Collusion in the market for generics*

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Abstract

The paper studies the consequences on social welfare and market entry of collusion between generic drugs producers as it happened in the *Biovail Corp.* case. We build a model with both endogenous horizontal and vertical differentiation where firms compete in prices and show that a social planner who values the higher perceived quality of branded drugs does not have an incentive to prevent collusion. This is however always true only if generics entry is simultaneous. Collusion favors entry by independent competitors, but not always the launch of authorized generic drugs as the branded drugs firm faces a trade off between a higher degree of competition in the market and additional profit made with the generics. If entry of generics is sequantial, the effect of collusion on social welfare is more ambiguous, whether or not vertical differentiation is taken into account.

1 Introduction

It is well-known since the late 1990's that some pharmaceutical drug manufacturers enter into collusive agreements with generics producers to deter entry of cheaper drugs in the middle of patent terms. Potential entrants receive transfers from the patent holder in order to stay out of the market, at the expense of consumers who keep paying high prices for drugs. Antitrust authorities are obviously concerned with this issue and they often sue branded drugs producers at law. This has been the case for instance when Cephalon, a company selling Provigil, a drug against sleep disorder, paid several generics producers to delay generics entry in the American market and avoid the uncertainty of a trial. As a consequence, pharmaceutical firms sometimes prefer to go to court complaining of patent infringements to protect themselves against generics competition rather than risking to get caught when reaching an agreement with potential

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entrants. If they lose, however, any producer proving the bioequivalence of his product is allowed to enter the market. If there are few generic drugs entering the market, for instance because first entrants benefit from an exclusivity period as in the Hatch-Waxman Act[1], they have an incentive to collude to avoid tough competition, even if the branded drug firm does not participate in the ring.

In *Biovail Corp.*, the Federal Trade Commission (FTC) investigated the market of US nipefidine, a coronary vasodilator used to cure hypertension[2]. The branded drug producer (Bayer) was selling two versions of the drug, corresponding to two strengths (30mg and 60mg). Both of them were protected by a patent, since Bayer was the original innovator. However, Bayer lost its trial for patent infringement against Elan, who was the first to file an Abbreviated New Drug Application (ANDA)[3] for the 30mg drug and Biovail who was the first for the 60mg strength. They therefore both obtained a period of exclusivity of 6 months according to the Hatch-Waxman Act. The two generics producers then decided that Biovail would distribute Elan's drug and benefit from the drug's revenues in exchange of payments to Elan, for a minimum term of 15 years. This is similar to maximizing joint profits, thereby suppressing competition between the two firms. The agreement was terminated by the FTC to restore competition in the generics market.

The objective of the paper is to study the effects of partial collusion in markets with both horizontal and vertical differentiation, such as pharmaceutical drug markets. Horizontal differentiation comes from the existence of various versions of a therapeutically equivalent drug. For instance, in the case of Biovail Corp. mentioned above, two dosages of the same drug were available. As for vertical differentiation, it is due to the presence of branded drugs and generics in the market. Branded drugs quality is perceived to be higher by consumers, but the willingness to pay for quality differs among consumers[4]. This can be due to the image conveyed by the brand, that has been in the market for a long time and is reliable from the consumer's point of view. We compare the equilibrium prices when generics compete and when they maximize their joint profit. Not surprisingly, we show that prices and profits are higher when there is collusion since competition is reduced. Also, a consequence of collusion is to suppress horizontal competition between the two versions of the drug. In terms of social welfare, we show that if differences in perceived quality are discarded, welfare is equal to first-best in both cases. However, taking account of perceived quality,

[1] The Hatch-Waxman Act (1984) stipulates that the first generic drugs firm to file an Abbreviated New Drug Application (ANDA) benefits from a period of exclusivity of six months. It aims to provide incentives for potential entrants who may face litigation from the patented drug producer.

[2] See www.ftc.gov/opa/2002/06/biovailelan.shtm.

[3] An ANDA is an application that a generic drug producer has to fill in order to be allowed to market the drug in the US.

[4] The higher perceived quality (and hence higher willingness to pay) for branded drugs has been used to explain the "generics paradox", which is the observed increase in branded drugs prices after generics entry (Frank and Salkever (1992, 1997)). A complementary explanation is that after the entry of generics, branded drugs target the most inelastic segments and leave elastic segments to generics (Grabowski and Vernon (1992)).

social welfare is higher when generics producers collude since the market shares of branded drugs are higher. In this case, the social planner has no incentives to prevent collusion between generics producers.

We also consider market entry by an additional generics producer (i.e. a third one) who does not collude. We show that if there exists an entry cost, there is no entry when incumbents compete. On the other hand, if there is collusion, colluding firms have an incentive to abandon the production of the drug for which there is head-on competition, thus accommodating entry. Furthermore, we show that collusion is optimal for generics producers only if they are impatient. If instead of being marketed independently by a new producer, this additional generic drug is sold under a licence awarded by the branded drug producer (hence there are still three generic drugs, but the third one is sold through a licence), entry can occur at any time during the exclusivity period. Again, licensing never occurs when generics incumbents compete. Collusion is not sufficient to induce entry and the license is more likely to be granted when they collude if horizontal differentiation is high relatively to vertical differentiation. Otherwise, the negative effect of the increase in competition over the profits from the branded drugs dominates the effect of the supplementary profits from the generic drug.

We discuss the consequences of collusion on social welfare when entry of generics is sequential and show that the conclusions are not as clear-cut as under simultaneous entry. Indeed, it may be the case that collusion decreases social welfare, since the total mismatch cost for consumers must be considered in an asymmetric equilibrium.

The literature on collusion in differentiated markets is quite large. Vertical and horizontal differentiation are however generally treated separately. In the case of horizontal differentiation, Chang (1991) shows that collusion is more difficult to sustain when products are close substitutes. Accounting for asymmetry between firms, Colombo (2009) shows that the smaller firm has the stronger incentive to deviate when differentiation is horizontal. Contrary to horizontally differentiated goods, Häckner (1994) shows that when products are vertically differentiated, collusion is facilitated if they are similar.

Some papers introduce quality competition in horizontally differentiated markets (Economides (1989), Ma and Burgess (1993)), but consumers do not differ in their willingness to pay. Our model share some similarities with Brekke *et al.* (2007) where the authors study the effects of reference pricing on profits and competition in a model with both horizontal and vertical differentiation. However, competition only occurs along the horizontal dimension since, on the vertical side, it is assumed that there are two types of consumers consuming one of the branded drugs (for the high type) or one of the generics (for the low type). On the other hand, our model deals with both horizontal and vertical differentiation, like in Gabszewicz and Resende (2008) where the authors consider the effect of quality uncertainty with two firms differentiated along the two dimensions. The model also shares some similarities with Matutes and Regibeau (1988), where consumers can purchase the two components of a system

from two different firms. Consumers' location within a square represents their preferences with respect to the four components. The main difference with our model is that we assume consumers only buy one of the four products.

The issue of entry on collusive agreements has been mainly studied by considering that potential entrants could be colluding with incumbents. Fershtman and Pakes (2000) analyze the effects of collusion on product variety and quality in a dynamic oligopoly where heterogenous firms may enter or exit the market. The decision to enter depends on whether collusion is sustainable after entry, which is determined by the size of incumbent firms. In a similar framework, De Roos (2004) shows that a potential entrant may decide to engage in a price war in the short run to benefit from a higher share of collusive profits in the long run, if profit shares are determined by market shares at the time of the agreement. Therefore, the entrant prefers to wait and obtain relatively high market shares to collude if the collusive agreement is a rule of thumb as in the market for lysine where profit shares were based on market shares under competition[5].

The rest of the paper is structured as follows. Section 2 introduces the model. In section 3, we discuss equilibrium outcomes when generics producers compete. In section 4, we compare the results with the collusive equilibrium. In section 5, we analyze the consequences on social welfare, and in section 6, we discuss the effects of entry by a third generics producer. We introduce the possibility of authorized generics entry in section 7. Finally, we study the case of sequential entry when prices are sticky in section 8 and we present some conclusions in section 9.

2 Model setting

We consider a given therapeutic market with two versions of the drug, corresponding for instance to different dosages. There are three firms producing the drug, one branded drug producer denoted B and two generics producers denoted G_0 and G_1. The branded drug firm sells the two drugs (denoted B_0 and B_1) while each generics firm only sells one version of the drug[6]. For consumers, the drugs produced by the branded drug producer and the generics producers are vertically differentiated, even though they are chemically identical. As we discussed above, the brand image has a positive effect on the consumer's valuation of the drug. For the firm, the investment in brand loyalty benefits all products. Therefore, there is no specific cost of perceived quality for a single drug, since vertical differentiation is due to the overall brand image. Hence, we will assume that the branded drug's valuation is equal to v and that the

[5] The main firms in this market agreed to fix prices at an international level for lysine in the mid-1990s. The US Department of Justice Antitrust Division decided to award a total fine of $105 million.

[6] Suppose for instance that each producer was the first one to prove the bioequivalence of the drug for one of the two versions like in the *Biovail Corp.* case mentioned above.

generics' drug valuation is equal to γv where $0 < \gamma < 1$. Furthermore, we will assume that the consumers' willingness to pay for the drug depends on a taste parameter θ distributed uniformly over the interval $\left[\underline{\theta}, \overline{\theta}\right]$, with $\overline{\theta} \geq 2\underline{\theta}$, to ensure that generics producers are not driven out of the market.

Finally, consumers have different preferences with respect to the dosage of the drug. Therefore, we will consider that consumers are distributed uniformly on $[0, 1]$ with the two drugs located at both ends. The location x of a consumer represents his ideal drug dosage. By consuming a different drug, he incurs a "mismatch" cost decreasing his utility equal to t per unit of distance. This cost can correspond for instance to the potential side effects of the drug.

We exogenously fix the branded drugs locations at both ends of the line, so that consumers' ideal choice along the horizontal differentiation dimension always lies in between the two existing drugs. Since generics producers have to produce similar drugs, they cannot choose their location. Therefore they are also located at both ends of the line. Hence, location is not a strategic variable in our game. We rather assume that location was decided *ex ante* by the branded drug firm.

The utility function of a consumer with taste parameter θ located at x and buying product i is equal to

$$U(\theta, x, p_i, l_i) = \begin{cases} \theta v - p_i - t\,|l_i - x| & if\ i = B_0, B_1 \\ \theta\gamma v - p_i - t\,|l_i - x| & if\ i = G_0, G_1 \end{cases}$$

where $l_{B_0} = l_{G_0} = 0$ and $l_{B_1} = l_{G_1} = 1$ [7]. Consumer (θ, x) can be seen as a point in the rectangle $[0, 1] \times \left[\underline{\theta}, \overline{\theta}\right]$. We assume that there is no price regulation, so firms are free to determine their prices. Also, the marginal cost of production is assumed to be equal to zero.

In order to compute the demand functions of the firms, we must identify the consumers indifferent between the two branded drugs (denoted $\widetilde{x}_B$), the two generics drugs (denoted $\widetilde{x}_G$), and between generics drugs and branded drugs (denoted $\widetilde{\theta}_{B_0G_0}$, $\widetilde{\theta}_{B_0G_1}$, $\widetilde{\theta}_{B_1G_0}$ and $\widetilde{\theta}_{B_1G_1}$). Concerning the horizontal dimension of the market, the indifferent consumers are characterized by their location, independently of their taste for the drug. By contrast, in the vertical dimension, they are determined by their taste parameter.

We first determine the location of the consumer indifferent between B_0 and B_1. Since he obtains the same net utility by consuming the two drugs, the following equality must be satisfied:

$$\theta v - p_{B_0} - t\,|l_{B_0} - \widetilde{x}_B| = \theta v - p_{B_1} - t\,|l_{B_1} - \widetilde{x}_B|$$

where $l_{B_0} = 0$ and $l_{B_1} = 1$.

