gamma_1^2 - 2\gamma_1^3 - 4\gamma_1^4}{7\gamma_1 + 5\gamma_1^2 - 9\gamma_1^3 + 2\gamma_1^4}, \frac{1}{\gamma_1} \right) \Rightarrow \\ p_G^{RP} > p_G^C \text{ for } \gamma_1 \in (0, 0.21) \text{ and } r \in (E, \min\{G, H, I\}). \end{array} \right. \\ \left\{ \begin{array}{l} a_{B2} \in \left( \frac{14 + 7\gamma_1 - 6\gamma_1^2}{4 + 17\gamma_1 - 6\gamma_1^2}, \frac{6 + 9\gamma_1 - 4\gamma_1^2 - 2\gamma_1^3 - 4\gamma_1^4}{7\gamma_1 + 5\gamma_1^2 - 9\gamma_1^3 + 2\gamma_1^4} \right) \Rightarrow \\ p_G^C > p_G^{RP} \forall \gamma_1 \in (0, 1) \text{ and } r \in (0, \min\{G, H, I\}). \end{array} \right. \end{array} \right.$$

$$\text{When (Cases 2 and 3)} \left\{ \begin{array}{l} a_{B2} \in \left( \frac{\gamma_1(3 + 4\gamma_1)}{2 + \gamma_1^2 + 4\gamma_1}, \frac{14 + 7\gamma_1 - 6\gamma_1^2}{4 + 17\gamma_1 - 6\gamma_1^2} \right) \Rightarrow \\ p_G^C > p_G^{RP} \forall \gamma_1 \in (0, 1) \text{ and } r \in (0, \min\{G, H, I\}). \end{array} \right.$$

Summarising then, when  $a_{B2}$  is low enough, prices under reference prices for the generic good are lower irrespective of the degree of product differentiation, under the relevant range for  $r$ . However, for a sufficiently high (potential) market size for the new branded good, the price of the generic drug can actually be higher under reference prices. For this to occur, the value of  $\gamma_1$  should be low enough (lower than 0.21) and the value of the reference price should be set high enough, so that the positive effect that the level of the reference price has on  $p_G^{RP}$  is sufficiently high to dominate and offset the negative effect that  $a_{B2}$  has on  $p_G^C$  (as shown in equation (2.66))<sup>12</sup>. Hence, only when  $r$  is set high enough, the market size for the new branded drug is sufficiently high, and the degree of product differentiation is low, will the generic producer have incentives to set its price higher under reference prices than under copayments.

Comparison between quantities yields that demand can be higher under reference prices depending on the value of the three parameters  $\gamma_1$ ,  $a_{B2}$  and  $r$ . More precisely, we have that

$$q_G^{RP} - q_G^C > 0 \Leftrightarrow r < \frac{10 + 15\gamma_1 - 20\gamma_1^2 - 20\gamma_1^3 + 20\gamma_1^4 - 5\gamma_1 a_{B2}(1 + \gamma_1 - \gamma_1^2)}{4(2 + 7\gamma_1 + \gamma_1^2 - 7\gamma_1^3 + 2\gamma_1^4)} \equiv F.$$

Depending on the value of  $a_{B2}$ , we can have two subcases. Let us consider one case at a time. Suppose that  $a_{B2}$  is sufficiently high, so that we are under conditions of Case 1, where

$$a_{B2} \in \left( \frac{14 + 7\gamma_1 - 6\gamma_1^2}{4 + 17\gamma_1 - 6\gamma_1^2}, \frac{1}{\gamma_1} \right).$$

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<sup>12</sup> recall that  $p_G^{RP} = r$ .

Then, when  $\gamma_1$  is sufficiently high (higher than 0.32),  $F < I$ , which implies that for positive values of  $r$  lower than  $F$ ,  $q_G^{RP} > q_G^C$ . However, should the reference price be set higher than  $F$ , the demand for the generic good will be higher under copayments. For lower values of  $\gamma_1$  ( $\gamma_1 \in (0, 0.32)$ ), then depending on the value that  $a_{B2}$  takes, the direction of the inequality will be reversed. For the highest values of  $a_{B2}$  possible (when

$$a_{B2} \in \left( \frac{6 - 3\gamma_1 - 10\gamma_1^2 + 12\gamma_1^3}{\gamma_1(7 + 5\gamma_1 - 9\gamma_1^2 + 2\gamma_1^3)}, \frac{1}{\gamma_1} \right),$$

simple algebraic manipulation shows that  $F > I$ . This implies that in this subcase, for whatever values that  $r$  takes in the interval required,  $q_G^{RP} > q_G^C$ . However, if the value of  $a_{B2}$  is reduced, so that

$$a_{B2} \in \left( \frac{14 + 7\gamma_1 - 6\gamma_1^2}{4 + 17\gamma_1 - 6\gamma_1^2}, \frac{6 - 3\gamma_1 - 10\gamma_1^2 + 12\gamma_1^3}{\gamma_1(7 + 5\gamma_1 - 9\gamma_1^2 + 2\gamma_1^3)} \right),$$

then  $F < I$ . Hence, when the reference price is set below (above)  $F$ ,  $q_G^{RP}$  will be higher (lower) than  $q_G^C$ .

