Reference pricing in the presence of pseudo-generics*

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Abstract

This paper looks at producers of branded and generic pharmaceuticals' pricing decisions under two possible reimbursement schemes - reference pricing and fixed percentage reimbursement - and under two settings - one where the branded producer only sells the (off-patent) branded pharmaceutical and another where, in addition, it may also sell its own generic version, a so called pseudo-generic. We find different pricing responses from firms under the two reimbursement schemes and across the two settings analysed (with or without a pseudo-generic), and show that pseudo-generics may have an anticompetitive effect. Our results have important policy implications such as showing that the presence of pseudo-generics reinforces reference pricing's advantages over alternative reimbursement schemes.

JEL Classification: I18, L13

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1 Introduction

Producers of branded pharmaceuticals sometimes sell, or allow others to sell, generic versions of their products - often referred to as pseudo-generics or authorised generics. These play an important role in pharmaceutical markets and particularly in the generic segment. In Canada, Hollis (2002, 2005) reports (within the sample he has used) that pseudo-generics represent 47% of total generic sales during the first four years of generic competition; in 1999, in markets in which generics entered in the previous 5 years, the market share of pseudo-generics in the generic segment was 35% (Hollis, 2003). Also with respect to Canada, Grootendorst (2007) reports pseudo-generic presence in 39% of the generic markets analysed. Löfgren (2009) estimates that some 20% of generic sales are associated with pseudo-generics in Australia. More recently, the European Commission (2009, p. 553) found that, between 2000 and 2007, 45% of branded pharmaceutical producers "... launched or seriously considered launching their own or an in-licensed generic".

There are claims that pseudo-generics are used for anticompetitive reasons: theoretical models have shown that they may soften competition with independent generic producers (Ferrándiz, 1999; Rodrigues et al., 2014).[1] However, the extant literature generally ignores important institutional features of pharmaceutical markets. Particularly, it generally ignores that, in large parts of the world, patients pay only a fraction of the total price of the pharmaceuticals they buy and this, as acknowledged by Hollis (2005), may significantly affect competition between producers. For instance, health-related markets (including the pharmaceutical market) in European countries are typically characterized by the existence of reimbursement schemes, whereby a third-party payer (often the government) partly finances its cost, with the objective of facilitating patients' access to health services.[2]

This paper explores the relation between reimbursement schemes and the competitive impact of pseudo-generics. We focus on two widely adopted reimbursement schemes - fixed percentage reimbursement (FPR) and reference pricing (RP) - in a theoretical model (based on Rodrigues et al., 2014) which allows for vertical (between branded and generic pharmaceuticals) and horizontal (between generics) product differentiation and compare market settings with and without the presence of pseudo-generics. Under a FPR scheme, the consumer supports a fixed percentage (copayment rate) of the pharmaceutical's headline price (which we refer to as the effective price),

[1] Another strand of the (theoretical) literature focuses on entry-related issues, insofar as the decision to produce pseudo-generics may deter or delay generic entry (Hollis, 2003; Kong and Seldon, 2004; Reiffen and Ward, 2007; Granier and Trinquard, 2012). Empirically, the evidence (broadly) appears to confirm these anticompetitive concerns (Hollis, 2002, 2003; Hollis and Liang, 2007; Aitken et al., 2013; Grootendorst, 2007; Berndt et al., 2007a, 2007b; Appelt, 2010); Kamien and Zang (1999) are among the few examples of authors finding pseudo-generics to have procompetitive effects. We are particularly interested in understanding competition between producers after generic entry; therefore, our paper explicitly leaves aside the entry decision (pseudo-generic and/or generic) into the market.

[2] Previous literature on reimbursement schemes for health care providers includes, among others, Ellis and McGuire (1986), Rickman and McGuire (1999) and more recently Bardey et al. (2012). In the pharmaceutical market, the classic reference is Mossialos et al. (2004).

whilst the government (or other third-party payers) is responsible for financing the remainder. By contrast, under a RP scheme, within each cluster of pharmaceuticals, a 'reference' pharmaceutical is identified - typically a generic - and its price is defined as the 'reference price'.[3,4] The government's contribution towards the purchase of pharmaceuticals is calculated on the basis of that reference price, i.e., if a consumer decides to purchase a more expensive pharmaceutical, the difference between that pharmaceutical's (headline) price and the reference price is fully borne by him.[5]

Similarly to Rodrigues et al. (2014), we find that the presence of a pseudo-generic raises prices and can be seen as a tool to soften competition between producers. When a pseudo-generic is not present, the branded pharmaceutical competes directly with the generic: any price reductions of the former attract demand previously purchasing the generic. By contrast, when present, it is the pseudo-generic that competes with the generic: a reduction in the pseudo-generic's price would attract demand previously purchasing the generic, but also (somewhat) cannibalize sales of the branded drug; therefore, there are fewer incentives for price competition. We also find that pseudo-generics reinforce the advantages of reference pricing *vis-a-vis* FPR schemes, both in terms of consumer surplus (lower effective prices) and government expenditure. Either reimbursement scheme consists of a public subsidy to consumers, who thus pay effective prices which are lower than the headline price. However, we find that, under a FPR scheme, it is pharmaceutical firms who effectively benefit from this public subsidy: firms adjust their headline prices in such a manner that consumers do not really benefit from lower effective prices. By contrast, under reference pricing, consumers do benefit from this public subsidy and this allows them to increase their consumer surplus.[6] Finally, from a welfare perspective, our results corroborate those of Brekke et al. (2007): using a welfare measure which excludes firms' profits from the analysis - a measure which is more suited in the case of countries where the pharmaceutical industry is absent -, RP is preferable to FPR, particularly when a pseudo-generic is present in the market.

From a policy viewpoint, these results confirm the adequacy of coupling the decision to reimburse a pharmaceutical with some sort of price regulation under FPR schemes, a common practice in EU countries (Garattini et al., 2007), as this may be a useful tool to bring down prices when RP has not or cannot be implemented. Moreover, when a pseudo-generic is present, RP emerges as a particularly advantageous reimbursement scheme. As such, the implementation of RP should be given more serious consideration whenever branded producers decide to market pseudo-generics. Also, the results suggest that efforts to assure patients that branded and generic drugs are equally

[3] Several criteria could be used to cluster pharmaceuticals: chemical, pharmacological or therapeutic (Miraldo, 2009).

[4] For a detailed review of reference pricing, see López-Casasnovas and Puig-Junoy (2000).

[5] Note that reference pricing is only different from FPR when generic competition becomes possible, otherwise only one branded pharmaceutical exists and it would automatically be the reference pharmaceutical.

[6] We thank a referee for suggesting this interpretation.

effective (i.e., efforts to reduce the perceived vertical differentiation between the two) have differentiated impacts across reimbursement schemes (both with or without the presence of pseudo-generics): under FPR, such efforts are worthwhile as they contribute towards an alignment in branded and generic prices which results in lower government expenditure; by contrast, under RP, this price alignment does not have a positive impact on government expenditure.[7]

This paper has the following structure: section 2 describes the model; sections 3 and 4 analyse the two reimbursement schemes in a setting where a pseudo-generic is absent or present respectively; section 5 presents the paper's main results, section 6 looks at welfare and section 7 concludes. An Appendix contains a detailed derivation of our results.