Therefore, his location is given by

[7] This justifies the notation of products as G_i and B_i with $i = \{0; 1\}$.

$$\widetilde{x}_B = \frac{p_{B_1} - p_{B_0} + t}{2t}$$

Similarly, the location of the consumer indifferent between G_0 and G_1 is given by

$$\theta\gamma v - p_{G_0} - t\left|l_{G_0} - \widetilde{x}_G\right| = \theta\gamma v - p_{G_1} - t\left|l_{G_1} - \widetilde{x}_G\right|$$

where $l_{G_0} = 0$ and $l_{G_1} = 1$, yielding

$$\widetilde{x}_G = \frac{p_{G_1} - p_{G_0} + t}{2t}$$

We next determine the consumers indifferent between B_i and G_i with $i = 0, 1$. Their net utility must satisfy the following equality

$$\widetilde{\theta}_{B_iG_i} v - p_{B_i} - t\left|l_{B_i} - x\right| = \widetilde{\theta}_{B_iG_i}\gamma v - p_{G_i} - t\left|l_{G_i} - x\right|$$

Since $l_{G_i} = l_{B_i}$, we obtain

$$\widetilde{\theta}_{B_iG_i} = \frac{p_{B_i} - p_{G_i}}{v(1-\gamma)}$$

Finally, we have to determine the consumers indifferent between B_i with $i = 0, 1$ and G_j with $j = 0, 1$ and $i \neq j$. Since net utility levels are identical by consuming B_i and G_j, we have

$$\widetilde{\theta}_{B_iG_j} v - p_{B_i} - t\left|l_{B_i} - x\right| = \widetilde{\theta}_{B_iG_j}\gamma v - p_{G_j} - t\left|l_{G_j} - x\right|$$

and we obtain[8]

$$\widetilde{\theta}_{B_0G_1}(x) = \frac{p_{B_0} - p_{G_1} - t + 2tx}{v(1-\gamma)} \text{ and } \widetilde{\theta}_{B_1G_0}(x) = \frac{p_{B_1} - p_{G_0} + t - 2tx}{v(1-\gamma)}$$

[8] We choose to solve for $\widetilde{\theta}_{B_iG_j}$ given x since we represent graphically $\widetilde{\theta}_{B_iG_j}$ on the vertical axis and x on the horizontal axis.

As illustrated in Figure 1., the thresholds determining consumers indifferent between B_0 and G_0 and between B_1 and G_1 are independent of consumers horizontal location[9]. However this is not case between B_0 and G_1 and between B_1 and G_0. This is because firms are then competing along the two dimensions since they are horizontally and vertically differentiated whereas in the case of $\widetilde{\theta}_{B_0G_0}$ and $\widetilde{\theta}_{B_1G_1}$, the drugs are only vertically differentiated.

Furthermore, there only exists consumers indifferent between B_1 and G_0 if $\widetilde{x}_G \geq \widetilde{x}_B$. When it is the case, G_0 is competing with B_0, B_1 and G_1, and B_1 is competing with B_0, G_0 and G_1 [10]. Symmetrically, there also only exists consumers indifferent between B_0 and G_1 if $\widetilde{x}_B \geq \widetilde{x}_G$.

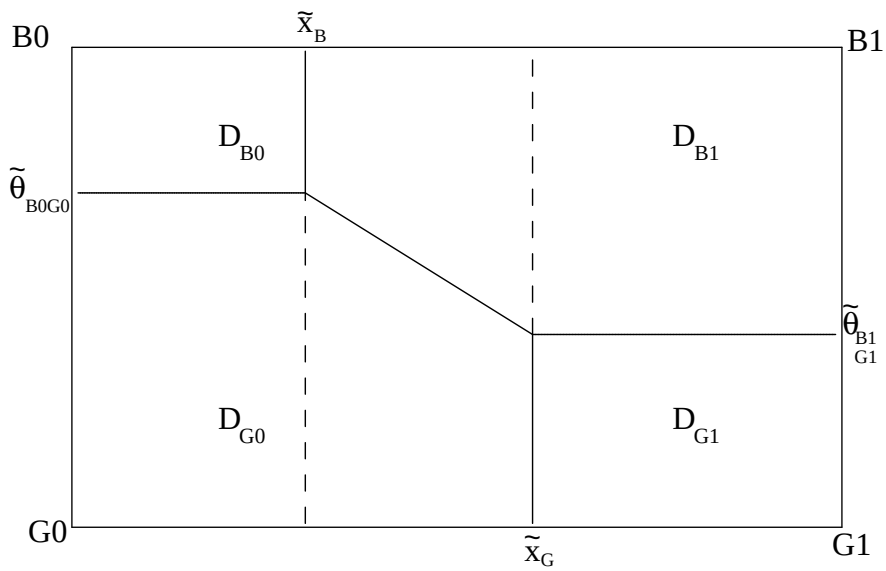

Figure 1: Graphical representation of demands when $\widetilde{x}_G \geq \widetilde{x}_B$.

Because the two cases are symmetric, we only compute demand functions for $\widetilde{x}_G \geq \widetilde{x}_B$.

Recalling that $x \in [0,1]$ and $\theta \in \left[\underline{\theta}, \overline{\theta}\right]$, both uniformly distributed, demand for product i is given by

[9] We can observe that $\widetilde{\theta}_{B_0G_1}(\widetilde{x}_B) = \widetilde{\theta}_{B_1G_1}$, $\widetilde{\theta}_{B_0G_1}(\widetilde{x}_G) = \widetilde{\theta}_{B_0G_0}$, $\widetilde{\theta}_{B_1G_0}(\widetilde{x}_B) = \widetilde{\theta}_{B_0G_0}$ and $\widetilde{\theta}_{B_1G_0}(\widetilde{x}_G) = \widetilde{\theta}_{B_1G_1}$.

[10] Note that there is no actual competition between B_0 and B_1 since they are both sold by the branded drug producer.

$$D_i = \begin{cases} \frac{1}{\overline{\theta}-\underline{\theta}} \left(\left(\widetilde{\theta}_{B_0G_0} - \underline{\theta} \right) \widetilde{x}_G - 0.5 \left(\widetilde{x}_G - \widetilde{x}_B \right) \left(\widetilde{\theta}_{B_0G_0} - \widetilde{\theta}_{B_1G_1} \right) \right) \ if \ i = G_0 \\ \frac{1}{\overline{\theta}-\underline{\theta}} \left(\overline{\theta} - \widetilde{\theta}_{B_0G_0} \right) \widetilde{x}_B \ if \ i = B_0 \\ \frac{1}{\overline{\theta}-\underline{\theta}} \left(\left(\overline{\theta} - \widetilde{\theta}_{B_1G_1} \right) (1 - \widetilde{x}_B) - 0.5 \left(\widetilde{x}_G - \widetilde{x}_B \right) \left(\widetilde{\theta}_{B_0G_0} - \widetilde{\theta}_{B_1G_1} \right) \right) \ if \ i = B_1 \\ \frac{1}{\overline{\theta}-\underline{\theta}} \left(\widetilde{\theta}_{B_1G_1} - \underline{\theta} \right) (1 - \widetilde{x}_G) \ if \ i = G_1 \end{cases}$$

and because the marginal cost of production is assumed to be equal to zero, profit functions are given by

$$\pi_i = p_i D_i$$

3 Competition between generics producers

In this section, we consider the benchmark case where the generics producers behave non cooperatively. Hence, each generics firm is facing competition both from the other generics producer, and from the branded drug producer. We assume that there is only one branded drugs producers, as in the case described in the introduction where Bayer was the only patented drugs producer. On the other hand, the branded drug producer is competing with the two generics firms. We assume that the "mismatch cost" t is low compared to v so that the market is fully covered at equilibrium. This can be justified based on the fact that if consumers have preferences for a specific drug dosage, they always prefer to consume rather than not buying one of the drug. We also assume full coverage of the market along the vertical differentiation dimension, i.e. consumers with the lowest valuation ($\theta = \underline{\theta}$) buy the drug in equilibrium[11].

Since we consider the case where generics producers behave non cooperatively, they each maximize their profit independently. Therefore, the optimization programs are respectively

$$\max_{p_{G_0}} \pi_{G_0} = p_{G_0} D_{G_0} \text{ and } \max_{p_{G_1}} \pi_{G_1} = p_{G_1} D_{G_1}$$

On the other hand, the branded drugs producer sells two drugs. Consumers are uniformly distributed, and the two generics drugs' locations are identical to the two branded drugs locations. Therefore, we will consider that the firm sets *ex ante* $p_{B_0} = p_{B_1} = p_B$ with p_B solution of

[11] A necessary and sufficient condition for full coverage along the two dimensions is that the consumer with the lowest valuation $\underline{\theta}$ and the highest "mismatch cost" (i.e located at $x = 0.5$) obtains a non-negative utility at equilibrium.

$$\max_{p_B} \pi_B = p_B D_{B_0} + p_B D_{B_1}$$

Since the generics producers are identical and face the same price for the two branded drugs, we focus on a symmetric equilibrium *ex post* on the generics side so that $p_{G_i} \equiv p_G$ [12]. As shown in Appendix A.1., the first order conditions with respect to p_{G_0} and p_{G_1} (which are equivalent to the single condition (1) given the symmetry assumption) and p_B are respectively

$$-p_B p_G + p_G^2 + t p_B - 2t p_G + \underline{\theta} v(1-\gamma)(p_G - t) = 0 \qquad (1)$$

and

$$\overline{\theta}(1-\gamma)v - 2p_B + p_G = 0 \qquad (2)$$

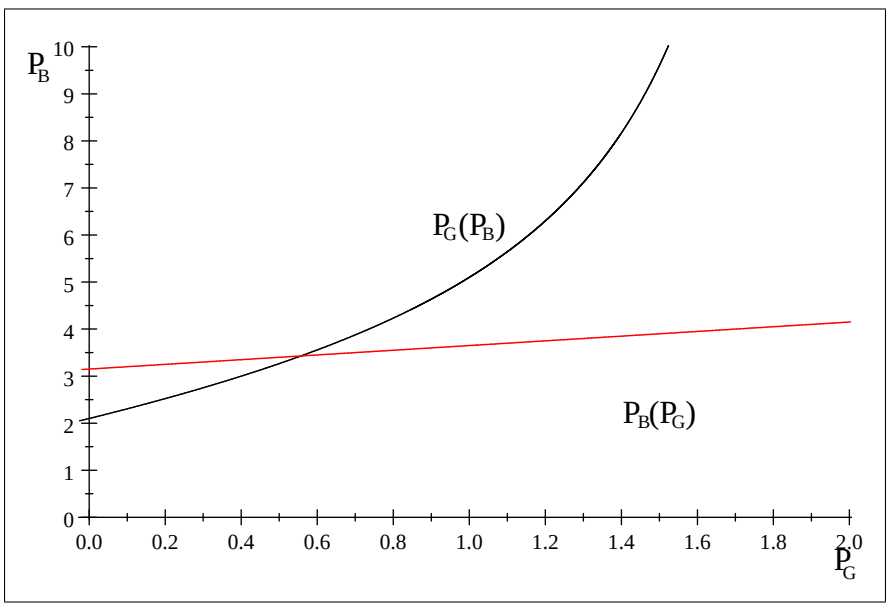

Figure 2: Best response functions when $\underline{\theta} = 1$, $\overline{\theta} = 3$, $v = 3$, $t = 2$ and $\gamma = 0.3$.

As usual in models with price competition, the firms best responses are upward slopping, which means that prices are strategic complements (see Figure 2). Solving for p_B from (1), we obtain

[12] Allain (2002) also focuses over a symmetric equilibrium in a model of spatial competition where demand functions correspond to rectangle areas (differentiation is however only horizontal).

As can be seen in the appendix, the first order conditions of profit maximization are quadratic and depend upon the three prices, leading to analytical difficulties when solving this system of equations.

$$p_B = \frac{1}{p_G - t}\left(-2tp_G + p_G^2 + v\theta\left(1-\gamma\right)\left(p_G - t\right)\right)$$

and we observe that $\lim_{p_G \to t^-} p_B = +\infty$. Therefore, when the branded drug price increases, the generics price reaches an upper bounded equal to t. In other words, having the branded drug producer's price very high is equivalent to eliminating vertical competition between the branded drug and generics. Hence, the generics price tends to the equilibrium price with only horizontal differentiation $p_G = t$ (i.e. the price that would prevail absent the two branded drugs). Solving for p_G and p_B in (1) and (2), we obtain the following proposition.

Proposition 1 *The unique symmetric price equilibrium of the game is* $p_G^* = C + 1.5t - \sqrt{(C+1.5t)^2 - 2tC}$ *with* $C = v(1-\gamma)(0.5\overline{\theta} - \underline{\theta})$ *and* $p_B^* = 0.5(\overline{\theta}(1-\gamma)v + p_G^*)$.