For Case 2, with

$$a_{B2} \in \left( 1, \frac{14 + 7\gamma_1 - 6\gamma_1^2}{4 + 17\gamma_1 - 6\gamma_1^2} \right),$$

we also have different subcases. For very low values of  $\gamma_1$  (lower than 0.32),  $F > I$  so that for the relevant range of  $r$ ,  $q_G^{RP} > q_G^C$ . When  $\gamma_1 \in (0.32, 0.48)$ , whenever

$$a_{B2} \in \left( 1, \frac{6 - 3\gamma_1 - 10\gamma_1^2 + 12\gamma_1^3}{\gamma_1(7 + 5\gamma_1 - 9\gamma_1^2 + 2\gamma_1^3)} \right),$$

$F > I$ , so that the demand for the generic good under reference prices will be higher than under copayments. However, when

$$a_{B2} \in \left( \frac{6 - 3\gamma_1 - 10\gamma_1^2 + 12\gamma_1^3}{\gamma_1(7 + 5\gamma_1 - 9\gamma_1^2 + 2\gamma_1^3)}, \frac{14 + 7\gamma_1 - 6\gamma_1^2}{4 + 17\gamma_1 - 6\gamma_1^2} \right),$$

$F < I$ , so that the demand for this good under reference prices will be higher depending on the magnitude of  $r$ . Finally, whenever  $\gamma_1$  is sufficiently high (higher than 0.48) so that the three goods become closer substitutes, then  $F < I$  always.

Finally, consider the case that

$$a_{B2} \in \left( \frac{\gamma_1(3 + 4\gamma_1)}{2 + \gamma_1^2 + 4\gamma_1}, 1 \right),$$

so that we are under the conditions that give rise to Case 3. When the degree of product differentiation is sufficiently low (lower than 0.48), then for the relevant range of  $a_{B2}$ ,  $F > H$ , so that  $q_G^{RP} > q_G^C$ . For higher values of  $\gamma_1$ , there are two subcases, depending on the value of  $a_{B2}$ . Whenever

$$a_{B2} \in \left( \frac{\gamma_1(3 + 4\gamma_1)}{2 + \gamma_1^2 + 4\gamma_1}, \frac{14 + 25\gamma_1 - 6\gamma_1^2 - 16\gamma_1^3 + 8\gamma_1^4}{8 + 35\gamma_1 + 9\gamma_1^2 - 37\gamma_1^3 + 10\gamma_1^4} \right),$$

$F > H$ , but when the value of this parameter increases, and

$$a_{B2} \in \left( \frac{14 + 25\gamma_1 - 6\gamma_1^2 - 16\gamma_1^3 + 8\gamma_1^4}{8 + 35\gamma_1 + 9\gamma_1^2 - 37\gamma_1^3 + 10\gamma_1^4}, 1 \right),$$

the direction of the previous inequality is reversed, so that  $F < H$ . Hence, if  $a_{B2}$  is around the lower values this parameter can take in this case, the demand for the generic good will be higher under reference prices; however, if  $a_{B2}$  increases and is closer to 1, and the degree of differentiation is high enough, then for sufficiently high levels of the reference price the demand for the generic drug can actually be higher under copayments.

The following proposition summarises the results presented in this section.

**Proposition 18** *When  $\gamma_2 = \gamma_1$ ,  $a_{B1} = a_G = 1$ ,  $\rho = 0.4$ ,  $r < \min \{G, H, I\}$ ,*

$$a_{B2} \in \left( \frac{\gamma_1(3 + 4\gamma_1)}{2 + \gamma_1^2 + 4\gamma_1}, \frac{1}{\gamma_1} \right),$$