2 Model

The model is similar to that of Rodrigues et al. (2014). Two firms, a branded producer (BP) and a generic producer (GP), compete by simultaneously setting prices. The branded producer sells a branded pharmaceutical product (denoted by b) and may also sell a generic, non-branded, variety of that product - a pseudo-generic denoted by pg. The generic producer only sells the generic variety (denoted by g). B, PG, and G refer (respectively) to the quantities (or demand functions) of these varieties.

Branded and generic varieties are assumed to be vertically differentiated in the eyes of consumers, who thus have a higher reservation price for the branded variety (β) than for the generic (γ), i.e., $\beta > \gamma > 0$. As Brekke et al. (2007) note, consumers may have different quality perceptions of the branded and generic varieties, possibly because of differences in advertising intensities or simply because of the longer and more established presence of the branded pharmaceutical in the market. In other words, if all prices were similar, all consumers would unequivocally choose the branded pharmaceutical.

Horizontal differentiation between generic varieties is also assumed.[8] As Rodrigues et al. (2014) note, this is plausible if generics differ in observable dimensions (e.g., flavor, shape, color, package, label or brand/identity of producer) other than the active substance (which, by definition, is the same). On consumer behavior towards generics, Hollis (2002) notes that a switching cost exists for patients (discomfort with different medication) and for pharmacists (who must spend time assuring

[7] Without a pseudo-generic, such efforts lead to a reduction in the branded price and an increase in the generic price; the latter is the reference price on which reimbursement is based, which thus leads to an increase in government expenditure. With a pseudo-generic, such efforts lead to branded price reductions and the generic price remains unchanged, which thus implies no changes in government expenditure.

[8] Typically, horizontal differentiation is justified because consumers have heterogeneous preferences (different tastes) or, in the standard Hotelling (1929) model, because they are physically located at different distances from the location of the firm they wish to purchase from. In the pharmaceutical market, Brekke et al. (2007) suggest that consumers support 'mismatch costs' between their ideal treatment - given by their location along the Hotelling interval - and the pharmaceutical variety they actually consume, because, for instance, the latter may have undesirable side-effects or contraindications which reduce a consumer's utility.

patients of the insignificant differences between generics). In addition, pharmacies may stock only a subset of all generic drugs available in the market and this influences patients' purchases. Therefore, we assume that uniformly distributed consumers must decide on their preferred product along an Hotelling interval $[0,1]$, where the generic producer is located at 0 and where the disutility of consuming a generic is assumed to be linear in the distance to the preferred variety, with slope $t > 0$. By assuming that horizontal differentiation only occurs between generic varieties, we are in fact assuming that the branded pharmaceutical is seen as the ideal treatment by all consumers, because its consumption yields no mismatch costs.[9]

Consumers will purchase a unit (of a pharmaceutical variety) if their surplus (CS_i) is positive and none otherwise. If the surplus is positive for more than one product variety, the consumer will choose the variety which yields the highest surplus:

$$CS_i = \begin{cases} \beta - \hat{p}_b & \text{if he buys } b \\ \gamma - \hat{p}_k - t \times |f_j - c_i|, k = g, pg & \text{if he buys } g \text{ or } pg \\ 0 & \text{otherwise} \end{cases} \quad (1)$$

where $(\hat{p}_b, \hat{p}_{pg}, \hat{p}_g)$ is the price vector relevant to consumers (which we refer to as *effective* prices), c_i denotes consumer i's type, i.e., c_i measures the distance between consumer i's location and the left endpoint of the unit interval, and f_j denotes firm j's location, $j \in \{BP, GP\}$.

We analyse two possible reimbursement schemes: a fixed percentage reimbursement (FPR) scheme (henceforth represented by the superscript 'F'), where consumers must pay the same percentage (copayment rate), $\theta \in [0,1]$, of their desired product varieties' headline price (set by the respective producer); and a reference pricing (RP) scheme (henceforth represented by the superscript 'R'), where the consumer's copayment is based on the price of the "reference" pharmaceutical, typically the generic. Under RP, a consumer must pay a percentage (copayment rate) of the reference pharmaceutical's headline price if he purchases it or, if he purchases another (more expensive) pharmaceutical, he must in addition pay the full (headline) price difference between the two. In order to highlight the differences between these two reimbursement schemes, under the FPR scheme the effective prices are given by:

$$\hat{p}_k^F = p_k^F - (1-\theta) p_k^F = \theta p_k^F, \; k = b, pg, g \quad (2)$$

where we define p_k^F $(k = b, pg, g)$ to be the headline prices set by firms when the FPR scheme is in place. By contrast, under a reference pricing scheme, the effective prices are given by:[10]

[9] This is plausible, because the branded pharmaceutical, during the patent protection period, will have already established a reputation for its treatment effectiveness.

[10] We assume that the reference pharmaceutical is the generic and that the copayment rate, θ, is similar across schemes. In equilibrium, we find that indeed the generic has the lowest price and would thus be the ideal candidate for the "reference" pharmaceutical.

$$\begin{aligned} \hat{p}_k^R &= p_k^R - (1-\theta)\, p_g^R,\ k = b, pg \\ \hat{p}_g^R &= p_g^R - (1-\theta)\, p_g^R = \theta p_g^R \end{aligned} \tag{3}$$

where p_k^R $(k = b, pg, g)$ are the headline prices set by firms when the RP scheme is in place. Note that we assume the reference price to be equal to the generic price. However, all our results hold under a more general formulation in which the reference price is a weighted average between the pseudo-generic and generic pharmaceuticals.[11,12]

We will also refer to the no reimbursement (NR) scenario - the setting analysed by Rodrigues et al. (2014) -, where consumers must support the headline prices in full; this is equivalent to setting $\theta = 1$ in equation (2) or (3). Finally, production costs are assumed to be zero and the total number of consumers is set equal to 1, i.e., product quantities can be interpreted as market shares.

3 The market with no pseudo-generics

We start by looking at a setting where the branded producer does not sell a pseudo-generic, i.e., it only sells the branded variety. In this case, the consumers' effective prices given by equations (2) and (3) do not include the pseudo-generic variety. Appendix A.1 provides more detail in the derivation of these results.

3.1 Fixed Percentage Reimbursement

Figure 1 illustrates consumers' decisions under FPR, assuming prices are such that both varieties have positive demand. This requires that the generic is sufficiently cheaper than the branded variety so as to compensate for its lower reservation price but not so cheap that every consumer would prefer it. Further, it also requires that prices are not so high that consumers would prefer not to buy any of the varieties. In Appendix A.1 we show that this is equivalent to imposing restrictions (32) and (33) on parameter values. Intuitively, these imply that the reservation price for the branded drug (β) cannot be either too high or too low: otherwise, everyone would buy it or

[11] For instance, under such a more general formulation, equation (3) would become $\hat{p}_k^R = p_k^R - (1-\theta)\left[\alpha p_{pg}^R + (1-\alpha)\, p_g^R\right],\ k = b, pg, g,\ \alpha \in (0,1)$.