Proof. From (2), we have $p_B^* = 0.5(\overline{\theta}(1-\gamma)v + p_G^*)$, and replacing it into (1) and solving for p_G^* we obtain two solutions $p_G^* = C + 1.5t - \sqrt{(C+1.5t)^2 - 2tC}$ and $p_G^* = C + 1.5t + \sqrt{(C+1.5t)^2 - 2tC}$. However, the second order condition is not satisfied in the latter case, hence the first root is the only equilibrium[13]. ■

As shown in Appendix A.2., the two equilibrium prices are increasing with the "mismatch cost" t. This is because, as in all models with only horizontal differentiation, a higher t softens competition between the two generics producers for the indifferent consumer $\widetilde{x}_G$. Therefore p_G^* increases, as well as p_B^*, since prices are strategic complements. Furthermore, profits increase with t, and we also show that $\partial\pi_G^*/\partial t < \partial\pi_B^*/\partial t$. The branded drug firm produces two horizontally differentiated drugs and is thus able to internalize the total effect of patients' disutility over its profits. On the other hand, the generics producers compete with the firm located at the other end of the horizontal line, and therefore cannot benefit as much as the branded drugs producer from a variation in t.

Equilibrium prices also increase when the quality differential $(1-\gamma)v$ increases, since competition between generics and branded drugs is less intense. On the other hand, if the interval $\left[\underline{\theta}, \overline{\theta}\right]$ is smaller, both generics and branded drugs prices are lower. Competition is tougher between them when the consumers' valuation is less heterogenous. Hence, generics producers compete more for consumers with a high θ when $\overline{\theta}$ decreases and the branded drugs producer behaves similarly with low valuation consumers when $\underline{\theta}$ increases. If $\overline{\theta} < 2\underline{\theta}$,

[13] The condition $\overline{\theta} \geq 2\underline{\theta}$ imposed above is sufficient to ensure that non negative equilibrium prices exist. Market shares are strictly positive at equilibrium for $\overline{\theta} > 2\underline{\theta}$.

only branded drugs are consumed as generics firms do not enter the market[14], even though the production cost is equal to zero. This is because when the differences in the taste parameter between consumers are low, branded drugs firms do not have an incentive to focus on consumers with a high θ and therefore prefer to serve the whole market, which blockades the entry of lower quality drugs.

4 Collusion between generics producers

In this section, we suppose generics producers collude by maximizing their joint profits, like it has been the case of Biovail and Elan mentioned in section 4.1. Similarly to the previous section, we assume that the market is fully covered. Therefore, the generics firms solve

$$\max_{p_{G_0}, p_{G_1}} \pi_G = p_{G_0} D_{G_0} + p_{G_1} D_{G_1}$$

whereas the profit function of the branded drug producer remains unchanged. As shown in appendix A.3., focusing again on a symmetric equilibrium, the firms best responses are

$$-\underline{\theta}(1-\gamma)v - 2p_G + p_B = 0 \qquad (3)$$

and

$$\overline{\theta}(1-\gamma)v - 2p_B + p_G = 0 \qquad (4)$$

Again, the best response functions are upward slopping, except that p_G is now a linear function of p_B.

Proposition 2 *The unique symmetric price equilibrium of the game is* $p_B^{**} = \frac{1}{3}(1-\gamma)v(2\overline{\theta} - \underline{\theta})$ *and* $p_G^{**} = \frac{1}{3}(1-\gamma)v(\overline{\theta} - 2\underline{\theta})$.

Proof. From (4), we have $p_G = -\overline{\theta}(1-\gamma)v + 2p_B$ and replacing it into (3), we obtain $p_G^{**} = \frac{1}{3}(1-\gamma)v(\overline{\theta} - 2\underline{\theta})$. As we mentioned earlier, we assume that the market is fully covered along the two dimensions. A necessary and sufficient condition when generics collude is to assume that $\frac{v}{3}\left(\gamma(\overline{\theta} + \underline{\theta}) - (\overline{\theta} - 2\underline{\theta})\right) - \frac{t}{2} \geq 0$. If this condition is satisfied, and since prices are lower when generics compete

[14] If $\overline{\theta}$ can be increased by advertising the drug, generics producers benefit from the branded drug producer marketing effort.

(as shown below), this condition also guarantees that the market is covered when the two generics producers compete. ■

Comparative statics results are similar to the competition case studied above, except with respect to t since when generics collude prices are independent of t. This is because generics producers do not compete anymore horizontally and internalize the effects of each generics price on the profit made by the other generic producer. Therefore, collusion between generics producers implies that firms only compete vertically.

Corollary 3 *Equilibrium prices and profits (assuming they are split equally) are higher when generics firms collude.*

Proof. See appendix A.4. ■

Horizontal competition between generics producers is eliminated when they collude. Under collusion, there are actually only two firms competing on the market, as opposed to three if generics firms do not collude. As a result, prices and profits increase.

5 Welfare analysis

In this section, we compare social welfare when generics producers collude and when they compete. We sequentially consider the case where the generics and the branded drugs are viewed as equivalent (hence $\gamma = 1$) by a paternalistic social planner so that artificial vertical differentiation is discarded, and the case where consumers' preferences regarding generics and branded drugs are taken into account. This can be the case for instance of an electoralist social planner, whose preferences would reflect consumers' preferences.

- When $\gamma = 1$, the consumers' surplus can be written as

$$\widehat{CS} = \widehat{CS}_{G_0} + \widehat{CS}_{G_1} + \widehat{CS}_{B_0} + \widehat{CS}_{B_1}$$

$$\text{where } \widehat{CS}_i = \begin{cases} \frac{1}{\overline{\theta}-\underline{\theta}} \int_{\underline{\theta}}^{\widetilde{\theta}_{B_0G_0}} \int_0^{\widetilde{x}_G} (\theta v - p_G - tx) dx d\theta \ if \ i = G_0 \\ \frac{1}{\overline{\theta}-\underline{\theta}} \int_{\underline{\theta}}^{\widetilde{\theta}_{B_1G_1}} \int_{\widetilde{x}_G}^{1} (\theta v - p_G - t(1-x)) dx d\theta \ if \ i = G_1 \\ \frac{1}{\overline{\theta}-\underline{\theta}} \int_{\widetilde{\theta}_{B_0G_0}}^{\overline{\theta}} \int_0^{\widetilde{x}_B} (\theta v - p_B - tx) dx d\theta \ if \ i = B_0 \\ \frac{1}{\overline{\theta}-\underline{\theta}} \int_{\widetilde{\theta}_{B_1G_1}}^{\overline{\theta}} \int_{\widetilde{x}_B}^{1} (\theta v - p_B - t(1-x)) dx d\theta \ if \ i = B_1 \end{cases}$$

and social welfare is equal to

$$\widehat{W} = \widehat{CS}_{G_0} + \pi_{G0} + \widehat{CS}_{G_1} + \pi_{G1} + \widehat{CS}_{B_0} + \pi_{B0} + \widehat{CS}_{B_1} + \pi_{B1}$$

$$\text{with } \widehat{CS}_i + \pi_i = \begin{cases} \frac{1}{\overline{\theta}-\underline{\theta}} \int_{\underline{\theta}}^{\widetilde{\theta}_{B_0G_0}} \int_0^{\widetilde{x}_G} (\theta v - tx) dx d\theta \ if \ i = G_0 \\ \frac{1}{\overline{\theta}-\underline{\theta}} \int_{\underline{\theta}}^{\widetilde{\theta}_{B_1G_1}} \int_{\widetilde{x}_G}^{1} (\theta v - t(1-x)) dx d\theta \ if \ i = G_1 \\ \frac{1}{\overline{\theta}-\underline{\theta}} \int_{\widetilde{\theta}_{B_0G_0}}^{\overline{\theta}} \int_0^{\widetilde{x}_B} (\theta v - tx) dx d\theta \ if \ i = B_0 \\ \frac{1}{\overline{\theta}-\underline{\theta}} \int_{\widetilde{\theta}_{B_1G_1}}^{\overline{\theta}} \int_{\widetilde{x}_B}^{1} (\theta v - t(1-x)) dx d\theta \ if \ i = B_1 \end{cases}$$

Since generics and branded drugs are objectively considered to be equivalent, market shares of producers determined by $\widetilde{\theta}_{B_0G_0}$ and $\widetilde{\theta}_{B_1G_1}$ do not modify social welfare. Furthermore, since $\widetilde{x}_G = \widetilde{x}_B = 0.5$ whether there is collusion or not, we can establish the following lemma.

Lemma 4 *If branded drugs and generics are treated equally, social welfare under collusion is equal to social welfare under competition. Furthermore, it is equal to the first-best.*

At first-best, total mismatch costs are minimized. This is the case when $\widetilde{x}_G = \widetilde{x}_B = 0.5$, so consumers located at $x \leq 0.5$ consume G_0 (or B_0 since gross valuation by the policy maker is always equal to v) and consumers located at $x > 0.5$ consume G_1 (or B_1).

Notice that this result does not hold if we assume that the market is not covered vertically, i.e consumers with a taste parameter in the interval $\left[\underline{\theta}, \widehat{\theta}\right]$ with $\widehat{\theta}$ solution of $\theta v - p_G = 0$ do not buy the drug[15]. Then social welfare is higher when p_G is lower since more consumers buy the drug, but it is always lower than at first-best.

On the other hand, since we assume that the market is covered, prices are pure transfers between consumers and producers, and because the social planner does not take vertical differentiation into account, social welfare is identical under collusion and competition. However, the sharing of social welfare between consumer surplus and profit differs in the two cases, since the increase in producers' profit under collusion is at the expense of consumers' surplus.

Also, the result relies on the assumption that competition is limited to prices and does not include location choices.

- Even if the social planner knows that vertical differentiation is only due to marketing efforts, he may still want to consider consumers preferences and make a distinction between generics and branded drugs, although they are therapeutically equivalent. One can think for instance to the substitutability policies between the two types of drugs. Some European

[15] The result does not hold either if the market is not covered horizontally.

countries, such as England, Norway, Greece or Ireland do not allow pharmacists to substitute generics to branded drugs, therefore taking account of the perceived differences in quality by consumers.

When $\gamma < 1$, consumers' preferences regarding branded drugs and generics are internalized by the social planner. Social welfare is equal to

$$W = CS_{G_0} + \pi_{G0} + CS_{G_1} + \pi_{G1} + CS_{B_0} + \pi_{B0} + CS_{B_1} + \pi_{B1}$$

where $CS_{B_0} = \widehat{CS}_{B_0}$ and $CS_{B_1} = \widehat{CS}_{B_1}$. However, because the consumers' valuation of generics is γv, the consumers' surplus when drugs are generics is equal to

$$CS_i = \begin{cases} \frac{1}{\overline{\theta}-\underline{\theta}} \int_{\underline{\theta}}^{\widetilde{\theta}_{B_0G_0}} \int_0^{\widetilde{x}_G} (\theta\gamma v - p_G - tx) dx d\theta \ if \ i = G_0 \\ \frac{1}{\overline{\theta}-\underline{\theta}} \int_{\underline{\theta}}^{\widetilde{\theta}_{B_1G_1}} \int_{\widetilde{x}_G}^{1} (\theta\gamma v - p_G - t(1-x)) dx d\theta \ if \ i = G_1 \end{cases}$$

Proposition 5 *If vertical differentiation is taken into account, social welfare is higher when generics producers collude.*

Proof. Again, whether generics collude or not, $\widetilde{x}_G = \widetilde{x}_B = 0.5$. However, $\widetilde{\theta}_{BG}$ is lower when firms collude since $\widetilde{\theta}^*_{BG} = \frac{1}{v(1-\gamma)}(p^*_B - p^*_G) > \widetilde{\theta}^{**}_{BG} = \frac{1}{v(1-\gamma)}(p^{**}_B - p^{**}_G)$ because $C^2 + Ct + \frac{9}{4}t^2 > \frac{1}{9}C^2 + Ct + \frac{9}{4}t^2$ where C is the constant defined in Proposition 4-1. Hence, more consumers buy branded drugs when generics firms collude, which increases social welfare measured using the subjective valuation of consumers. ■

The branded drugs producer obtains larger market shares when generics collude. This is because collusion implies that horizontal competition between generics firms is eliminated which leads to higher prices and thus lower quantities. Therefore, generics firms only compete with the branded drugs and competition is softened. As a consequence, more consumers buy branded drugs and subjective social welfare is higher. This result raises the question of the social planner's incentives to prevent partial collusion in this case and more generally to promote the use of generic drugs.