prices for the old branded drug and the new branded drug are higher under copayments. Generic prices are higher under copayments when  $\alpha_{B2}$  is low enough for all values of  $\gamma_1 \in (0, 1)$ . However, when  $\alpha_{B2}$  is sufficiently high, the price of the generic good can be higher under reference prices. For this to happen, we require that  $\gamma_1$  is sufficiently low and the reference price is set high enough. Otherwise, the price of the generic alternative will be higher under copayments. Demand for the old and new branded drug can be higher under reference prices whenever  $\alpha_{B2}$  is high enough and the reference price is set high enough. However, for lower values of  $\alpha_{B2}$ , demand for this branded drug will be higher under copayments under the relevant range for  $r$  that gives rise to a well-defined equilibrium. Demand for the generic drug can also be higher under reference prices whenever the reference price is set low enough. Moreover, we also require that the parameters  $\alpha_{B2}$  and  $\gamma_1$  take certain values. Consider the case when  $\alpha_{B2}$  lies in the upper part of the interval it must lie in for the equilibria described to be well defined (i.e. the total market size for the new drug is high). Then, for high values of  $\gamma_1$ , the price of the generic good is higher under reference prices if the reference price is not set too high. However, for lower values of  $\gamma_1$ , implying higher product differentiation, we can have that irrespective of the level of the reference price set, demand for this drug will be higher under reference prices. As  $\alpha_{B2}$  starts to decrease this relationship is qualitatively maintained; for lower values of  $\gamma_1$  demand for the generic drug will always be higher under reference prices under the condition that  $r < \min \{G, H, I\}$ . However, for the higher values of  $\gamma_1$ , demand for the generic producer will be higher under reference prices only when the reference price is set low enough.

## 2.5 Substitution.

This section analyses whether or not the incumbent firm has incentives to remove the old drug from the market if a second drug is produced. When the leader firm produces a breakthrough drug, so that two distinct markets exist, then it is clear that this firm will never have incentives to remove the old drug from the market. This is because the two goods compete in different markets. However, when only enough resources are spent so that a me-too drug is produced, the appearance of this second drug cannibalises part of the demand of the old branded drug. Hence, what we want to see is whether removing the old drug actually leaves the incumbent firm better off than producing two goods.

Before making the comparisons, we need to be careful how to define the inverse demand functions. Recall that demand functions with three goods were:

$$q_{B1}^3 = \frac{(1 - \gamma_2^2)(a_{B1} - \hat{p}_{B1}) - \gamma_2(1 - \gamma_1)(a_{B2} - \hat{p}_{B2}) - (\gamma_1 - \gamma_2^2)(a_G - \hat{p}_G)}{1 + 2\gamma_1\gamma_2^2 - \gamma_1^2 - 2\gamma_2^2},$$

$$q_{B2}^3 = \frac{(1 + \gamma_1)(a_{B2} - \hat{p}_{B2}) - \gamma_2(a_{B1} + a_G) + \gamma_2(\hat{p}_G + \hat{p}_{B1})}{1 + \gamma_1 - 2\gamma_2^2},$$

$$q_G^3 = \frac{(1 - \gamma_2^2)(a_G - \hat{p}_G) - (\gamma_1 - \gamma_2^2)(a_{B1} - \hat{p}_{B1}) - \gamma_2(1 - \gamma_1)(a_{B2} - \hat{p}_{B2})}{1 + 2\gamma_1\gamma_2^2 - \gamma_1^2 - 2\gamma_2^2},$$

where the superscript 3 refers to the situation with three goods in the market. Total (potential) market size in this situation is hence  $\frac{2 + a_{B2}}{1 + 2\gamma_1}$  (when  $p_{B1} = p_{B2} = p_G = 0$ ), and given that  $a_{B1} = a_G = 1$ .

However, with only two goods, so that the good denoted by  $B1$  is removed from the market and only stay the new branded ( $B2$ ) and the generic drug ( $G$ ), inverse demand functions become:

$$\hat{p}_{B2} = \hat{a}_{B2} - q_{B2} - \gamma_2 q_G,$$

$$\hat{p}_G = 1 - q_G - \gamma_2 q_{B2}.$$

Recall that  $\hat{p}_i, i = B2, G$  stands for the net price paid by the consumer for the new branded drug and the generic drug respectively. Moreover, we are assuming that  $a_G = 1$ . The parameter  $\hat{a}_{B2}$  is the crucial one when comparing the situations between two or three goods. Moreover, we cannot directly assume that  $\hat{a}_{B2} = a_{B2}$ , since this could lead to erroneous conclusions. This is because we have to consider various possible situations when the old drug is replaced by the new one: we can have a market expansion effect, market reduction effect, or no change in the total market size. Depending on the relationship between  $\hat{a}_{B2}$  and  $a_{B2}$ , one of three possible situations will occur.

Demand functions with the two goods are:

$$q_{B2}^2 = \frac{\hat{a}_{B2} - \gamma_2 - \hat{p}_{B2} + \gamma_2 \hat{p}_G}{1 - \gamma_2^2},$$

$$q_G^2 = \frac{1 - \gamma_2 \hat{a}_{B2} - \hat{p}_G + \gamma_2 \hat{p}_{B2}}{1 - \gamma_2^2},$$

where the superscript 2 in this case denotes the situation with two goods, the new branded and the old generic. Total market size when there are two goods is  $\frac{1 + \hat{a}_{B2}}{1 + \gamma_1}$ . Comparing total market sizes with two and three goods, we obtain that if  $\frac{1 + \hat{a}_{B2}}{1 + \gamma_1} > \frac{2 + a_{B2}}{1 + 2\gamma_1}$ , then there will be a market expansion effect.