[12] In particular, under such a general formulation in which the reference price is a weighted average of the pseudo-generic and generic prices, the location of the indifferent consumers does not change (see Appendix A.1 and A.2) because the reference price impacts on *all* effective prices in the same way. That is, given headline prices, a change in the reference price formulation increases or decreases all effective prices (branded, pseudo-generic and generic) in the same amount. Therefore, equilibrium (headline) prices, quantities and firms' profits are not affected by the reference price formulation (thus, propositions 1, 2 and 3 hold under this more general formulation). The latter only affects consumer surplus and government expenditure. In particular, this more general reference price formulation (compared to our assumption - see equation (3)) would lead to an increase in the reference price, a decrease in all effective prices and, thus, an increase in consumer surplus; but this is exactly offset (because quantities are the same) by an increase in government expenditure. Therefore, welfare results are unchanged: both social welfare and welfare are exactly the same regardless of the reference price formulation (thus, propositions 4 and 5 also hold under this more general formulation).

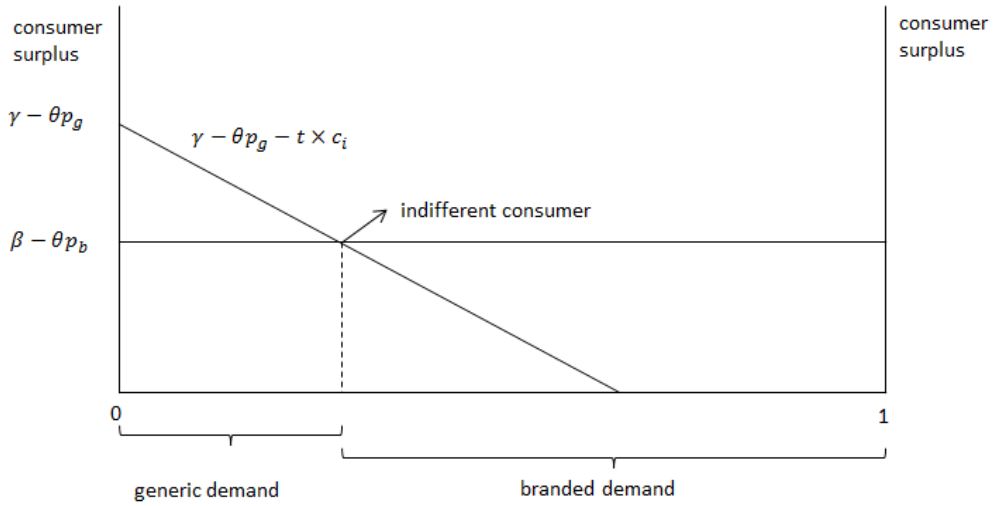

Figure 1: Illustration of consumer decisions under FPR with no pseudo-generics

no one would; the range of acceptable values for β depends on the other parameters of the model (γ, t, θ). Under these restrictions, generic demand is given by all consumers whose surplus when purchasing the generic is larger than (or equal to) when purchasing the branded drug, that is, all consumers located to the left of the 'indifferent consumer'.

In equilibrium, both firms (BP and GP) choose prices to as to maximize profits. If the aforementioned restrictions hold, under a FPR scheme, (Nash) equilibrium headline prices are given by:

$$\begin{aligned} p_b^F &= \frac{2}{3\theta}t + \frac{1}{3\theta}(\beta - \gamma) \\ p_g^F &= \frac{1}{3\theta}t - \frac{1}{3\theta}(\beta - \gamma) \end{aligned} \tag{4}$$

Note that $p_k^F = \frac{1}{\theta}p_k^{NR}$, with $k = b, g$, that is, when no reimbursement (NR) scheme exists ($\theta = 1$) we obtain the results of Rodrigues et al. (2014). Under a fixed percentage reimbursement scheme, firms mark-up their headline prices in an inversely proportional manner relative to the copayment rate: the higher is the copayment rate, the lower is that mark-up under a FPR scheme. This implies that the effective price paid by consumers is equal in both cases and therefore equilibrium quantities are also the same, i.e., $\hat{p}_k^F = \hat{p}_k^{NR}$ $(k = b, g)$, $B^F = B^{NR}$ and $G^F = G^{NR}$. Profit levels become $\Pi_j^F = \frac{1}{\theta}\Pi_j^{NR}$, $j = BP, GP$, i.e., firms also increase their profits in an inversely proportional manner relative to the copayment rate. Headline prices, p_b and p_g, are lowest when the consumer's copayment rate is maximal, i.e., when $\theta = 1$. This result is similar to that of Brekke et al. (2007). Consequently, consumer surplus (CS) does not depend on θ : as outlined above, the existence of a copayment rate has no impact on the effective prices consumers must face, $\hat{p}_b^F$ and $\hat{p}_g^F$. Hence, the existence of a FPR scheme (through parameter θ) does not affect consumer surplus ($CS^F = CS^{NR}$).

Note, in addition, that branded headline (and effective) prices are positively affected by the branded drug's perceived 'superiority' in quality $(\beta - \gamma)$. A decrease in $(\beta - \gamma)$ - effectively a reduction in consumers' perception of the branded drug's superior quality - 'shifts' the location of the indifferent consumer (between the branded and generic variety) towards the right end point of the interval, thus (assuming all else equal) decreasing the branded drug's demand. This forces the branded producer to decrease its prices but the generic producer does the opposite to take advantage of this demand expansion (both of which occur in equilibrium). From a policy viewpoint, this suggests that information efforts which help 'convince' patients under treatment that generics are as effective as the branded drug (thus reducing $(\beta - \gamma)$) contribute towards the reduction (increase) of the branded (generic) drug's headline and effective prices, thus contributing towards the 'alignment' of branded and generic drug prices. This is beneficial in terms of (total and government) pharmaceutical expenditure (see equations (30) and (31)), both of which decrease as $(\beta - \gamma)$ also decreases.

By contrast, an increase in the disutility of consuming a generic variety (t) - equivalent to an increase in horizontal differentiation - shifts the location of the indifferent consumer to the left end point of the interval. This expands the demand for the branded drug and allows the branded producer to raise its price; strategic complementarity drives the generic producer to do the same. Interestingly, the increase in the branded price is very significant and (in equilibrium) reduces branded demand; by contrast, although the generic producer also raises its prices, it does so to a lesser extent and (in equilibrium) generic demand increases (see equation (27)). Therefore, the impact of a change in t on individual profits, total and government pharmaceutical expenditure is a priori not clear, because the magnitude of these two offsetting effects - price and quantity - depends on other variables (namely on $(\beta - \gamma)$ and t itself).

3.2 Reference Pricing

When a reference pricing scheme is in place, the consumer indifferent between purchasing a generic or a branded pharmaceutical has the same location as the marginal consumer when no reimbursement scheme exists (found by setting $\theta = 1$ in equation (23)).[13] In other words, if (headline) prices were similar under FPR and RP, generic demand would be higher under RP because the branded drug's effective price is higher and, thus, the generic is comparatively cheaper.[14] In the face of such lower demand, the branded producer now has incentives to reduce its prices and strategic complementarity drives the generic producer to do the same.

In equilibrium, demand and profit functions, as well as quantities and prices are equal in these

[13] Graphically, this is equivalent to saying that the indifferent consumer under RP is located to the right of that represented in Figure 1.