The result however depends on whether the profits of all the firms are included in the definition of social welfare. This may not be the case if for instance some drugs are imported, which is often true for generics. Then, prices are no more transfers between consumers and firms, and the higher prices when generics producers collude have a negative effect on social welfare. This can explain why in Biovail Corp. the FTC terminated the agreement between Elan and Biovail (which are both foreign firms, respectively from Ireland and Canada)[16].

[16] See www.ftc.gov/opa/2002/06/biovailelan.shtm.

6 Market entry

So far we have considered the case of two generics firms competing with the branded drug producer, each producer selling one of the two versions. However, if a third producer proves the bioequivalence of his product with the branded drug, entry is possible after the end of the exclusivity period of the incumbent generics firm, which would imply that four firms are present in the market. In this section, we study the entry decision when G_0 and G_1 compete and when they collude and how potential entry affects *ex ante* the incentive to collude for G_0 and G_1. Therefore, it can be seen as a two-stage game where G_0 and G_1 first decide to collude or to compete and the potential entrant decides in the second stage. Hence, solving the game by backward induction, we first determine the choice of the potential entrant.

6.1 Entry when incumbents compete

Since we consider entry by a producer of a generic drug, the new firm has to produce one of the existing versions of the drug, and so locate at either $l = 0$ or $l = 1$. Wherever he locates, there is Bertrand competition with the incumbent generics producer and both firms obtain a profit equal to zero. Consider for instance entry at $l = 1$, which implies $p_{G_1} = 0$.[17] If we assume that there exists an entry cost, we can establish the following lemma.

Lemma 6 *When entry is costly, no new generics producer enters if he anticipates price competition by the generics incumbent.*

The entry cost can be due to the need to prove the bioequivalence of the drug or to obtain marketing approval by authorities, but it can also be due to the shelving fees in drugstores, where new producers have to negotiate in order to be sold. Because of Bertrand competition, we have $p_{G_1} = 0$ and therefore the entrant's operation profit is equal to zero. Hence, even with an arbitrarily small cost of entry, entry is not profitable.

6.2 Entry when incumbents collude

If the producers of generics collude, they behave like a single firm producing two drugs, as opposed to two firms producing a single drug each. Hence, the incumbents have to choose between either head-on competition by selling the two

[17] Entry of a new firm at $l = 0$ can be treated symmetrically.

drugs even after entry or differentiation by abandoning the drug for which there is competition from the entrant. Since selling the two drugs implies Bertrand competition at $l = 1$ (assuming the entrant locates at $l = 1$), it is equivalent to deterring entry. On the other hand collusive firms accommodate entry if they only sell one drug after entry.

Lemma 7 *If generics collude prior to entry, they abandon the drug for which there is competition after entry.*

Proof. Consider again the case of an entrant locating at $l = 1$. If colluding firms decide to only produce the drug at $l = 0$ and abandon the other drug for which there is competition, the price equilibrium is similar to the benchmark case discussed above where the two firms are competing. However, since there are now two colluding firms located at $l = 0$, they obtain each $0.5\pi_G^*$ if we assume that joint profits are split equally.

However, if there is head-on competition, the outcome is similar to a situation with G_0 and G_1 competing initially. As discussed in the previous section, we then have Bertrand competition at $l = 1$, which implies $p_{G_1} = 0$. Hence, colluding firms obtain $0.5\pi_G^*(\ p_{G_1} = 0)$ each where $\pi_G^*(\ p_{G_1} = 0)$ is the benchmark profit under competition with $p_{G_1} = 0$. Since prices are strategic complements, we have $0.5\pi_G^*(p_{G_1} = 0) < 0.5\pi_G^*(p_{G_1} > 0)$ and it is therefore optimal for incumbents to abandon the production of the drug at $l = 1$.

We assume implicitly that it is optimal for the entrant to produce if generics firms are colluding, so denoting F the entry cost, we assume that $\pi_G^* \geq F$, which is likely since entry cost are low for generics producers. ■

Colluding generics producers prefer to differentiate and accommodate entry rather than competing head-on since competition on one end of the line has a negative externality on the profit made with the other drug. Entry accommodation also benefits the branded drug producer because his profit decreases with the degree of competition on the generics market.

Furthermore, only one firm enters the market, since we then have competition between the entrant and the colluding firms G_0 and G_1, both located at $l = 0$ if the entrant is located at $l = 1$. Its is equivalent to having G_0 and G_1 competing prior to entry, and we know that entry does not occur in this case.

6.3 The choice between colluding and competing *ex ante*

We have shown that entry is the optimal strategy for a potential competitor if incumbents are colluding while it is not the case if G_0 and G_1 are competing. However, in the market for generics, entry can only occur after the six months exclusivity period during which the incumbents cannot face competition from

a new generics firm. Hence, collusion is clearly optimal until competition is allowed. More generally, collusion is optimal as long as entry is blockaded by law.

Consider for instance that incumbents do not face competition for one period because of the exclusivity granted by the Hatch-Waxman Act and that they know with probability equal to one that entry will occur in the next period. The discounted profit of a generics incumbent is equal to

$$\pi_G^{**} + \frac{\delta}{2(1-\delta)}\pi_G^*$$

where $0 < \delta < 1$ is the discount factor of the generics incumbent if they collude. On the contrary, it is equal to $\frac{\pi_G^*}{1-\delta}$ if they compete, since it earns π_G^* from the beginning. We can therefore establish the following proposition.

Proposition 8 *Generics producers collude only if they are impatient.*

Proof. We have $\pi_G^{**} + \frac{\delta}{2(1-\delta)}\pi_G^* \geq \frac{\pi_G^*}{1-\delta}$ if $\pi_G^{**} \geq \frac{\pi_G^*}{1-\delta}(1-0.5\delta)$ where $\frac{\partial\left(\frac{1-0.5\delta}{1-\delta}\right)}{\partial\delta} = \frac{0.5}{(1-\delta)^2} > 0$ so G_0 and G_1 only collude if δ is small (i.e. when they are impatient). ■

Incumbents face a trade off between short run profits and incentives for potential entrants. In *Biovail Corp.*, we can conclude that Elan and Biovail were likely to be short-sighted. In any case, the branded drug producer is better off when generics collude, even for a short period of time.

Also, we can notice that although exclusivity was originally supposed to encourage market entry by generics and increase competition, it is actually giving G_0 and G_1 incentives to collude since they know that entry will not occur before the end of the exclusivity period. In the previous example, if G_0 and G_1 know that the entrant will compete from the first period, they always prefer to compete.

7 Entry of authorized generics

So far we have considered entry by new producers of generics after the six months exclusivity period who only produce one version of the drug. We have shown that it is always profitable for them to enter when incumbents generics

firms collude. However, it is possible for the branded drug producer to conclude a licensing agreement with a generics producer and therefore to sell a generic counterpart of the drug, even during the exclusivity period.

In the example discussed in the introduction, Bayer chose to go to courts to prevent the entry of generics. In some cases, however, branded drugs producers prefer to compete in the market for generics by licensing the rights to market and sell the drug to a producer of generic drugs. This was for instance the case for Zocor, a cholesterol drug sold by Merck who faced competition from Teva and Ranbaxy, two generics firms that were allowed to market the drug in the US for various dosages. Merck decided to sign an agreement with Dr. Reddy's Laboratories Ltd. to sell an authorized generic version of Zocor instead of suing at law.

We discuss here the conditions under which a branded drug producer finds it profitable to sell a generic drug through a license.[18] Intuitively, it involves a trade-off between higher profits since part of them are then made on the generics market and increased competition which indirectly lowers the profit made with the branded drugs.

We assume that the drug is produced and sold by an independent generics producer, who fixes the price of the drug by maximizing his own profit. The profits are then shared with the branded drug producer according to the licensing agreement.

Again, we have to make a distinction between collusion and competition by the incumbent generics producers. If they compete, the branded drug firm does not sell a generic drug since it would trigger Bertrand competition for this drug. As a result, the profit from selling the generic drug would be equal to zero and the profits made with the branded drugs would be lower. On the other hand, if the generic incumbents collude, the branded drug producer may prefer a licensing agreement.[19] This is because if incumbents collude and entry occurs, it is optimal for the colluding firms to abandon the drug for which there is entry, as we saw above. Hence, the profit made with the licensed generic drug is positive.

Lemma 9 *The branded drug firm chooses to grant a license to an outside generics producer when incumbent generics firms collude if* $\pi_B^* + \alpha\pi_G^* \geq \pi_B^{**}$*, where* α *is the profits' share of the branded drug producer made with the licensed generic drug.*

Proof. When the branded drug producer does not grant a license and incumbent generics firms collude, its profit is equal to π_B^{**}. On the other hand,when

[18] A branded drug producer could also decide to market its own generic drug if there exists a generics division within the firm. However, this is not always the preferred option as the examples above show. Therefore, we choose to focus on licensing agreements.

[19] Note that similarly to entry by a new generics producer discussed above, a licensing agreement only concerns one version of the drug (i.e. the drug located at either $l = 0$ or at $l = 1$) since selling the second version of the drug as well would trigger Bertrand competition, which is not optimal for the branded drug firm.

incumbents collude a licensing agreement implies that each generic drug yields a profit equal to π_G^* since incumbents prefer to differentiate by abandoning the drug for which there is entry.[20] Therefore, in a symmetric equilibrium, the generics price is equal to p_G^*, the equilibrium price when the two generic incumbents compete. Also, the profit made with the branded drugs is equal to π_B^*, which is equal to the profit made when the incumbents compete. ■

In Figure 3, we draw a frontier representing the choice to grant or not to grant a licence by the branded drug producer as a function of the horizontal differentiation parameter (t) and the vertical differentiation parameter $(1-\gamma)$.

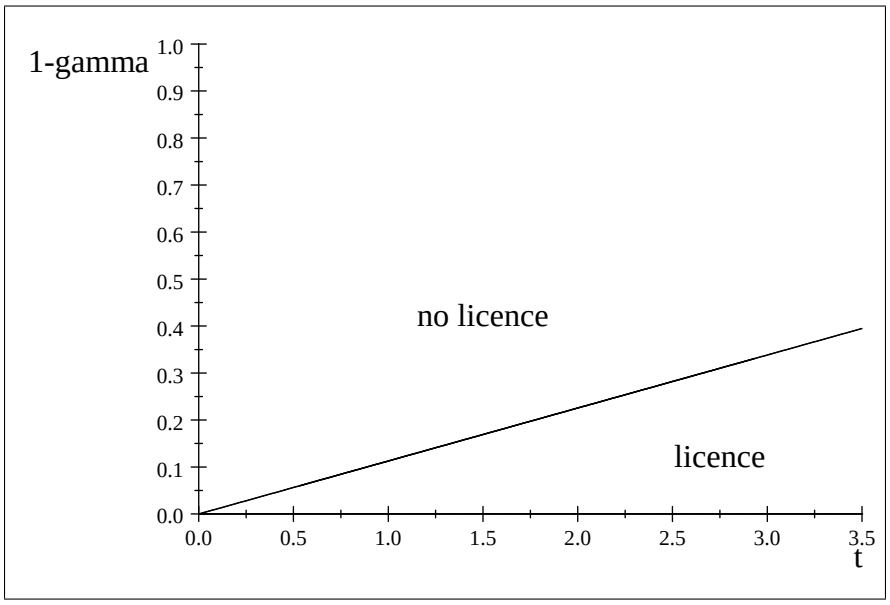

Figure 3: Frontier determining the branded drug producer decision to grant a licence for $\overline{\theta}=3$, $\underline{\theta}=1$, $v=2$ and $\alpha=0.5$.

The frontier is upward slopping since higher vertical differentiation, represented by an increase in $(1-\gamma)$, makes competition less intense and increases profit more when the firm does not launch a generic than when it does. A larger interval $\left[\underline{\theta},\overline{\theta}\right]$ has a similar effect and therefore shifts the frontier to the right.

On the other hand, higher horizontal differentiation gives more incentives to launch a generic drug. This is because horizontal competition is softened when t increases, which in turn means that selling a generic drug has a smaller negative

[20] Contrary to the previous section, we do not assume an entry cost of an authorized generic drug, since there is no need to prove the bio-equivalence of the drug or to obtain approval from authorities if the branded drug producer provides a certification of equivalence.