For comparison purposes, let us fix first the parameter  $a_{B2} = 1$  (which lies in the interval defined for this parameter that ensures that the equilibrium that gives rise to a me-too drug is well behaved). Hence, a market expansion effect will occur whenever

$$\frac{1 + \hat{a}_{B2}}{1 + \gamma_1} > \frac{3}{1 + 2\gamma_1} \Leftrightarrow$$

$$\hat{a}_{B2} > \frac{2 + \gamma_1}{1 + 2\gamma_1} (> 1 = a_{B2}).$$

The last inequality implies that if  $\hat{a}_{B2}$  is sufficiently high (and not just bigger than  $a_{B2} = 1$ ), then a market expansion effect will occur. Taking this into account, we can compare prices and quantities obtained with two and three drugs in the market under copayments and reference prices to examine when will the incumbent firm have incentives to substitute the old drug by the new one.

Consider first when copayments are enforced. Recall equations (2.66)-(2.71) that define the equilibrium obtained under such price regulation system. When the old drug is removed, we have that equilibrium prices are<sup>13</sup>:

$$p_{B2}^{C2} = 1.25 \frac{(2 - \gamma_1^2) \hat{a}_{B2} - \gamma_1}{(2 - \gamma_1^2)},$$

$$p_G^{C2} = 0.625 \frac{(4 - 3\gamma_1^2) - \gamma_1(2 - \gamma_1^2) \hat{a}_{B2}}{(2 - \gamma_1^2)},$$

with the associated equilibrium quantities:

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<sup>13</sup> We have proceeded also by backward induction, where the incumbent firm is treated as a Stackelberg leader.

$$q_{B2}^{C2} = \frac{1}{4} \frac{(2 - \gamma_1^2) \hat{a}_{B2} - \gamma_1}{1 - \gamma_1^2},$$

$$q_G^{C2} = \frac{1}{4} \frac{4 - 3\gamma_1^2 - \gamma_1(2 - \gamma_1^2)\hat{a}_{B2}}{(2 - \gamma_1^2)(1 - \gamma_1^2)}.$$

Recall that the superscript  $C2$  stands for the situation under copayments with *two* goods in the market.

The next step is to compare equilibrium values with two and three goods. To make the analysis tractable, a simulation exercise was carried out, giving useful intuition. The following table summarises these simulation results.

**Table 1 COPAYMENTS: Simulation results with  $a_{B2} = 1$ .**

	$\gamma_1 = 0.1$	$\gamma_1 = 0.3$	$\gamma_1 = 0.5$	$\gamma_1 = 0.7$	$\gamma_1 = 0.9$
$p_G^{C3} > p_G^{C2}$	$1.86 < \hat{a}_{B2}$	$1.63 < \hat{a}_{B2}$	$1.45 < \hat{a}_{B2}$	$1.29 < \hat{a}_{B2}$	$1.12 < \hat{a}_{B2} a_4$
$q_G^{C3} > q_G^{C2}$	$1.71 < \hat{a}_{B2}$	$1.35 < \hat{a}_{B2}$	$1.16 < \hat{a}_{B2}$	$1.07 < \hat{a}_{B2}$	$1.02 < \hat{a}_{B2}$
$p_{B2}^{C3} > p_{B2}^{C2}$	$\hat{a}_{B2} < .999$	$\hat{a}_{B2} < .995$	$\hat{a}_{B2} < .986$	$\hat{a}_{B2} < .972$	$\hat{a}_{B2} < .972$
$q_{B2}^{C3} > q_{B2}^{C2}$	$\hat{a}_{B2} < .92$	$\hat{a}_{B2} < .82$	$\hat{a}_{B2} < .79$	$\hat{a}_{B2} < .80$	$\hat{a}_{B2} < .90$
$\frac{2+\gamma_1}{1+2\gamma_1}$	1.75	1.44	1.25	1.125	1.04

The superscripts  $C3$  and  $C2$  stand for the situation under copayments with three and two goods respectively. The last row shows the critical value for which if the parameter  $\hat{a}_{B2}$  is higher than this value, there is a market expansion effect. This critical value depends negatively on the value for  $\gamma_1$  i.e. the higher the degree of product differentiation (lower  $\gamma_1$ ), the higher this critical value. We can see from the table above that the comparisons follow a similar trend: the price and quantity of the generic good will be both higher (implying higher profits) when there are three goods only when there is a market expansion effect and potential demand for the only branded drug in the market is sufficiently high. Therefore, it seems that the generic producer prefers that the branded good producer becomes multi-

product only when there is a high potential demand for the new drug when this producer remains single-product. The reason for this is that if the leader removes the old drug from the market, and the potential demand for the new drug is very high, then the generic producer will be left worse off because in relative terms, it will lose market share. Hence, if this is the case, this generic producer prefers to compete with two products rather than with one with very high potential demand.