[14] For a given headline price vector, note that the effective price of the generic under FPR and RP is the same, but the effective price of the branded drug is higher under RP as long as $p_b > p_g$. See equations (2) and (3).

two scenarios (NR and RP). In particular, $p_k^R = p_k^{NR} = p_k^F\big|_{\theta=1}$, with $k = b, g$.[15] Therefore, reference pricing leads to headline prices equivalent to the lowest possible prices obtainable under FPR (when $\theta = 1$, or, equivalently, when no reimbursement scheme exists). Notably, this result does not depend on θ : regardless of the copayment rate, as long as the consumer's copayment is calculated on the basis of the reference pharmaceutical - in this case the generic -, both firms will have incentives to lower their prices compared to FPR and reference pricing is more successful in bringing about price competition than a FPR scheme. Interestingly, the restrictions which need to be satisfied for generic competition to occur (see Appendix A.1) are less restrictive than under FPR. Indeed, because RP leads to lower effective prices, consumer surplus will be positive for a wider range of parameter values.

As in the case of FPR, branded (generic) headline and effective prices increase (decrease) with the branded drug's perceived 'superiority' in quality $(\beta - \gamma)$. However, in contrast with FPR, a reduction in $(\beta - \gamma)$ associated with a possible policy effort to assure patients that branded and generic drugs are of equal quality leads to a decrease in total pharmaceutical expenditure (see equation (36)) but an increase in government expenditure (see equation (37)). This is understandable because although it contributes towards an alignment between branded and generic prices, it does so through reductions in the branded price and increases in the generic price, and the latter is the reference price on which reimbursement is based.

Table 1 (below) presents a summary of these comparative statics under FPR and RP when the branded producer does not sell the pseudo-generic.

4 The market with a pseudo-generic

Now suppose that the branded producer also sells a pseudo-generic in addition to the branded variety and let $f_{BP} \in (0, 1)$ represent the pseudo-generic's location in the product space.[16] Appendix A.2 provides more detail in the derivation of these results.

[15] As in the previous section, for both varieties to be sold in equilibrium, restrictions (32) and (33) must be imposed in the parameters. See Appendix A.1 for more details.

[16] We assume that this location is fixed, i.e., it is not a decision variable for the branded producer. Location, in our model is a metaphor for the degree of differentiation perceived by consumers. The pseudo-generic and the generic differ in observable characteristics such as the physical shape of the pharmaceutical, its colour, the package size and shape or the producer identity (often branded producers license the production of pseudo-generics to other firms, rather than producing it themselves). Producers can choose these variables, of course (except, maybe, their identity). However, the resulting differentiation effect in consumers' eyes is difficult, if at all possible, to manipulate strategically with any degree of precision. This is particularly so for the branded producer, who in this type of market is typically a first-mover (pseudo-generics enter the market early, generally before other generics do). Therefore, he has no ability to control the extent to which generics will physically resemble his own product.

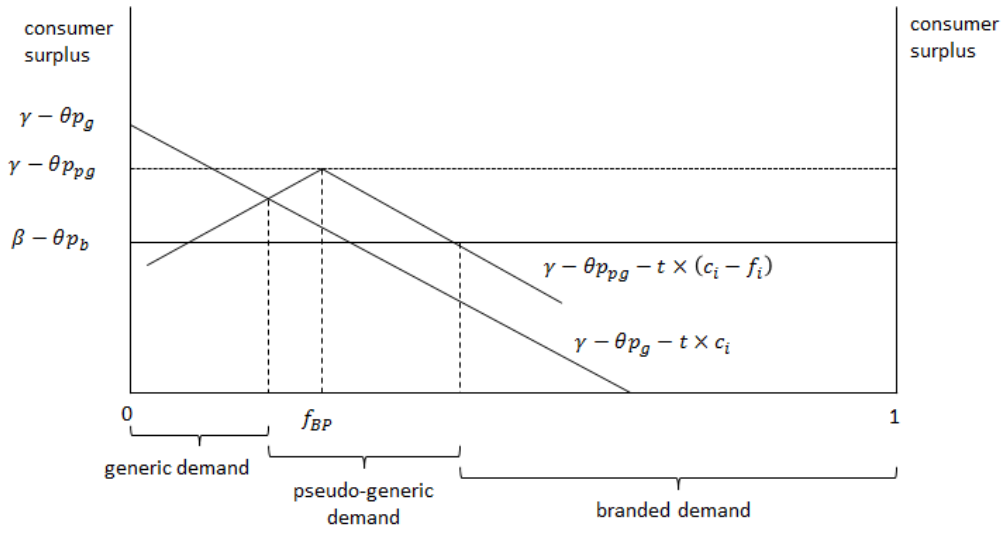

Figure 2: Illustration of consumer decisions under FPR with a pseudo-generic

4.1 Fixed Percentage Reimbursement

Figure 2 illustrates consumers' decisions under FPR in the presence of a pseudo-generic. As in the no-pseudo-generic scenario, it assumes that parameter values are such that every product variety is sold in equilibrium. Appendix A.2 shows that restrictions (50), (51) and (52) must be imposed for that to be the case. Generic demand is then given by all consumers whose surplus when purchasing the generic is larger than (or equal to) when purchasing the pseudo-generic, which is assumed to be located sufficiently close to the generic producer's location for some consumers to be indifferent between the two, while others are indifferent between the pseudo-generic and the branded drug. In a sense, then, when it is present, the pseudo-generic separates the true generic and the branded drug, avoiding that they compete directly against each other. Although our model does not fully endogeneize the choice of the location of the pseudo-generic, it is worthwhile to note that this is to be expected as an equilibrium property of such an enlarged model: the branded drug producer would not be interested in selling a pseudo-generic if this was going to compete directly against its own premium product but not against its generic competitor; this would only cannibalize its own premium market with no strategic advantage.[17]

When the aforementioned restrictions hold, under FPR and with a pseudo-generic in the market, (Nash) equilibrium headline prices are given by (the underscore is used to easily identify this scenario where a pseudo-generic is assumed to be present in the market):

[17] This is discussed at more length in Rodrigues et al. (2014).

$$\begin{aligned}
\underline{p}_b^F &= \frac{11}{6\theta}t - \frac{5}{6\theta}tf_{BP} + \frac{1}{2\theta}(\beta - \gamma) \\
\underline{p}_{pg}^F &= \frac{4}{3\theta}t - \frac{1}{3\theta}tf_{BP} \\
\underline{p}_g^F &= \frac{2}{3\theta}t + \frac{1}{3\theta}tf_{BP} \qquad (5)
\end{aligned}$$

As mentioned earlier, when no reimbursement (NR) scheme exists, $\theta = 1$. Similarly to the results of Section 3.1, $\underline{p}_k^F = \frac{1}{\theta}\underline{p}_k^{NR}$, with $k = b, pg, g$: headline prices are marked-up in an inversely proportional manner relative to the copayment rate, which implies that the effective price paid by consumers and the quantities they purchase are equal in both cases. Headline prices, p_b, p_{pg} and p_g, are lowest when the consumer's copayment rate is maximal, i.e., when $\theta = 1$. Profit levels are $\underline{\Pi}_j^F = \frac{1}{\theta}\underline{\Pi}_j^{NR}$, $j = BP, GP$. Consumer surplus ($\underline{CS}^F$) does not depend on θ because effective prices paid by consumers do not depend on the existence of a copayment rate. Hence, $\underline{CS}^F = \underline{CS}^{NR}$.