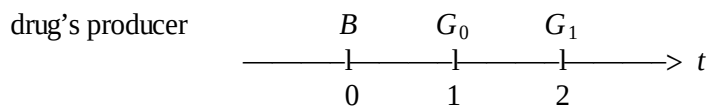

Figure 4: Timing of entry

effect on the profits made with the branded drugs. Furthermore, this effect is then dominated by the additional profits made with the generic drug. On the other hand, t has no effect on the profits of the branded drugs producer when he does not sell a generic drug. Hence, it becomes more likely that a licence is granted when horizontal differentiation is high.

8 Sequential entry and myopic firms

So far, we have assumed that the entry of generics producers is simultaneous, since the model draws on *Biovail Corp.*. We have also assumed initially that incumbent firms could change their prices following the entry of generics. Empirical evidence however suggests that there exists some degree of price stickiness in the drugs market. In their study, Bils *et al.* (2003) show that drugs' prices can be considered as sticky with a median time between two price changes of 15 months. In this section, we will further assume that incumbents do not anticipate entry of competitors and study how sequential entry and myopia affect the pricing decisions of the firms and social welfare when G_0 and G_1 compete and when they collude.

8.1 Price equilibria

We first compute the equilibrium prices of the four drugs, in order to study the consequences of collusion upon social welfare. Since the firms are myopic, the game is solved forward as they enter the market. Figure 4. represents the timing of entry, assuming G_0 enters first (the problem can be treated symmetrically if we assume it is G_1).

8.1.1 Branded drugs price

The brand holder behaves myopically and determines prices maximizing its monopoly profit. We still assume that the branded drugs producer fixes the

same price for the two horizontally differentiated drugs located at the ends of the market. However, we do not assume anymore that the market is necessarily fully covered as in the case of two generics and two branded drugs studied above. Since there is no generic drug in the market initially, we rather assume that some consumers do not buy any drug.[21] Therefore, the monopolist problem is

$$\max_{p_B} p_B D_{B_0} + p_B D_{B_1}$$

where $D_{B_0} = \int_0^{\widetilde{x}_B} \left(\overline{\theta} - \widetilde{\theta}_{B_0}(x)\right) dx$ and $D_{B_1} = \int_{\widetilde{x}_B}^{1} \left(\overline{\theta} - \widetilde{\theta}_{B_1}(1-x)\right) dx$ and $\widetilde{\theta}_{B_0}(x)$ and $\widetilde{\theta}_{B_1}(1-x)$ are respectively the consumers indifferent between consuming B_0 and B_1 and not consuming any drug as a function of their taste parameter θ and $\widetilde{x}_B$ is the consumer indifferent between B_0 and B_1. As shown in appendix A.5., the equilibrium price is $p_B^{*M} = \frac{\overline{\theta}v}{2} - \frac{t}{8}$ and the horizontal location $\widetilde{x}_B$ of the indifferent consumer between B_0 and B_1 is then equal to 0.5.

The equilibrium price is a decreasing function of t since the products located at the ends of the line belong to the same firm as opposed to when there is competition between the products (if B_0 and B_1 were competing, p_B^{*M} would be increasing with t). This is because if the firm can charge a higher price than it would in a competitive context, it must decrease its price when the consumers' mismatch cost is higher.

8.1.2 First generics entrant's price

Entry of generics firms occurs sequentially, and the first firm to enter[22] maximizes its profit given the price of the branded drugs p_B but does not anticipate entry from the second generics producer. Two cases can arise, depending on whether the generic drug is competing with only one branded drugs or with two. A graphical representation of demands for the three drugs is given below.

- In the first case (Figure 5), the demand for G_0 is given by

[21] A necessary and sufficient condition is that $\underline{\theta}v - p_B^{*M} < 0$, where p_B^{*M} is the equilibrium price of branded drugs computed below.

[22] We arbitrarily fix its location at $l = 0$. The other case ($l = 1$) can be treated symmetrically.

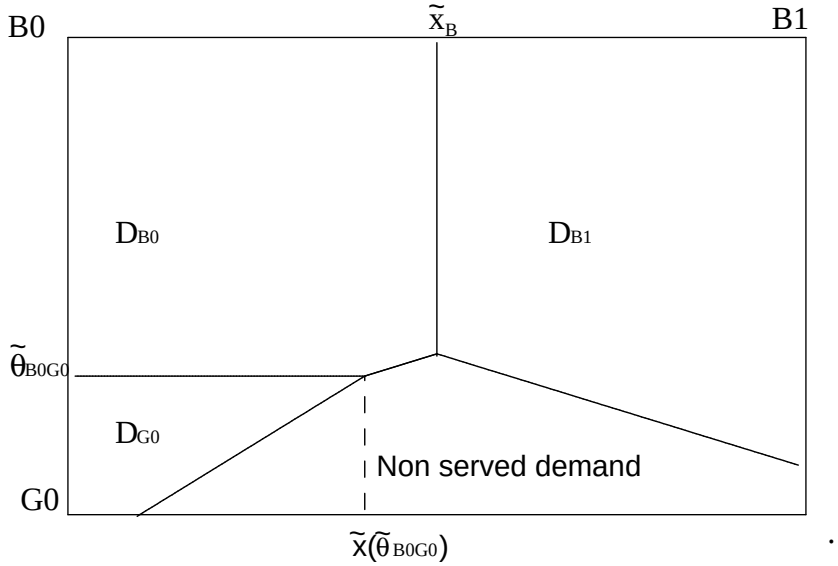

Figure 5: Demands when the generic drug is competing with only one branded drug (B_0)

$$D_{G_0} = \left(\widetilde{\theta}_{B_0G_0} - \underline{\theta}\right) * \widetilde{x}(\widetilde{\theta}_{B_0G_0}) - \int_{\frac{\underline{\theta}\gamma v - p_{G_0}}{t}}^{\widetilde{x}(\widetilde{\theta}_{B_0G_0})} \left(\widetilde{\theta}_{G_0}(x) - \underline{\theta}\right) dx$$

with $\widetilde{x}(\widetilde{\theta}_{B_0G_0})$ being the horizontal location of the consumer who is indifferent between B_0, G_0 and not consuming any drug. This is the expression of the demand for G_0 as long as $\widetilde{x}(\widetilde{\theta}_{B_0G_0}) \leq 0.5$, since beyond 0.5, the drug is competing with B_1.

- In the second case (Figure 6), demand is given by

$$D_{G_0} = \frac{\widetilde{\theta}_{B_0G_0} - \underline{\theta}}{2} + \int_{0.5}^{\widetilde{x}(\widetilde{\theta}_{B_1G_0})} \left(\widetilde{\theta}_{B_1G_0}(x) - \underline{\theta}\right) dx - \int_{\frac{\underline{\theta}\gamma v - p_{G_0}}{t}}^{\widetilde{x}(\widetilde{\theta}_{B_1G_0})} \left(\widetilde{\theta}_{G_0}(x) - \underline{\theta}\right) dx$$

with $\widetilde{x}(\widetilde{\theta}_{B_1G_0})$ being the horizontal location of the consumer who is indifferent between B_1, G_0 and not consuming any drug. This is true as long as $\widetilde{x}(\widetilde{\theta}_{B_1G_0}) \geq 0.5$. Furthermore, demand is continuous since

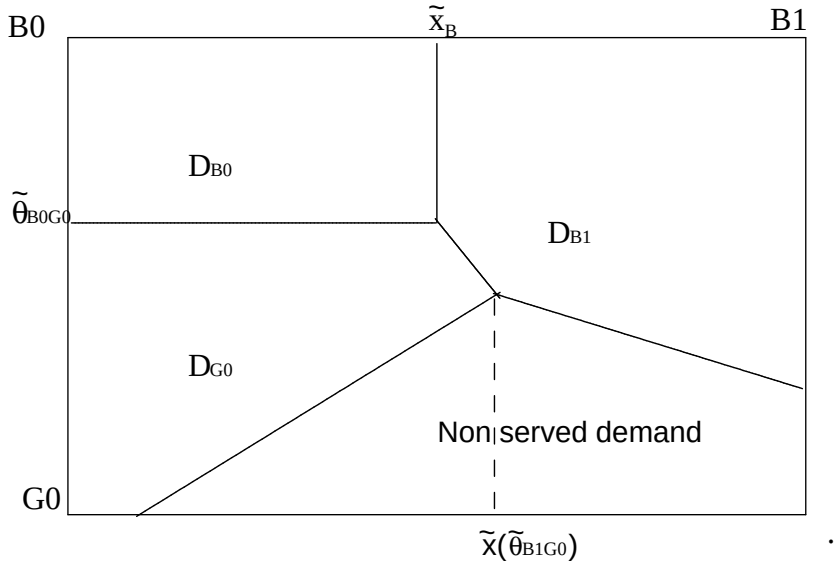

Figure 6: Demands when the generic drug is competing with the two branded drugs (B_0 and B_1)

$$D_{G_0} = \frac{\widetilde{\theta}_{B_0G_0} - \underline{\theta}}{2} - \int_{\frac{\underline{\theta}\gamma v - p_{G_0}}{t}}^{0.5} \left(\widetilde{\theta}_{G_0}(x) - \underline{\theta}\right) dx$$

when $\widetilde{x}(\widetilde{\theta}_{B_0G_0}) = \widetilde{x}(\widetilde{\theta}_{B_1G_0}) = 0.5$. We show in Appendix A.5. that there exists a unique price equilibrium $p_{G_0}^{*M}$ determined by the exogenous parameters of the model. The consumers who do not consume any drug are those with a low valuation of the drug and located towards the end of the line. This is intuitive because they are the ones who are located the furthest away from existing drugs.

Fig. 7 shows that since $\widetilde{x}(\widetilde{\theta}_{B_0G_0}) = \dfrac{\gamma p_B^{*M}(t) - p_{G_0}^{*M}(t)}{(1-\gamma)t}$ decreases with t, the generics producer is more likely to compete with the two branded drugs when horizontal differentiation is low.

This is because even though both p_B^{*M} and $p_{G_0}^{*M}$ are decreasing with t (which increases consumers' utility), a higher mismatch cost implies that more consumers do not consume any drug, hence $\widetilde{x}(\widetilde{\theta}_{B_0G_0})$ shifts to the left when t increases.

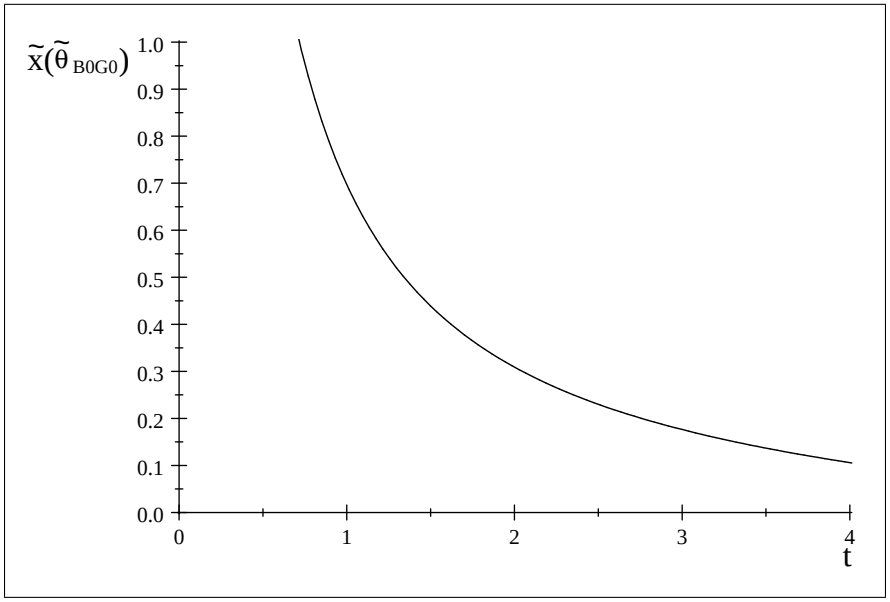

Figure 7: Horizontal location $\widetilde{x}(\widetilde{\theta}_{B_0G_0})$ of the indifferent consumer between B_0, G_0 and not consuming, as a function of t when $\underline{\theta} = 1$, $\overline{\theta} = 3$, $v = 3$ and $\gamma = 0.3$.