Alternatively, the branded good producer will set higher prices for the new branded drug when this firm becomes multi-product only when the parameter  $\hat{a}_{B2}$  is low enough. Moreover, it seems from the simulations that  $\hat{a}_{B2}$  requires to be less than  $a_{B2} = 1$  for this result to be true. Therefore, if the potential demand for the new drug (when this new drug is the only branded drug in the market) is not sufficiently high, then the branded good producer will earn higher profits from the new branded good when it is multiproduct<sup>14</sup>. In order to conclude when the incumbent firm will have incentives to substitute the old drug by the new one, we have to consider that when this firm is multiproduct, there are two sources of revenues (old and new drug). However, when only the new drug remains in the market, then there is only one revenue source. Hence, we need to compare:

$$p_{B2}^{C3} q_{B2}^{C3} + p_{B2}^{C3} q_{B2}^{C3} < p_{B2}^{C2} q_{B2}^{C2}.$$

Continuing with the simulations, we can summarise the results obtained with the next table.

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<sup>14</sup> Note that since  $a_{B2} = 1$  ( $= a_{B1}$ ), the price and quantity for the old branded good will be equal to the price and quantity of the new branded drug when the firm is multiproduct.

**Table 2 COPAYMENTS: Incentives to remove the old drug ( $a_{B2} = 1$ ).**

	$\gamma_1 = 0.1$	$\gamma_1 = 0.3$	$\gamma_1 = 0.5$	$\gamma_1 = 0.7$	$\gamma_1 = 0.9$
$p_{B2}^{C2} q_{B2}^{C2} > p_{B2}^{C3} q_{B2}^{C3} + p_{B2}^{C3} q_{B2}^{C3}$	$1.3 < \hat{a}_{B2}$	$1.2 < \hat{a}_{B2}$	$1.1 < \hat{a}_{B2}$	$1.0 < \hat{a}_{B2}$	$1.0 < \hat{a}_{B2}$

It seems from the results shown above that for the leader firm to remove the old drug from the market, the potential total market size for the new drug when there are only two goods in the market ( $B2$  and  $G$ ) has to be sufficiently high. Moreover, recall that  $a_{B2}$  was equal to one, so it seems that a necessary (but not sufficient) condition for there to be incentives to remove the old drug is that  $\hat{a}_{B2} > a_{B2}$ . The table also shows that the lower the degree of differentiation (higher  $\gamma_1$ ) between the drugs in the market, the more probable that the incumbent firm will have incentives to remove the old drug from the market. The intuition is that when  $\gamma_1$  is very low, then firms have higher monopoly power, since goods are more differentiated. Hence, it is as if it is better for the leader to keep both goods in the market. Under this case, the leader firm requires that the potential market for the new branded drug when this firm is single-product is higher. It appears that for low values of  $\gamma_1$ , the incumbent firm is sacrificing profits by substituting one drug for the other. However, for high values of  $\gamma_1$ , implying that goods are very similar, firms have less market power, so that it is easier to remove the old drug because profits earned for each product are lower. Hence, in this case, it is better to sacrifice profits earned from the older drug, eliminating competition in the market, and concentrating sales in just one drug. Let us concentrate now on the case when reference prices are enforced. Recall that with three goods, demand

functions are given by equations (2.72)-(2.76), plus the fact that  $p_G^{RP3} = r^{15}$ . With two goods, equilibrium prices are<sup>16</sup>

$$p_{B2}^{RP2} = 0.5(\hat{a}_{B2} - \gamma_1) + (0.3 + 0.2\gamma_1) r,$$

$$p_G^{RP2} = r.$$

The associated equilibrium quantities are

$$q_{B1}^{RP2} = 0.1 \frac{5(\hat{a}_{B2} - \gamma_1) + (3 + 2\gamma_1) r}{(1 + \gamma_1)(1 - \gamma_1)},$$

$$q_G^{RP2} = 0.1 \frac{5(2 - \gamma_1^2 - \gamma_1 \hat{a}_{B2}) - (4 + 3\gamma_1 - 2\gamma_1^2) r}{(1 + \gamma_1)(1 - \gamma_1)}.$$

We know that the price of the generic drug will be the same and equal to  $r$  irrespectively of the number of goods in the market. Again, evaluating  $a_{B2} = 1$  for simulation purposes, we can compare equilibrium prices and quantities when the leader produces one and two goods respectively. The next table presents the simulation results.

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<sup>15</sup> Notice that we distinguish again the situation with three goods with the superscript 3 and the situation with two goods with the superscript 2.

<sup>16</sup> In this case, we also proceed by backward induction, and a corner solution for the generic producer is obtained.