Note also that the pseudo-generic's location (f_{BP}) clearly affects headline (and effective) prices: assuming all else equal, if the pseudo-generic is located closer to the left end point of the interval (lower f_{BP}), this increases (decreases) the branded producer's (generic producer's) demand and triggers as a competitive response a price reduction of the generic producer. The branded producer, by contrast, takes advantage of increased demand (for the branded and pseudo-generic drugs) to increase its prices; however, in doing so, it 'sacrifices' its pseudo-generic (which has a lower demand in equilibrium) to the benefit of the (more profitable) branded drug (which in equilibrium has a higher demand).[18]

Interestingly, the branded drug's perceived 'superiority' in quality ($\beta - \gamma$) only affects (in equilibrium) the branded drug's headline price. Assuming all else equal, a decrease in ($\beta - \gamma$) 'shifts' the location of consumer indifferent between the branded and the pseudo-generic variety towards the right end point of the interval, thus decreasing the branded drug's demand, whilst increasing (maintaining) the pseudo-generic (generic) demand. In equilibrium, the branded producer reacts by only lowering the branded drug's headline price in such a way that the branded (pseudo-generic) demand reduction (increase) is profit-maximizing. The branded producer's profits unequivocally decrease, whilst the generic producer's equilibrium prices, quantities and profits are unaffected by this. As in the case without a pseudo-generic, this is clearly beneficial in terms of (total and government) pharmaceutical expenditure (see equations (45) and (46)), both of which decrease as ($\beta - \gamma$) also decreases.

In turn, an increase in the disutility of consuming a generic variety (t) shifts the location of the indifferent consumer between the generic and the pseudo-generic to the left end point of the interval, thus increasing demand for the branded producer's drugs (branded and pseudo-generic) and an increase in its prices. Through strategic complementarity, the generic producer also raises

[18] Equilibrium demand can be seen in equation (42).

its prices. In equilibrium, the branded producer sees the branded drug's quantity decrease, but the pseudo-generic quantity increases, that is, the branded drug's price increase is, in relative terms, more significant (than the pseudo-generic price increase). Also, the generic producer's price increase, in equilibrium, is such that the generic quantity sold remains unchanged. Therefore, an increase in t clearly benefits the generic producer (through higher profits - see equation (43)) but has an ambiguous effect on the branded producer's profit. Therefore, the impact of a change in t on total and government pharmaceutical expenditure is a priori not clear, because it depends on the magnitude of the (offsetting) price and quantity effects, which depend on other variables ($(\beta - \gamma)$, f_{BP} and t).

4.2 Reference Pricing

Under RP, it is straightforward to show that the location of the consumer who is indifferent between the branded and pseudo-generic products and between the pseudo-generic and the generic products is equivalent to the NR scenario. Hence, equilibrium quantities, prices and profits are equal to those in that scenario (namely $\underline{p}_k^R = \underline{p}_k^{NR}$, with $k = b, pg, g$, and the latter can be found by setting $\theta = 1$ in equation (41)).[19] Therefore, as in the case where a pseudo-generic is not present, reference pricing leads to the lowest possible headline prices obtainable under FPR, which occur when $\theta = 1$. Reference pricing thus successfully generates price competition (compared to FPR) and this does not depend on the copayment rate. Interestingly, the restrictions which need to be satisfied for our RP results to hold (see Appendix A.2) are less restrictive than under FPR. Therefore, under RP, pseudo-generics are more likely to appear than under FPR.[20]

Similarly to the case of FPR (with a pseudo-generic), only the branded drug's price is (positively) affected by changes in $(\beta - \gamma)$ (the branded drug's perceived superiority over generic varieties). In particular, as $(\beta - \gamma)$ decreases, although the branded producer (in equilibrium) faces a decreased (increased) demand for the branded (pseudo-generic) drug, this does not affect the generic producer's equilibrium price and quantity. Therefore, this leads to a decrease in total pharmaceutical expenditure (see equation (54)) but government expenditure (see equation (55)) remains unchanged, because the generic price - which is the reference price - does not change.

Although, as in the case of FPR with a pseudo-generic, an increase in t has an ambiguous effect on total pharmaceutical expenditure, it unequivocally raises government expenditure: effectively, an increase in t raises the generic's price and, consequently, also raises the reference price.

We summarise all the (headline and effective) price comparative statics (with and without the pseudo-generic) under FPR and RP in Table 1.

[19] Again, three conditions must hold for the three varieties of the product to be sold in equilibrium and for these to be equilibrium prices: equations (50), (51) and (52). See Appendix A.2 for more details.

[20] We thank an anonymous referee for pointing this out.

			Impact of a change in → / on ↓	θ	$(\beta-\gamma)$	t	f_{BP}
No pseudo-generic	FPR	Headline prices	p_b^F	–	+	+	n.a.
			p_g^F	–	–	+	n.a.
		Effective prices	$\hat{p}_b^F$	0	+	+	n.a.
			$\hat{p}_g^F$	0	–	+	n.a.
	RP	Headline prices	p_b^R	0	+	+	n.a.
			p_g^R	0	–	+	n.a.
		Effective prices	$\hat{p}_b^R$	+	+	+	n.a.
			$\hat{p}_g^R$	+	–	+	n.a.
With pseudo-generic	FPR	Headline prices	$\underline{p}_b^F$	–	+	+	–
			$\underline{p}_{pg}^F$	–	0	+	–
			$\underline{p}_g^F$	–	0	+	+
		Effective prices	$\underline{\hat{p}}_b^F$	0	+	+	–
			$\underline{\hat{p}}_{pg}^F$	0	0	+	–
			$\underline{\hat{p}}_g^F$	0	0	+	+
	RP	Headline prices	$\underline{p}_b^R$	0	+	+	–
			$\underline{p}_{pg}^R$	0	0	+	–
			$\underline{p}_g^R$	0	0	+	+
		Effective prices	$\underline{\hat{p}}_b^R$	+	+	+	–
			$\underline{\hat{p}}_{pg}^R$	+	0	+	–
			$\underline{\hat{p}}_g^R$	+	0	+	+

Table 1: Comparative statics of headline and effective prices

4.3 Comparison of branded producer profit levels

An interesting question is whether introducing a pseudo-generic is more profitable, for the branded producer, than not introducing it.[21] In order to address it, we can compare branded producer profit levels under each reimbursement scheme. Starting with FPR, when no pseudo-generic is sold, branded producer profit levels are given by equation (28), whilst when the pseudo-generic is sold they are given by equation (43). In order for the sale of the pseudo-generic to yield higher profits, the following must be true:

[21] We thank an anonymous referee for suggesting this line of analysis.