8.1.3 Second generics entrant's price

The second generic drug G_1 enters afterwards. The producer takes the price of the three other drugs as given. In line with the assumptions made initially when entry is simultaneous, we assume full coverage of the market once the four drugs are sold. The firm can decide to collude or not with G_0.[23] However, the decision only modifies p_{G_1} since p_{G_0} is assumed to be sticky.

Again, two cases may arise, depending on whether the consumer with the lowest valuation $\underline{\theta}$ who is indifferent between G_0 and not consuming any drug is located beyond $\widetilde{x}_B = 0.5$ or not.

- If $\frac{\underline{\theta}\gamma v - p_{G_0}}{t} \geq 0.5$:

- either G_1 does not collude with G_0; then the price is set according to the following first order condition coming from profit maximization

[23] Since the price $p_{G_1}^{**M}$ proposed under collusion is higher as we show below, full coverage occurs if the consumer located at $x = \frac{\underline{\theta}\gamma v - p_G}{t}$ and with valuation $\theta = \underline{\theta}$ obtains a non-negative utility when he is consuming G_1, i.e. if $2\underline{\theta}\gamma v + p_{G_0}^{**M} - t > p_{G_1}^{**M}$.

$p_{G_0}^{*M} p_B^{*M} - 2p_B^{*M} p_{G_1} - 2p_{G_1} p_{G_0}^{*M} + 3p_{G_1}^2 + t(p_B^{*M} - 2p_{G_1}) + \underline{\theta} v(1-\gamma)(2p_{G_1} - p_{G_0}^{*M} - t) = 0 \quad (5)$

which is similar to the FOC obtained when entry is simultaneous (See appendix A.1.). However, in this setting the firm producing G_1 knows the price proposed by the other firms.

- or collusion occurs; then the price is set according to the following equation

$tp_B^{*M} - 2p_{G_1} p_B^{*M} + 2p_{G_0}^{*M} p_B^{*M} - 2tp_{G_1} + 3p_{G_1}^2 - 3p_{G_0}^{*M} p_{G_1} - \underline{\theta} v(1-\gamma)(-2p_{G_1} + 2p_{G_0}^{*M} + t) = 0 \quad (6)$

which is the FOC of profit maximization with respect to p_{G_1} when entry is simultaneous and producers collude (See appendix A.3).

- If $\frac{\underline{\theta}\gamma v - p_{G_0}}{t} \leq 0.5$:

- either G_1 competes with G_0; then the price is given by solving

$p_{G_0}^{*M} p_B^{*M} - 2p_B^{*M} p_{G_1} + 1.5p_{G_1}^2 - 0.5\left(p_{G_0}^{*M}\right)^2 + t(p_B^{*M} - 2p_{G_1}) + \underline{\theta} v(1-\gamma)(2p_{G_1} - p_{G_0}^{*M} - t) = 0 \quad (7)$

which is equivalent to (9) (see Appendix A.1.), and permuting G_0 and G_1.

- or they collude; then p_{G_1} is the solution of

$-2p_B^{*M} p_{G_1} + tp_B^{*M} + 1.5p_{G_1}^2 - 2tp_{G_1} - \underline{\theta} v(1-\gamma)(2p_{G_0}^{*M} - 2p_{G_1} + t) - 1.5\left(p_{G_0}^{*M}\right)^2 + 2p_{G_0}^{*M} p_B^{*M} = 0 \quad (8)$

which is equivalent to (12) (see Appendix A.3.), and permuting G_0 and G_1.

As we show in Appendix A.6., there exists a unique price equilibrium for the four FOCs above (5)-(8). Furthermore, the equilibrium price when firms collude is as expected higher in the two cases. We can notice that unlike in the initial model with simultaneous entry where we assumed a symmetric equilibrium, any assumption is unnecessary here in order to show that it is unique.

8.2 Social welfare

The consequences of collusion on social welfare are not as straightforward when entry is sequential as when entry is simultaneous. Again, we have to make a distinction on whether the consumer with the lowest valuation $\theta = \underline{\theta}$ and indifferent between consuming G_0 and not consuming is located beyond 0.5 or not (i.e. if $\frac{\underline{\theta}\gamma v - p_{G_0}^{*M}}{t} \gtrless 0.5$). The following proposition summarizes the effects of collusion on social welfare when the social planner considers the perceived quality of drugs.

Proposition 10 *If perceived quality is taken into account, social welfare is higher when firms collude if* $\frac{\underline{\theta}\gamma v - p_{G_0}^{*M}}{t} \leq 0.5$. *Otherwise, the consequences of collusion are ambiguous.*

As explained above, social welfare is equal to

$$W = CS_{G_0} + \pi_{G0} + CS_{G_1} + \pi_{G1} + CS_{B_0} + \pi_{B0} + CS_{B_1} + \pi_{B1}$$

$$CS_i + \pi_i = \begin{cases} \frac{1}{\overline{\theta}-\underline{\theta}} \int_{\underline{\theta}}^{\widetilde{\theta}_{B_0G_0}} \int_0^{\widetilde{x}_G} (\theta\gamma v - tx) dx d\theta \ if \ i = G_0 \\ \frac{1}{\overline{\theta}-\underline{\theta}} \int_{\underline{\theta}}^{\widetilde{\theta}_{B_1G_1}} \int_{\widetilde{x}_G}^1 (\theta\gamma v - t(1-x)) dx d\theta \ if \ i = G_1 \\ \frac{1}{\overline{\theta}-\underline{\theta}} \int_{\widetilde{\theta}_{B_0G_0}}^{\overline{\theta}} \int_0^{\widetilde{x}_B} (\theta v - tx) dx d\theta \ if \ i = B_0 \\ \frac{1}{\overline{\theta}-\underline{\theta}} \int_{\widetilde{\theta}_{B_1G_1}}^{\overline{\theta}} \int_{\widetilde{x}_B}^1 (\theta v - t(1-x)) dx d\theta \ if \ i = B_1 \end{cases}$$

Therefore, social welfare depends on $\widetilde{\theta}_{B_0G_0}$, $\widetilde{\theta}_{B_1G_1}$, $\widetilde{x}_B$ and $\widetilde{x}_G$. Since prices are sticky, collusion only affects $\widetilde{\theta}_{B_1G_1}$ and $\widetilde{x}_G$. The price of G_1 is higher when firms collude, so that $\widetilde{\theta}_{B_1G_1}$ is lower and more consumers buy branded drugs, which increases welfare.

Collusion also decreases total transportation costs of generics consumption when $\frac{\underline{\theta}\gamma v - p_{G_0}^{*M}}{t} \leq 0.5$, hence it has a second positive effect on social welfare. This is because $\widetilde{x}_G$ increases with p_{G_1} and total transportation costs decrease with $\widetilde{x}_G$ for $\widetilde{x}_G \in [0, 0.5]$, as it is always the case here since we assume full coverage of the market with the four drugs.[24] The overall effect on social welfare is therefore positive.

On the other hand, if $\frac{\underline{\theta}\gamma v - p_{G_0}^{*M}}{t} \geq 0.5$, total transportation costs increase with $\widetilde{x}_G$, so collusion has a negative effect on social welfare in terms of total mismatch cost. Hence, the overall effect is ambiguous.

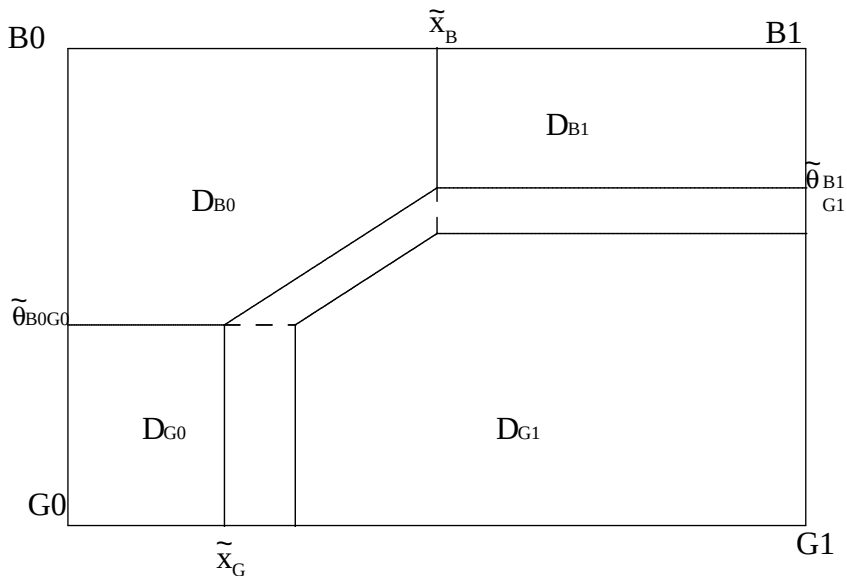

Figure 8: Graphical representation of demands when $\frac{\underline{\theta}\gamma v - p^{*M}_{G_0}}{t} \leq 0.5$.

In both Fig. 8 and Fig. 9, we can observe that $\widetilde{\theta}_{B_1G_1}$ is decreasing when generics collude (since p_{G_1} is higher) which means that branded drug B_1 is more consumed, whereas the indifferent consumer between G_0 and G_1 ($\widetilde{x}_G$) shifts to the right so that G_1 is also losing market shares to the benefit of G_0. However, in Fig. 8, collusion implies that $\widetilde{x}_G$ is closer to the middle of the horizontal line (which decreases transportation costs and hence increase welfare), whereas it is moving away from the middle in Fig. 9, which contributes to increase total transportation costs.

If on the other hand, the social planner discards the perceived quality of drugs, social welfare is equal to

$$\widehat{W} = \widehat{CS}_{G_0} + \pi_{G0} + \widehat{CS}_{G_1} + \pi_{G1} + \widehat{CS}_{B_0} + \pi_{B0} + \widehat{CS}_{B_1} + \pi_{B1}$$

where $CS_{B_0} = \widehat{CS}_{B_0}$, $CS_{B_1} = \widehat{CS}_{B_1}$ and

$$\widehat{CS}_i + \pi_i = \begin{cases} \frac{1}{\overline{\theta}-\underline{\theta}} \int_{\underline{\theta}}^{\widetilde{\theta}_{B_0G_0}} \int_0^{\widetilde{x}_G} (\theta v - tx) dx d\theta \ if \ i = G_0 \\ \frac{1}{\overline{\theta}-\underline{\theta}} \int_{\underline{\theta}}^{\widetilde{\theta}_{B_1G_1}} \int_{\widetilde{x}_G}^{1} (\theta v - t(1-x)) dx d\theta \ if \ i = G_1 \end{cases}$$

[24] We show in Appendix A.7. that total transportation costs decrease with $\widetilde{x}_G$ for $\widetilde{x}_G \in [0, 0.5]$.

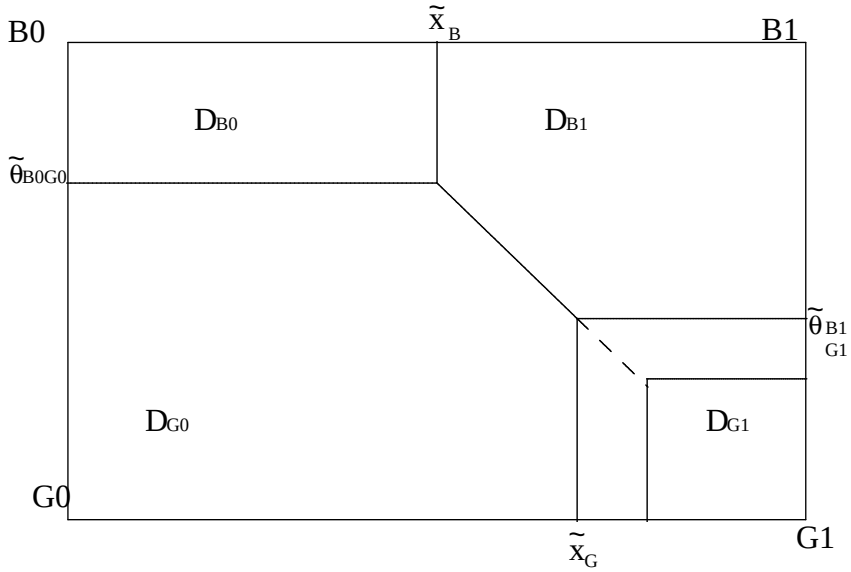

Figure 9: Graphical representation of demands when $\frac{\theta\gamma v - p_{G_0}^{*M}}{t} \geq 0.5$.