**Table 3 RPs: Simulation results with  $a_{B2} = 1$ .**

	$p_{B2}^{RP2} > p_{B2}^{RP3}$	$q_{B2}^{RP2} > q_{B2}^{RP3}$
$\gamma_1 = 0.1$	$\hat{a}_{B2} > 1.0$	$r > -18.75\hat{a}_{B2} + 17.34 (> 0 \Leftrightarrow \hat{a}_{B2} < 0.93)$
$\gamma_1 = 0.3$	$\hat{a}_{B2} > 1.0$	$r > -7.41\hat{a}_{B2} + 6.44 (> 0 \Leftrightarrow \hat{a}_{B2} < 0.87)$
$\gamma_1 = 0.5$	$\hat{a}_{B2} > 1.0$	$r > -5.0\hat{a}_{B2} + 4.34 (> 0 \Leftrightarrow \hat{a}_{B2} < 0.88)$
$\gamma_1 = 0.7$	$\hat{a}_{B2} > 1.0$	$r > -3.90\hat{a}_{B2} + 3.56 (> 0 \Leftrightarrow \hat{a}_{B2} < 0.91)$
$\gamma_1 = 0.9$	$\hat{a}_{B2} > 1.0$	$r > -3.24\hat{a}_{B2} + 3.14 (> 0 \Leftrightarrow \hat{a}_{B2} < 0.97)$

We obtain that  $p_{B2}^{RP2} > p_{B2}^{RP3}$  whenever  $\hat{a}_{B2} > 1$ . Moreover, since  $a_{B2} = 1$ ,  $p_{B1}^{RP2} > p_{B2}^{RP3}$  when  $\hat{a}_{B2} > 1$ . Hence, if  $\hat{a}_{B2} = a_{B2} = 1$ , then  $p_{B1}^{RP3} = p_{B2}^{RP3} = p_{B2}^{RP2}$ . Therefore, the incumbent firm will charge a higher price for the new drug when being multiproduct only when the potential market size for the new branded drug when being singled-product is low enough. When we compare demands for the new branded drug, we can observe from the table that demand for this drug will be higher with only two goods in the market ( $B2$  and  $G$ ) for a reference price higher than a critical value. However, notice that for the values of  $\gamma_1$  presented in the table, this critical value of  $r$  can be negative if the value  $\hat{a}_{B2}$  is high enough. Hence, what this is saying is that it seems that whenever  $\hat{a}_{B2}$  is sufficiently high, then demand for the new branded drug will be higher when the incumbent firm just produces the new (me-too) drug, since  $r$  is always (strictly) positive. Nevertheless, we have to take into consideration that when the branded good producer is multiproduct, this firm obtains revenue from two sources, the old and the branded drug. Therefore, this firm will have incentives to substitute the old drug with the new drug, under reference prices, whenever:

$$p_{B2}^{RP2} q_{B2}^{RP2} > p_{B2}^{RP3} q_{B2}^{RP3} + p_{B1}^{RP3} q_{B1}^{RP3}.$$

This inequality, under the parameter values chosen for our simulation exercise, is reduced to:

$$p_{B2}^{RP2} q_{B2}^{RP2} > 2p_{B2}^{RP3} q_{B2}^{RP3},$$

given that  $p_{B2}^{RP3} = p_{B1}^{RP3}$ , and  $q_{B2}^{RP3} = q_{B1}^{RP3}$ , since  $a_{B2} = a_{B1} = 1$ . A necessary (although not sufficient) condition for this firm to have incentives to remove the old drug from the market once a me-too drug is produced is hence

$$p_{B2}^{RP2} > p_{B2}^{RP3}, \text{ and}$$

$$q_{B2}^{RP2} > q_{B2}^{RP3}.$$

It seems from the simulation results that these two inequalities are met for a sufficiently high level of  $\hat{a}_{B2}$  i.e. when the potential total demand for the new branded drug alone is sufficient to sacrifice the profits earned when selling the old drug.

## 2.6 Comparisons.

The aim of this section is to provide the conditions under which the incumbent firm will produce the breakthrough drug or the me-too drug.

Given a reference price system, the profit obtained by the incumbent firm when a breakthrough drug is produced and becomes multiproduct is:

$$\pi_B^{RP3}(\gamma_2 = 0) = 0.01 \frac{(5(1 - \gamma_1) + (3 + 2\gamma_1)r)^2}{(1 + \gamma_1)(1 - \gamma_1)} + (0.5a_{B2} + 0.3r)^2 - C(k_{\max}),$$

while profits when producing a me-too drug are

$$\pi_B^{RP3}(\gamma_2 = \gamma_1) = 0.01 \left[ (5(1 - \gamma_1) + (3 + 2\gamma_1)r) \frac{5(1 - \gamma_1 a_{B2}) + (2\gamma_1 + 3)r}{(1 - \gamma_1)(2\gamma_1 + 1)} \right] + 0.01 \left[ \frac{50a_{2B}(1 + \gamma_1 - 2\gamma_1^2) - 50\gamma_1(1 + \gamma_1 - 2\gamma_1^2) + 5ra_{2B}(3 + 5\gamma_1 + 2\gamma_1^2) - 10r\gamma_1(3 + 2\gamma_1) + r^2(9 + 12\gamma_1 + 4\gamma_1^2)}{1 + \gamma_1 - 2\gamma_1^2} \right] - C(k^*),$$

For tractability reasons, we must use simulations to compare these two profit levels. Again,

we will fix  $a_{B2} = 1$ . The following table shows the results.