$$\underline{\Pi}^F_{BP} = \frac{1}{36\theta}\left(t\left(41 - f_{BP}\left(34 - 11f_{BP}\right)\right) + 18\left(1 - f_{BP}\right)\left(\beta - \gamma\right) + \frac{9\left(\beta - \gamma\right)^2}{t}\right) >$$
$$> \Pi^F_{BP} = \frac{1}{\theta}\left(\frac{4}{9}t + \frac{4}{9}\left(\beta - \gamma\right) + \frac{\left(\beta - \gamma\right)^2}{9t}\right) \quad (6)$$

This is equivalent to:

$$\frac{1}{36\theta}\left[t\left(25 - 34f_{BP} + 11f^2_{BP}\right) + \left(2 - 18f_{BP}\right)\left(\beta - \gamma\right) + \frac{5\left(\beta - \gamma\right)^2}{t}\right] > 0 \quad (7)$$

The latter term $\left(5\left(\beta - \gamma\right)^2/t\right)$ is always positive. Therefore, a sufficient condition for this inequality to hold is (note that $\left(2 - 18f_{BP}\right) < 0$ whenever condition (51) is satisfied):

$$\begin{aligned} & t\left(25 - 34f_{BP} + 11f^2_{BP}\right) + \left(2 - 18f_{BP}\right)\left(\beta - \gamma\right) > 0 \\ \Leftrightarrow \quad & \left(2 - 18f_{BP}\right)\beta > \left(2 - 18f_{BP}\right)\gamma - t\left(25 - 34f_{BP} + 11f^2_{BP}\right) \\ \Leftrightarrow \quad & \beta < \gamma - \frac{t\left(25 - 34f_{BP} + 11f^2_{BP}\right)}{\left(2 - 18f_{BP}\right)} \end{aligned} \quad (8)$$

This is less restrictive than condition (50); therefore, it is always satisfied when the latter holds. In conclusion, whenever the parameter values are such that the pseudo-generic would be sold in equilibrium (conditions (50), (51) and (52)), selling the pseudo-generic is more profitable (for the branded producer) than not doing so. Under RP, profit levels are equal to FPR profit levels when $\theta = 1$. Therefore, the above result also holds for RP.

However, this does not mean that the branded producer will *always* prefer to sell the pseudo-generic, a result which is similar to Rodrigues et al. (2014). The parameter restrictions which need to hold for our FPR and RP results, with and without the pseudo-generic (see Appendix A.1 and A.2), suggest that whenever the pseudo-generic is regarded as very similar to either the generic or the branded pharmaceutical (thus not satisfying condition (51)) or when the degree of vertical differentiation between the branded and the generic pharmaceuticals is too high (thus not satisfying condition ((50)), either (i) the pseudo-generic is not sold in equilibrium (both under FPR or RP) but generic competition is possible, or (ii) generic competition is not profitable and only the branded pharmaceutical is sold (see Rodrigues et al., 2014, for a more detailed analysis). This may help explain why branded producers do not choose to produce pseudo-generics in all markets open to generic competition.

5 Market impact of the pseudo-generic

Rodrigues et al. (2014) show, in their Proposition 1, that the presence of a pseudo-generic raises the prices of all pharmaceuticals under a setup where no reimbursement scheme exists. We extend

this result by claiming that:

Proposition 1 *For parameter values satisfying equations (50), (51) and (52), the presence of a pseudo-generic raises the headline price of the branded and generic varieties under both reimbursement schemes (FPR and RP), i.e.,* $\underline{p}_k^F > p_k^F$ *and* $\underline{p}_k^R > p_k^R$ $(k = b, g)$.

Proof. Under a FPR scheme with $\theta > 0$, $\underline{p}_b^F > p_b^F$ is equivalent to requiring that $\beta > \gamma - 7t + 5tf_{BP}$; in order for $\underline{p}_g^F > p_g^F$, we must have $\beta > \gamma - t + tf_{BP}$. Both hold for any $\beta > \gamma$, $t > 0$ and $f_{BP} \in (0, 1)$.

Under a RP scheme, headline prices are equivalent to a no reimbursement scenario. Thus, using equation (41) and setting $\theta = 1$, it is easily shown that $\underline{p}_b^{NR} = \underline{p}_b^R > p_b^{NR} = p_b^R$ and $\underline{p}_g^{NR} = \underline{p}_g^R > p_g^{NR} = p_g^R$ for any $\beta > \gamma$, $t > 0$ and $f_{BP} \in (0, 1)$. ■

Similarly to Rodrigues et al. (2014), in the absence of the pseudo-generic, the branded drug competes directly with the generic producer's variety. By contrast, when present in the market, it is the pseudo-generic that competes directly with the generic producer's variety, thus softening competition between the branded producer and the generic producer. In particular, a price reduction of the branded drug in the absence of a pseudo-generic would attract demand previously purchasing the generic; in the presence of a pseudo-generic, a branded drug's price reduction would only attract demand previously purchasing the pseudo-generic, leaving unchanged the demand for the true generic. In that sense, competition between the branded producer and the generic producer materializes through reductions in the pseudo-generic price, which may divert demand from the generic producer's variety, but also cannibalize the branded drug's sales. Therefore, there are fewer incentives to compete in prices in the presence of a pseudo-generic, and this is true regardless of the reimbursement scheme in place (FPR or RP). Viewed from a different perspective, both FPR and RP affect the headline *price level* of all drugs in the market (with or without a pseudo-generic present), but do not affect the *relative prices* of drugs. Therefore, the competitive forces at work are similar to those which occur under a no reimbursement scheme (NR), as in the case of Rodrigues et al. (2014).

From a consumer's perspective, although the headline prices are not fully borne because of the reimbursement scheme, we can still state that:

Proposition 2 *Under both reimbursement schemes (FPR and RP), and assuming equations (50), (51) and (52) hold, consumer surplus is lower when a pseudo-generic is present in the market.*

Proof. Under a FPR scheme, consumer surplus with a pseudo-generic is given by equation (29), whilst equation (44) contains the expression for consumer surplus with no pseudo-generic. In order for $\underline{CS}^F - CS^F < 0$, the following must be verified:

$$\underline{CS}^F - CS^F = \frac{(\beta - \gamma)\left[5(\beta - \gamma) - 22t - 18tf_{BP}\right] - \left(71 - 86f_{BP} + 61f_{BP}^2\right)t^2}{72t} < 0 \qquad (9)$$

The denominator is always positive ($t > 0$ by assumption); hence, a sufficient condition for the expression to be negative is for both terms in the numerator to be negative. Starting with the second term, $\left[-\left(71 - 86f_{BP} + 61f_{BP}^2\right)t^2\right]$, it is always negative for any $t > 0$ and $f_{BP} \in (0,1)$; as for the first term, $(\beta - \gamma) > 0$ (by assumption) and in order for $5(\beta - \gamma) - 22t - 18tf_{BP} < 0$ the following must hold:

$$\beta < \gamma + \frac{22}{5}t + \frac{18}{5}tf_{BP} \tag{10}$$

This is less restrictive than equation (50) and hence always satisfied when this restriction is active.