Therefore, the sizes of generics and branded drugs market shares do not matter any more since they are considered as equivalent. Hence, only transportation costs matter and we can establish the following proposition.

Proposition 11 *If generics and branded drugs are viewed as perfect substitutes, social welfare is higher under collusion if* $\frac{\theta\gamma v - p_{G_0}^{*M}}{t} \leq 0.5$ *and lower otherwise.*

We are only interested in how collusion affects the consumer indifferent between G_0 and G_1 located at $\widetilde{x}_G$. Since $\widetilde{x}_G$ is shifting towards the middle of the horizontal line when $\frac{\theta\gamma v - p_{G_0}^{*M}}{t} \leq 0.5$ and firms collude, welfare is increasing because total transportation costs decrease. It is the reverse when $\frac{\theta\gamma v - p_{G_0}^{*M}}{t} \geq 0.5$. We can observe that contrary to the simultaneous entry case described above, collusion and competition are not equivalent in terms of social welfare, since we do not have $\widetilde{x}_G = 0.5$ in both settings anymore. Again, it should be recalled that we abstract from location considerations, as they are assumed to be the same in all industrial configurations.

9 Conclusion

In this paper, we have studied a case of collusion between two generics firms that enter the market before the expiration of patents held by a pharmaceutical firm selling two branded products. We have introduced both horizontal and vertical differentiation to account for preferences with respect to the two versions of the drug and the difference in perceived quality between generics and branded drugs. We have discussed the incentives of generics firms to collude and the consequences over market entry and social welfare. As expected, prices are higher when there is partial collusion in the market, as the consequence of collusion is to suppress horizontal competition in the market. However, collusion increases social welfare if the social planner takes into account perceived quality since it implies that the market shares of branded drugs increase. This means that a social planner who values the perception of drugs by consumers has in this case no incentives to stop collusion in the market. Also, entry in the market only occurs if there is collusion, whether the drug is sold by an independent producer or through a license agreement. This is however not sufficient in the case of a license agreement, since the branded drugs producer faces a trade-off between more profits on the generics side and a higher degree of competition for the branded drugs. Hence, horizontal differentiation must be high relatively to vertical differentiation in order to lead to entry.

When generics initially enter the market sequentially, the effect of collusion on welfare depends on the degree of horizontal differentiation and is ambiguous whether the social planner takes into account vertical differentiation or not. Since the equilibrium market shares are asymmetric between the two generic drugs, the effect of collusion on total mismatch costs must be considered in any case to determine the consequences on social welfare. We however have focused on the case of sticky prices, and a possible extension of the paper could consist in computing the subgame perfect price equilibria.

10 Appendix

A.1. First order conditions of profit maximization when generics do not collude.

We first consider the generics firm producing G_0. The profit function is $\pi_{G_0} = p_{G_0} D_{G_0} = p_{G_0} \frac{1}{\overline{\theta}-\underline{\theta}} \left(\left(\widetilde{\theta}_{B_0 G_0} - \underline{\theta} \right) \widetilde{x}_G - 0.5 \left(\widetilde{x}_G - \widetilde{x}_B \right) \left(\widetilde{\theta}_{B_0 G_0} - \widetilde{\theta}_{B_1 G_1} \right) \right)$. Hence, the first order condition (FOC) is the following

$$p_{G_1} p_B - 2 p_B p_{G_0} + 1.5 p_{G_0}^2 - 0.5 p_{G_1}^2 + t(p_B - 2p_{G_0}) + \underline{\theta} v (1-\gamma)(2p_{G_0} - p_{G_1} - t) = 0 \quad (9)$$

The firm producing G_1 maximizes $\pi_{G_1} = p_{G_1} D_{G_1} = p_{G_1} \frac{1}{\overline{\theta}-\underline{\theta}} \left(\widetilde{\theta}_{B_1 G_1} - \underline{\theta}\right)(1-\widetilde{x}_G)$ and the FOC is

$$p_{G_0} p_B - 2p_B p_{G_1} - 2p_{G_1} p_{G_0} + 3p_{G_1}^2 + t(p_B - 2p_{G_1}) + \underline{\theta} v(1-\gamma)(2p_{G_1} - p_{G_0} - t) = 0 \quad (10)$$

Finally, the branded drug producer maximizes $\pi_B = p_B D_{B_0} + p_B D_{B_1}$. Therefore the FOC with respect to p_B is

$$4t\overline{\theta} v(1-\gamma) - 8tp_B + 2tp_{G_0} + 2tp_{G_1} - (p_{G_1} - p_{G_0})^2 = 0 \qquad (11)$$

Because we only consider a symmetric equilibrium where $p_{G_i} \equiv p_G$, (9) and (10) are equivalent to (1) and (11) to (2).

A.2. Comparative statics of equilibrium prices.

Since $\frac{\partial p_G^*}{\partial t} = 1.5 - 0.5(2 * 1.5(C + 1.5t) - 2C)\left((C + 1.5t)^2 - 2tC\right)^{-0.5}$ and $C^2 + Ct + \frac{9}{4}t^2 > \frac{1}{9}C^2 + Ct + \frac{9}{4}t^2$, we have $\frac{\partial p_G^*}{\partial t} > 0$. Also, $\frac{\partial p_G^*}{\partial C} = 1 - 0.5(2(C + 1.5t) - 2t)\left((C + 1.5t)^2 - 2tC\right)^{-0.5}$ and $C^2 + Ct + \frac{9}{4}t^2 > C^2 + Ct + \frac{1}{4}t^2$, we have $\frac{\partial p_G^*}{\partial C} > 0$. Because $\frac{\partial C}{\partial v(1-\gamma)} > 0$ and $\frac{\partial C}{\partial \overline{\theta}} > 0$, $\frac{\partial p_G^*}{\partial v(1-\gamma)} > 0$ and $\frac{\partial p_G^*}{\partial \overline{\theta}} > 0$. On the other hand, $\frac{\partial C}{\partial \underline{\theta}} < 0$, so $\frac{\partial p_G^*}{\partial \underline{\theta}} < 0$.

Finally, $\frac{\partial p_B^*}{\partial t} = 0.5\frac{\partial p_G^*}{\partial t}$ so $\frac{\partial p_B^*}{\partial t} > 0$. Also, $\frac{\partial p_B^*}{\partial v(1-\gamma)} = 0.5\left(\overline{\theta} + \frac{\partial p_G^*}{\partial v(1-\gamma)}\right)$ and $\frac{\partial p_B^*}{\partial \overline{\theta}} = 0.5\left(v(1-\gamma) + \frac{\partial p_G^*}{\partial v(1-\gamma)}\right)$ so $\frac{\partial p_B^*}{\partial v(1-\gamma)} > 0$ and $\frac{\partial p_B^*}{\partial \overline{\theta}} > 0$. On the other hand, $\frac{\partial p_B^*}{\partial \underline{\theta}} = 0.5\frac{\partial p_G^*}{\partial \underline{\theta}}$ so $\frac{\partial p_B^*}{\partial \underline{\theta}} < 0$.

Concerning profits, we have $\pi_G^* = \frac{1}{4v(1-\gamma)(\overline{\theta}-\underline{\theta})}\left(3t\sqrt{(C + 1.5t)^2 - 2tC} - Ct - 4.5t^2\right)$ and $\frac{\partial \pi_G^*}{\partial t} = \frac{1}{4v(1-\gamma)(\overline{\theta}-\underline{\theta})}\left(3\sqrt{(C + 1.5t)^2 - 2tC} + 1.5t(C + 4.5t)((C + 1.5t)^2 - 2tC)^{-0.5} - C - 9t\right)$ > 0 and $\pi_B^* = \frac{1}{4v(1-\gamma)(\overline{\theta}-\underline{\theta})}\left(1.5\overline{\theta}v(1-\gamma) - \underline{\theta}v(1-\gamma) + 1.5t - \sqrt{(C + 1.5t)^2 - 2tC}\right)^2$ and $\frac{\partial \pi_B^*}{\partial t} = \frac{1}{4v(1-\gamma)(\overline{\theta}-\underline{\theta})}\left(3 - (C + 4.5t)((C + 1.5t)^2 - 2tC)^{-0.5}\right)$ $\left(1.5\overline{\theta}(1-\gamma)v - \underline{\theta}(1-\gamma)v + 1.5t - \sqrt{(C + 1.5t)^2 - 2tC}\right) > 0$. Also, $\frac{\partial \pi_G^*}{\partial t} < \frac{\partial \pi_B^*}{\partial t}$ given we assume $\frac{v}{3}\left(\gamma(\overline{\theta} + \underline{\theta}) - (\overline{\theta} - 2\underline{\theta})\right) - \frac{t}{2} \geq 0$

A.3. First order conditions of profit maximization when generics collude.

The branded drug producer maximizes $\pi_B = p_B D_{B_0} + p_B D_{B_1}$, hence the FOC with respect to p_B is given by (11) which is equivalent to (2). The generics producers maximize $\pi_G = p_{G_0} D_{G_0} + p_{G_1} D_{G_1}$ so the FOC with respect to p_{G_0} is

$$-2p_B p_{G_0} + tp_B + 1.5p_{G_0}^2 - 2tp_{G_0} - \underline{\theta} v(1-\gamma)(2p_{G_1} - 2p_{G_0} + t) - 1.5p_{G_1}^2 + 2p_{G_1} p_B = 0 \quad (12)$$

and with respect to p_{G_1}

$$tp_B - 2p_{G_1} p_B + 2p_{G_0} p_B - 2tp_{G_1} + 3p_{G_1}^2 - 3p_{G_0} p_{G_1} - \underline{\theta} v(1-\gamma)(-2p_{G_1} + 2p_{G_0} + t) = 0 \quad (13)$$

If we consider a symmetric equilibrium, these FOCs are equivalent to (3).

A.4. Proof of Corollary 4.1.

We know $p_G^{**} = \frac{1}{3}(1-\gamma)v(\overline{\theta} - 2\underline{\theta}) = \frac{2}{3}C$ and $\frac{2}{3}C > C + 1.5t - \sqrt{(C+1.5t)^2 - 2tC}$ because $C^2 + Ct + \frac{9}{4}t^2 > \frac{1}{9}C^2 + Ct + \frac{9}{4}t^2$ so $p_G^{**} > p_G^*$. On the other hand, $p_B^{**} > p_B^*$ also if $\frac{2}{3}C > C + 1.5t - \sqrt{(C+1.5t)^2 - 2tC}$ which is always true.

Furthermore, since generics producers share profits equally when they collude, they obtain $0.5\pi_G^{**} = \frac{1}{18(\overline{\theta}-\underline{\theta})} v(1-\gamma)\left(\overline{\theta} - 2\underline{\theta}\right)^2 >$
$\pi_G^* = \frac{1}{4v(1-\gamma)\left(\overline{\theta}-\underline{\theta}\right)}\left(3t\sqrt{(C+1.5t)^2 - 2tC} - Ct - 4.5t^2\right)$ since this is equivalent to $3t\sqrt{(C+1.5t)^2 - 2tC} - Ct - 4.5t^2 < \frac{8}{9}C^2$ which is always true.

Also, $\pi_B^{**} = \frac{1}{9(\overline{\theta}-\underline{\theta})} v(1-\gamma)\left(2\overline{\theta} - \underline{\theta}\right)^2 >$
$\pi_B^* = \frac{1}{4v(1-\gamma)(\overline{\theta}-\underline{\theta})}\left(1.5\overline{\theta}v(1-\gamma) - \underline{\theta}v(1-\gamma) + 1.5t - \sqrt{(C+1.5t)^2 - 2tC}\right)^2$
because it is equivalent to $0.5C + \frac{9}{4}t - 1.5\sqrt{(C+1.5t)^2 - 2tC} > 0$ which is always true.

A.5. Price equilibria when entry is sequential.

When the incumbent determines the prices of branded drugs, he maximizes $\pi_B = p_B D_{B_0} + p_B D_{B_1}$ where $D_{B_0} = \int_0^{\widetilde{x}_B} \overline{\theta} - \widetilde{\theta}_{B_0}(x)dx$ and $D_{B_1} = \int_{\widetilde{x}_B}^1 \overline{\theta} - \widetilde{\theta}_{B_1}(1-x)dx$ and $\widetilde{\theta}_{B_0}(x)$ and $\widetilde{\theta}_{B_1}(1-x)$ are respectively the consumers indifferent between consuming B_0 and B_1 and not consuming any drug as a function of their taste parameter θ. Furthermore, as defined earlier, $\widetilde{x}_B = \dfrac{p_{B_1} - p_{B_0} + t}{2t} = 0.5$.