**Table 4 Reference Prices: Breakthrough or Me-too?**

$a_{B2} = 1$	$\pi_B^{RP3}(\gamma_2 = 0) > \pi_B^{RP3}(\gamma_2 = \gamma_1)$
$\gamma_1 = 0.1$	$\left\{ \begin{array}{l} -0.18 + 0.19r + 0.004r^2 > \Psi, \\ \text{where } -0.18 + 0.19r + 0.004r^2 > 0 \Leftrightarrow 0.95 < r \end{array} \right.$
$\gamma_1 = 0.3$	$\left\{ \begin{array}{l} -0.07 + 0.24r + 0.00099r^2 > \Psi, \\ \text{where } -0.07 + 0.24r + 0.00099r^2 > 0 \Leftrightarrow 0.32 < r \end{array} \right.$
$\gamma_1 = 0.5$	$\left\{ \begin{array}{l} 0.02 + 0.27r - 0.017r^2 > \Psi, \\ \text{where } 0.02 + 0.27r - 0.017r^2 > 0 \Leftrightarrow 0 < r < 16.08 \end{array} \right.$
$\gamma_1 = 0.7$	$\left\{ \begin{array}{l} 0.11 + 0.28r - 0.07r^2 > \Psi, \\ \text{where } 0.11 + 0.28r - 0.07r^2 > 0 \Leftrightarrow 0 < r < 4.53 \end{array} \right.$
$\gamma_1 = 0.9$	$\left\{ \begin{array}{l} 0.20 + 0.30r - 0.34r^2 > \Psi, \\ \text{where } 0.20 + 0.30r - 0.34r^2 > 0 \Leftrightarrow 0 < r < 1.31 \end{array} \right.$

where  $\Psi \equiv C(k_{\max}) - C(k^*) > 0$  (by assumption).

Table 4 shows that there is an ambiguous relationship between  $\pi_B^{RP3}(\gamma_2 = 0)$  and  $\pi_B^{RP3}(\gamma_2 = \gamma_1)$ , and no clear cut conclusion can be arrived to. It seems however, that when there is high product differentiation (low  $\gamma_1$ ), then the reference price has to be set high enough for the incumbent firm to have incentives to produce the breakthrough drug; however, for high values of  $\gamma_1$  the reference price should be set not too high for the leader to prefer to pro-



duce the breakthrough drug. Also note that as expected, the lower the cost associated to the breakthrough drug compared to the me-too, the more probable that the leader will produce a breakthrough drug, *ceteris paribus*.

Let us analyse the case when copayments are enforced. We will proceed the same way as with reference prices. Recall that the profits earned by the leader when the breakthrough drug is produced are given by:

$$\pi_B^{C3}(\gamma_2 = 0) = 0.31 (2 - \gamma_1 - \gamma_1^2) \frac{2 + \gamma_1}{(2 - \gamma_1^2)(1 + \gamma_1)} + 0.625a_{2B}^2 - C(k_{\max}),$$

and when a me-too:

$$\pi_B^{C3}(\gamma_2 = \gamma_1) = 0.16 \frac{(1 - \gamma_1 a_{2B})(2 + 3\gamma_1)^2}{(1 + \gamma_1)(2\gamma_1 + 1)(1 + \gamma_1 - \gamma_1^2)} + 0.16 (2a_{2B}(1 + \gamma_1 - \gamma_1^2) - \gamma_1 - \gamma_1^2) \frac{a_{2B}(2 + 4\gamma_1\gamma_1^2) - 3\gamma_1 - 4\gamma_1^2}{(-1 - \gamma_1 + \gamma_1^2)(2\gamma_1^2 - \gamma_1 - 1)(1 + \gamma_1)} - C(k^*).$$

Again, simulation results are presented in the next table (still assuming that  $a_{2B} = 1$ ).