Under a RP scheme, consumer surplus without and with a pseudo-generic is given by equations (35) and (53) respectively. Thus, the difference between the two is given by:

$$\underline{CS}^R - CS^R = \frac{(\beta - \gamma)\left[5(\beta - \gamma) + (2 - 24\theta)t - 18tf_{BP}\right] - \left(47 + 24\theta - 110f_{BP} + 24\theta f_{BP} + 61f_{BP}^2\right)t^2}{72t} \tag{11}$$

The denominator is always positive ($t > 0$); the second term in the numerator is always negative for any $\theta > 1$ and $2/5 < f_{BP} < 5/8$ (the active restriction given by equation (51)); in order for the first term to be negative, the following must hold:

$$\beta < \gamma - \left(\frac{2}{5} - \frac{24}{5}\theta\right)t + \frac{18}{5}tf_{BP} \tag{12}$$

This is less restrictive than equation (50) provided $f_{BP} > 31/94$, which is satisfied when the restriction embodied in equation (51) is active. ■

In the case of FPR, the interpretation is relatively straightforward: effective consumer prices (see equation (2)) are given by $\hat{p}_k^F = \theta p_k^F$ $(k = b, g)$ and $\underline{\hat{p}}_j^F = \theta \underline{p}_j^F$ $(j = b, pg, g)$ without or with a pseudo-generic in the market (respectively). Therefore, if headline prices are higher with a pseudo-generic in the market (Proposition 1), effective prices will also be higher for a given copayment rate, thus reducing consumer surplus. Similarly, under RP, the generic producer's variety has a higher headline price - i.e., the reference price is higher - and, consequently, its effective price is also higher. When equilibrium prices and demand are taken into account, consumer surplus in the presence of a pseudo-generic is unambiguously lower than in its absence. Therefore, both under FPR as well as RP, consumers' out-of-pocket expenditure is higher in the presence of a pseudo-generic.

Reference pricing, from the consumers viewpoint, is clearly better than the FPR scheme, but it is particularly advantageous when a pseudo-generic is sold in the market:

Proposition 3 *Assuming equations (50), (51) and (52) hold, reference pricing yields a higher consumer surplus than a fixed percentage reimbursement scheme, but the difference between the two is larger when a pseudo-generic is present in the market.*

Proof. Reference pricing leads to a higher consumer surplus than the FPR scheme, as we can see from the following expressions::

$$\begin{aligned} CS^R - CS^F &= \frac{1-\theta}{3}\left[t - (\beta - \gamma)\right] > 0 \\ \underline{CS}^R - \underline{CS}^F &= \frac{t\,(1-\theta)\,(f_{BP}+2)}{3} > 0 \end{aligned} \tag{13}$$

The first expression is clearly positive because equation (32) holds, i.e., $(\beta - \gamma) < t$; the second expression is always positive for any $t > 0$, $\theta < 1$ and $f_{BP} \in (0,1)$.

Comparing the differences in consumer surplus between RP and FPR with and without a pseudo-generic (equation (13)), we obtain the following result:

$$\left(\underline{CS}^R - \underline{CS}^F\right) - \left(CS^R - CS^F\right) = \frac{1-\theta}{3}\left[t + (\beta - \gamma) + tf_{BP}\right] \tag{14}$$

This expression is positive for any $\theta < 1$, $t > 0$, $\beta > \gamma$ and $f_{BP} \in (0,1)$. ■

The rationale is straightforward: headline prices are equal under a RP or a NR scheme, but in the latter the consumer supports the full (headline) price of pharmaceuticals whilst under RP he only supports part of it, and this yields lower effective prices. By contrast, effective prices are equal under FPR and NR and higher than under RP, and this leads to a lower consumer surplus. Moreover, our result suggests that, from a consumer's viewpoint, there is particular merit in introducing reference pricing when a pseudo-generic is present, as this leads to a more significant increase in consumer surplus (relative to a FPR scheme). Therefore, under an alternative interpretation of Proposition 3, if a RP scheme has not or cannot be implemented, our result indicates a more pressing need for pharmaceutical price regulation - a common practice by regulatory authorities in Europe (see Garattini et al., 2007) - when a pseudo-generic is present.

6 Welfare analysis

Inevitably, the relative merits of each reimbursement scheme should not be assessed solely by looking at their effects on consumer surplus. Social welfare (SW) - the sum of consumer and producer surplus minus government expenditure with pharmaceuticals - is a more encompassing welfare measure and we find that:

Proposition 4 *Assuming equations (50), (51) and (52) hold, social welfare in a setting with no pseudo-generic is equal regardless of the reimbursement scheme; the same is true in a setting with a pseudo-generic, i.e.,* $SW^{NR} = SW^F = SW^R$ *and* $\underline{SW}^{NR} = \underline{SW}^F = \underline{SW}^R$ *respectively.*

Proof. Without a pseudo-generic, social welfare in the case of a FPR scheme is given by $SW^F = CS^F + \Pi^F - G^F$. As we can see from equation (29), $CS^F = CS^{NR}$, because consumer surplus does not depend on θ. Additionally, $\Pi^F = \frac{1}{\theta}\Pi^{NR}$ and $G^F = \frac{1-\theta}{\theta}\Pi^{NR}$. Hence:

$$\begin{aligned} SW^F &= CS^F + \Pi^F - G^F \\ &= CS^{NR} + \frac{1}{\theta}\Pi^{NR} - \frac{1-\theta}{\theta}\Pi^{NR} \\ &= CS^{NR} + \Pi^{NR} = SW^{NR} \end{aligned} \tag{15}$$

Under reference pricing, equation (13) tells us that $CS^R = CS^F + \frac{1-\theta}{3}\left[t - (\beta - \gamma)\right] = CS^{NR} + \frac{1-\theta}{3}\left[t - (\beta - \gamma)\right]$. As we have seen in Section 3.2, total profits under reference pricing are equal to a no reimbursement scenario, i.e., $\Pi^R = \Pi^{NR}$. Finally, government expenditure is given by equation (37). Therefore:

$$\begin{aligned} SW^R &= CS^R + \Pi^R - G^R \\ &= CS^{NR} + \frac{1-\theta}{3}\left[t - (\beta - \gamma)\right] + \Pi^{NR} - \frac{(1-\theta)}{3}\left[t - (\beta - \gamma)\right] \\ &= CS^{NR} + \Pi^{NR} = SW^{NR} \end{aligned} \tag{16}$$

When a pseudo-generic is present, $\underline{SW}^F = \underline{CS}^F + \underline{\Pi}^F - \underline{G}^F$. From equation (44), we know that $\underline{CS}^F = \underline{CS}^{NR}$. Equation (45) tells us that $\underline{\Pi}^F = \frac{1}{\theta}\underline{\Pi}^{NR}$ whilst government expenditure, from equation (46), is simply $\underline{G}^F = \frac{1-\theta}{\theta}\underline{\Pi}^{NR}$. Hence:

$$\begin{aligned} \underline{SW}^F &= \underline{CS}^F + \underline{\Pi}^F - \underline{G}^F \\ &= \underline{CS}^{NR} + \frac{1}{\theta}\underline{\Pi}^{NR} - \frac{1-\theta}{\theta}\underline{\Pi}^{NR} \\ &= \underline{CS}^{NR} + \underline{\Pi}^{NR} = \underline{SW}^{NR} \end{aligned} \tag{17}$$