Therefore, we obtain $D_{B_0} = \int_0^{0.5} \overline{\theta} - \frac{p_B + tx}{v} dx$ and $D_{B_1} = \int_{0.5}^{1} \overline{\theta} - \frac{p_B + t(1-x)}{v} dx$.
The first order conditions are :

$$\frac{\partial \pi}{\partial p_B} = \frac{(\overline{\theta} v - 2p_B)}{2} - \frac{1}{2t} p_B(\overline{\theta} - 2p_B) - \frac{t}{8} + \frac{p_B}{4} + \frac{1}{2t} p_B(\overline{\theta} - 2p_B) - \frac{p_B}{2} + \frac{p_B}{4} = 0$$

which leads to $p_{B_0}^{*M} = p_{B_1}^{*M} = p_B^{*M} = \frac{\overline{\theta} v}{2} - \frac{t}{8}$.

The first generic firm to enter maximizes its profit given p_B^{*M}, which is equal to

$$\pi_{G_0} = \left(\left(\widetilde{\theta}_{B_0 G_0} - \underline{\theta} \right) * \widetilde{x}(\widetilde{\theta}_{B_0 G_0}) - \int_{\frac{\underline{\theta}\gamma v - p_{G_0}}{t}}^{\widetilde{x}(\widetilde{\theta}_{B_0 G_0})} \left(\widetilde{\theta}_{G_0}(x) - \underline{\theta} \right) dx \right) p_{G_0}$$
$$= \left(\frac{(p_B^{*M} - p_{G_0} - \underline{\theta} v(1-\gamma))(\gamma p_B^{*M} - p_{G_0})}{(1-\gamma)^2 vt} - 0.5 \left(\frac{\gamma p_B^{*M} - p_{G_0}}{(1-\gamma)t} - \frac{\underline{\theta}\gamma v(1-\gamma) - p_{G_0}(1-\gamma)}{(1-\gamma)t} \right) \left(\frac{p_B^{*M} - p_{G_0} - \underline{\theta} v(1-\gamma)}{(1-\gamma)v} \right) \right) p_{G_0}$$

in the first case and the first order condition is equal to

$$\frac{\partial \pi_{G_0}}{\partial p_{G_0}} = (2 - 0.5\gamma) p_{G_0}^2 - 2p_{G_0}(p_B^{*M} - (1-\gamma)^2 \underline{\theta} v) + 0.5\gamma \left(p_B^{*M} \right)^2 + 0.5\gamma \underline{\theta}^2 v^2 (1-\gamma)^2 = 0$$

There are two solutions, $p_{G_0}^{*M} = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$ with $a = (2 - 0.5\gamma)$, $b = -2(p_B^{*M} - (1-\gamma)^2 \underline{\theta} v)$ and $c = 0.5\gamma \left(p_B^{*M} \right)^2 + 0.5\gamma \underline{\theta}^2 v^2 (1-\gamma)^2$ but only $p_{G_0}^{*M} = \frac{-b - \sqrt{b^2 - 4ac}}{2a}$ satisfies the second order condition.

If the generic drug is competing with the two branded drugs, the profit function is equal to

$$\pi_{G_0} = \left(\frac{\widetilde{\theta}_{B_0 G_0} - \underline{\theta}}{2} + \int_{0.5}^{\widetilde{x}(\widetilde{\theta}_{B_1 G_0})} \left(\widetilde{\theta}_{B_1 G_0}(x) - \underline{\theta} \right) dx - \int_{\frac{\underline{\theta}\gamma v - p_{G_0}}{t}}^{\widetilde{x}(\widetilde{\theta}_{B_1 G_0})} \left(\widetilde{\theta}_{G_0}(x) - \underline{\theta} \right) dx \right) p_{G_0}$$
$$= \left(\frac{p_B^{*M} - p_{G_0} - \underline{\theta} v(1-\gamma)}{2v(1-\gamma)} + 0.5 \left(\frac{p_B^{*M} - p_{G_0}}{v(1-\gamma)} - \frac{p_{G_0} + 0.5t}{\gamma v} \right) \left(\frac{\gamma p_B^{*M} - p_{G_0} + \gamma t}{t(1+\gamma)} - 0.5 \right) \right) p_{G_0}$$
$$-0.5 \left(\frac{\gamma p_B^{*M} - p_{G_0} + \gamma t}{t(1+\gamma)} - \frac{\underline{\theta}\gamma v(1-\gamma) - p_{G_0}(1-\gamma)}{(1-\gamma)t} \right) \left(\frac{\gamma \left(p_B^{*M} - p_{G_0} \right) + \gamma t}{(1+\gamma)^2} - \underline{\theta} \right) p_{G_0}$$

and the first order condition is equal to

$\frac{\partial \pi_{G_0}}{\partial p_{G_0}} = 3p_{G_0}^2(2(1+\gamma)^2 + 2v\gamma(1-\gamma)) - 2p_{G_0}(t(1+\gamma)^3 + 4p_B^{*M}\gamma(1+\gamma)^2 + 2t\gamma(1+\gamma)^2 - t(1-\gamma)(1+\gamma)^2 - 2t\gamma v(1-\gamma)^2 + 2v(1-\gamma)\underline{\theta}(1+\gamma)^2 - 2v^2\gamma^2\underline{\theta}(1+\gamma)(1-\gamma)) + (2-\gamma)\, p_B^{*M} t(1+\gamma)^3 - 2\underline{\theta}v(1-\gamma)t(1+\gamma)^3 + 2(1+t)\left(p_B^{*M}\right)^2\gamma^2(1+\gamma)^2 - p_B^{*M}t\gamma(1-\gamma)(1+\gamma)^2 - t^2\gamma(1-\gamma)(1+\gamma)^2 + 0.5t^2(1-\gamma)(1+\gamma)^3 - 2\left(p_B^{*M}\right)^2 v\gamma^2(1-\gamma) - 2t\gamma^2 p_B^{*M} v(1-\gamma) + 2p_B^{*M}\gamma v\underline{\theta}(1+\gamma)^2(1-\gamma) - 2t$
$v\gamma^2(1-\gamma)p_B^{*M} - 2t^2\gamma^2 v(1-\gamma) + 2t\gamma(1-\gamma)\underline{\theta}(1+\gamma)^2 + 2\underline{\theta}\gamma^2 v^2(1+\gamma)(1-\gamma)\left(p_B^{*M}+t\right) - 2\underline{\theta}^2(1+\gamma)^3\gamma v^2(1-\gamma) = 0$

There are two solutions, $p_{G_0}^{*M} = \frac{-b \pm \sqrt{b^2-4ac}}{2a}$ with $a = 2(1+\gamma)^2 + 2v\gamma(1-\gamma)$,
$-b = t(1+\gamma)^3 + 4p_B^{*M}\gamma(1+\gamma)^2 + 2t\gamma(1+\gamma)^2 - t(1-\gamma)(1+\gamma)^2 - 2t\gamma v(1-\gamma)^2 + 2v(1-\gamma)\underline{\theta}(1+\gamma)^2 - 2v^2\gamma^2\underline{\theta}(1+\gamma)(1-\gamma)$ and $c = (2-\gamma)\, p_B^{*M} t(1+\gamma)^3 - 2\underline{\theta}v(1-\gamma)t(1+\gamma)^3 + 2(1+t)\left(p_B^{*M}\right)^2\gamma^2(1+\gamma)^2 - p_B^{*M}t\gamma(1-\gamma)(1+\gamma)^2 - t^2\gamma(1-\gamma)(1+\gamma)^2 + 0.5t^2(1-\gamma)(1+\gamma)^3 - 2\left(p_B^{*M}\right)^2 v\gamma^2(1-\gamma) - 2t\gamma^2 p_B^{*M} v(1-\gamma) + 2p_B^{*M}\gamma v\underline{\theta}(1+\gamma)^2(1-\gamma) - 2t$
$v\gamma^2(1-\gamma)p_B^{*M} - 2t^2\gamma^2 v(1-\gamma) + 2t\gamma(1-\gamma)\underline{\theta}(1+\gamma)^2 + 2\underline{\theta}\gamma^2 v^2(1+\gamma)(1-\gamma)\left(p_B^{*M}+t\right) - 2\underline{\theta}^2(1+\gamma)^3\gamma v^2(1-\gamma)$

but only $p_{G_0}^{*M} = \frac{-b - \sqrt{b^2-4ac}}{2a}$ satisfies the second order condition.

A.6. Uniqueness of price equilibria for $p_{G_1}^{*M}$ and $p_{G_1}^{**M}$.

There are two solutions for (5) and (6), which are respectively

$p_{G_1}^{*M} = \frac{-b \pm \sqrt{b^2-4ac}}{2a}$ and $p_{G_1}^{**M} = \frac{-d \pm \sqrt{d^2-4ae}}{2a}$ with $a = 3$, $b = -2(p_B^{*M} + p_{G_0}^{*M} + t - \underline{\theta}v(1-\gamma))$, $c = p_{G_0}^{*M}p_B^{*M} + tp_B^{*M} - \underline{\theta}v(1-\gamma)(p_{G_0}^{*M}+t)$ and $d = -2p_B^{*M} - 3p_{G_0}^{*M} - 2t + 2\underline{\theta}v(1-\gamma)$ and $e = 2p_{G_0}^{*M}p_B^{*M} + tp_B^{*M} - \underline{\theta}v(1-\gamma)(2p_{G_0}^{*M}+t)$.

However, only $p_{G_1}^{*M} = \frac{-b - \sqrt{b^2-4ac}}{2a}$ and $p_{G_1}^{**M} = \frac{-d - \sqrt{d^2-4ae}}{2a}$ satisfy the second order conditions. Furthermore, we have $p_{G_1}^{*M} < p_{G_1}^{**M}$.

There are also two solutions for (7) and (8), which are respectively

$p_{G_1}^{*M} = \frac{-g \pm \sqrt{g^2-4fh}}{2f}$ and $p_{G_1}^{**M} = \frac{-g \pm \sqrt{g^2-4fi}}{2f}$ with $f = 1.5$, $g = -2(p_B^{*M} + t - \underline{\theta}v(1-\gamma))$, $h = p_{G_0}^{*M}p_B^{*M} - 0.5(p_{G_0}^{*M})^2 + tp_B^{*M} - \underline{\theta}v(1-\gamma)(p_{G_0}^{*M}+t)$ and $i = 2p_{G_0}^{*M}p_B^{*M} + tp_B^{*M} - \underline{\theta}v(1-\gamma)(2p_{G_0}^{*M}+t) - 1.5(p_{G_0}^{*M})^2$.

However, only $p_{G_1}^{*M} = \dfrac{-g-\sqrt{g^2-4fh}}{2f}$ and $p_{G_1}^{**M} = \dfrac{-g-\sqrt{g^2-4fi}}{2f}$ satisfy the second order conditions. Furthermore, we have $p_{G_1}^{*M} < p_{G_1}^{**M}$ since $p_B^{*M} - p_{G_0}^{*M} - \underline{\theta}v(1-\gamma) \geq 0$.

A.7. Total transportation costs when entry of generics is sequential

To show that total transportation costs (TTC) of generics consumption reach a minimum for $\widetilde{x}_G = 0.5$, we only consider the horizontal dimension of the problem, without any loss of generality. They are equal to

$TTC = \int_0^{\widetilde{x}_G}(tx)dx + \int_{\widetilde{x}_G}^1(t(1-x))dx = 0.5t\widetilde{x}_G^2 + t - 0.5t - t\widetilde{x}_G + 0.5t\widetilde{x}_G^2 = 0.5t - t\widetilde{x}_G + t\widetilde{x}_G^2$.

Furthermore, $\dfrac{\partial TTC}{\partial \widetilde{x}_G} = -t + 2t\widetilde{x}_G$ so $\dfrac{\partial TTC}{\partial \widetilde{x}_G} = 0$ for $\widetilde{x}_G = 0.5$ and $\dfrac{\partial TTC}{\partial \widetilde{x}_G} < 0$ for $\widetilde{x}_G \in [0, 0.5]$.

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