**Table 5 Copayments: Breakthrough or Me-too?**

$a_{B2} = 1$	$\pi_B^{C3}(\gamma_2 = 0) > \pi_B^C(\gamma_2 = \gamma_1)$
$\gamma_1 = 0.1$	$0.26 > C(k_{\max}) - C(k^*)$
$\gamma_1 = 0.3$	$0.57 > C(k_{\max}) - C(k^*)$
$\gamma_1 = 0.5$	$0.74 > C(k_{\max}) - C(k^*)$
$\gamma_1 = 0.7$	$0.82 > C(k_{\max}) - C(k^*)$
$\gamma_1 = 0.9$	$0.81 > C(k_{\max}) - C(k^*)$

Table 5 shows that under copayments, it seems that only whenever the R&D cost of obtaining the breakthrough drug is not too high, then the incumbent firm will tend to produce the breakthrough drug. Moreover, from the simulation results, we can say that the higher the value of  $\gamma_1$ , the higher the value that  $C(k_{\max})$  can take to give rise to a breakthrough

drug, *ceteris paribus*. The intuition behind this result is that with high product differentiation (implying lower value of  $\gamma_1$ ), firms have more market power, so that it is beneficial for the incumbent firm to spend less R&D resources, obtain a me-too drug and compete directly with the (own) existing branded and generic in the same market. However, if goods are very similar, then it is actually more plausible that the leader will have incentives to spend  $k_{\max}$ , since the trade off between the cost of R&D and the revenue obtained from selling the product favours spending the maximum amount of resources.

## 2.7 Conclusion.

The aim of this paper has been to analyse how the R&D decision of a branded good producer is affected by the existence of either a reference price system or copayments. We observe that in the pharmaceutical industry, firms compete through innovation, and broadly speaking, the outcome of their research can result in a breakthrough drug, or alternatively, a me-too. The main difference between these two kind of drugs is that in the former case, the appearance of such drug opens or creates a new market since the good is highly innovative; in the latter, the drug produced is a marginal improvement of existing ones. Moreover, when it is introduced in the market, it usually competes with existing ethical drugs.

We want to analyse how the decision of producing a breakthrough or a me-too drug is affected by the price regulation in the demand side. More precisely, we want to examine whether a change in the net price paid by the consumer actually affects the R&D decision of pharmaceutical firms. The two possible regulations we consider are copayments and reference prices. Copayments involve the consumer paying a fixed percentage of the price,

irrespectively of the good purchased. When reference prices are enforced, the situation differs because if the consumer buys the branded good, with a price higher than the generic, then (s)he not only pays the same copayment as before, but this time associated to the reference price, but also the difference between the price of the branded good and the reference price. If the consumer decides to buy the generic good, the situation is unchanged, in the sense that (s)he pays the same copayment of the price of the generic as before.

Results obtained show that changing a copayment system to a reference price system can actually affect the R&D decision of firms. When a breakthrough drug is produced, one of the (short-run) objectives of reference prices is actually achieved: prices are lower than with copayments. However, we can have cases where the demand for the branded drugs is also lower under reference prices, so that overall, profits for the incumbent firm might be reduced. Hence, if this is the case, Health Authorities might actually discourage the production of breakthrough drugs if reference prices substitute copayments, since profits for these firms will be reduced. The story is somewhat similar when a me-too drug is produced. Prices for the branded drugs are reduced with the introduction of reference prices. Again, under certain conditions, demand for these goods can be higher under such system. For this to be the case, we require that the reference price is set high enough. Moreover, the demand for the new drug produced has to be sufficiently high. Otherwise, the incumbent firm will again be left worse off under reference prices.

The incumbent firm will not substitute the old drug by the new one when a breakthrough drug is produced, assuming that the cost of obtaining such drug is not too high, irrespectively of whether reference prices or copayments are enforced. However, when a me-too

drug is produced, this decision depends on the degree of product differentiation between the existing drugs and the new one produced, and the (potential) demand for this new drug. If the demand for the new drug is not too high when the incumbent firm remains singled-product, then this firm will have incentives to become multiproduct, given that either reference prices or copayments are in place.

Finally, it is not clear from the results obtained when will profits be higher for the leader, irrespectively of the price system enforced, if when producing a breakthrough or a me-too. This result actually seems to depend on two factors: the difference in R&D cost between obtaining one of the two drugs (as expected), but also on the degree of monopoly power (or product differentiation) of firms. Simulation results show that the higher the monopoly power, the more difficult to obtain the breakthrough drug. This is because with high degree of market power, firms do not need to spend too many R&D resources, and are actually better off just producing a me-too drug.

It must be mentioned that some of the results obtained are based on simulations. However, we feel that the results can be treated as fairly robust. Nevertheless, it is true that changing the values of the parameters may change the results quantitatively. Throughout the whole analysis, we have (implicitly) assumed that the total market size for the generic drug is lower than the total potential size of the branded drug. This seems consistent with what we are observing in reality at the moment, although this could change in the next years. This is because generic drugs will become increasingly important, specially due to the interest Health Authorities are demonstrating, promoting their use and production.

The main result that can be extracted from this article is that Health Authorities must be careful when to set reference prices, and to what level. We have seen different effects for the branded and generic producers, and that these effects also depend on the existing degree of market competition. Hence, Authorities should not only look at price levels when deciding whether to implement a reference price system, but also should analyse the market structure.

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