Under reference pricing, equation (13) tells us that $\underline{CS}^R = \underline{CS}^F + \frac{t(1-\theta)(f_{BP}+2)}{3} = \underline{CS}^{NR} + \frac{t(1-\theta)(f_{BP}+2)}{3}$ whilst equation (54) tells us that $\underline{\Pi}^R = \underline{\Pi}^{NR}$. Finally, government expenditure is given by equation (55), and we obtain:

$$\begin{aligned} \underline{SW}^R &= \underline{CS}^R + \underline{\Pi}^R - \underline{G}^R \\ &= \underline{CS}^{NR} + \frac{t\,(1-\theta)\,(f_{BP}+2)}{3} + \underline{\Pi}^{NR} - \frac{t\,(1-\theta)\,(f_{BP}+2)}{3} \\ &= \underline{CS}^{NR} + \underline{\Pi}^{NR} = \underline{SW}^{NR} \end{aligned} \tag{18}$$

■

This result is similar to Brekke et al. (2007) (Proposition 6). With or without a pseudo-generic, it is particularly interesting to note that, under a FPR scheme, pharmaceutical firms (and not consumers) benefit from the public subsidy implicit in the reimbursement scheme: by marking-up headline prices, effective prices are unaffected and, thus, firms are the true beneficiaries of this public

subsidy, which is neutral from a social welfare perspective. This result (again) clearly indicates the need for pharmaceutical price regulation prior to inclusion in a FPR scheme, in accordance with what is done by (most) regulatory authorities in reality (Garattini et al., 2007).

By contrast, under reference pricing, it is consumers who benefit from the public subsidy: firms do not adjust headline prices and this allows them to increase their consumer surplus because they no longer bear the full headline price of pharmaceuticals (and pay a lower effective price). From a social welfare perspective, this transfer is also neutral, because firms' profits are equal to a NR scenario.

Brekke et al. (2007) suggest a different welfare measure which may be more relevant in countries which do not have a significant pharmaceutical industry. In those cases, it is unlikely that profits would enter the welfare function. Thus, welfare (W) can be more narrowly defined from a public payer's perspective, only taking into account consumer surplus net of government expenditure. Following this approach, we can state that:

Proposition 5 *Assuming equations (50), (51) and (52) hold,* $W^{NR} = W^R > W^F$ *and* $\underline{W}^{NR} = \underline{W}^R > \underline{W}^F$, *i.e., a FPR scheme is worse than RP or NR from a public payer's welfare perspective. In addition, reference pricing is particularly advantageous relative to FPR when a pseudo-generic is present in the market, i.e.,* $\left(\underline{W}^R - \underline{W}^F\right) > \left(W^R - W^F\right)$.

Proof. In a setting with no pseudo-generic, $W^F = CS^F - G^F = CS^{NR} - \frac{1-\theta}{\theta}\Pi^{NR}$ whilst $W^R = CS^R - G^R = CS^{NR}$ (see proof of Proposition 4). Hence, $W^{NR} = W^R > W^F$.

When a pseudo-generic is present, $\underline{W}^F = \underline{CS}^F - \underline{G}^F = \underline{CS}^{NR} - \frac{1-\theta}{\theta}\underline{\Pi}^{NR}$, whereas $\underline{W}^R = \underline{CS}^R - \underline{G}^R = \underline{CS}^{NR}$ (see proof of Proposition 4) and hence $\underline{W}^{NR} = \underline{W}^R > \underline{W}^F$.

We thus know that $\left(\underline{W}^R - \underline{W}^F\right) = \frac{1-\theta}{\theta}\underline{\Pi}^R$ and $\left(W^R - W^F\right) = \frac{1-\theta}{\theta}\Pi^R$. Therefore, in order for $\left(\underline{W}^R - \underline{W}^F\right) > \left(W^R - W^F\right)$, it is sufficient to demonstrate that $\underline{\Pi}^R > \Pi^R$, provided $0 < \theta < 1$:

$$\underline{\Pi}^R - \Pi^R = \frac{1}{36t}\left[29t^2 + 10t\left(\beta - \gamma\right) - 26t^2 f_{BP} + 13t^2 f_{BP}^2 - 18t f_{BP}\left(\beta - \gamma\right) + \left(\beta - \gamma\right)^2\right] \tag{19}$$

Note that the last term, $\left(\beta - \gamma\right)^2$, is always positive. Hence, the expression is positive provided $29t^2 + 10t\left(\beta - \gamma\right) - 26t^2 f_{BP} + 13t^2 f_{BP}^2 - 18t f_{BP}\left(\beta - \gamma\right) > 0$. This is equivalent to requiring that:

$$t\left(10 - 18f_{BP}\right)\beta > t\left(10 - 18f_{BP}\right)\gamma + t^2\left(-29 + 26f_{BP} - 13f_{BP}^2\right) \tag{20}$$

When $f_{BP} < 5/9$ (and the left-hand side term is positive), this is equivalent to:

$$\beta > \gamma + \frac{t\left(-29 + 26f_{BP} - 13f_{BP}^2\right)}{10 - 18f_{BP}} \tag{21}$$

in which case the denominator (of the second term) is positive (because $f_{BP} < 5/9$) and the numerator (of the second term) is always negative. Hence any $\beta > \gamma$ satisfies this inequality.

By contrast, when $f_{BP} > 5/9$ (and the left-hand side term is negative) the above inequality becomes:

$$\beta < \gamma + \frac{t\left(-29 + 26f_{BP} - 13f_{BP}^2\right)}{10 - 18f_{BP}} \tag{22}$$

This is less restrictive than equation (50) and hence always satisfied if this restriction is active.

■

Intuitively, reference pricing brings about a more significant increase in welfare from a public payer's perspective (or, equivalently, a more significant reduction in government expenditure), compared to a FPR scheme, when a pseudo-generic is present. This is because under a FPR scheme, as we have seen, prices and profits are 'marked-up' relative to a RP scheme. If, as we show, total profits (or total pharmaceutical expenditure) are higher when a pseudo-generic is present, then this 'mark-up' will necessarily be higher in absolute terms. Hence, the introduction of reference pricing, by eliminating this 'mark-up', will bring about a more significant increase in welfare in that setting.

7 Conclusion

This paper considers two widely adopted reimbursement schemes (fixed percentage reimbursement and reference pricing) in a model encompassing both vertical (between branded and generic pharmaceuticals) and horizontal (between generics) product differentiation in settings with and without the presence of a pseudo-generic in the market, effectively a generic variety produced by the same firm selling the branded drug. A number of interesting results are uncovered, some of which with relevant policy implications. First, under either reimbursement scheme, the results of Rodrigues et al. (2014) hold: the presence of a pseudo-generic raises the prices of all pharmaceuticals and can be used as a tool to soften competition between the branded and generic pharmaceutical producers. In addition, reference pricing is shown to bring about lower prices and thus higher consumer surplus than FPR schemes, but this effect is more significant when a pseudo-generic is present. Second, from a welfare perspective, our results are equivalent to those of Brekke et al. (2007): if firms' profits are excluded from the analysis - a public payer's welfare perspective, relevant in countries where the pharmaceutical industry is absent - reference pricing is also superior to FPR. We further show that this difference is larger when a pseudo-generic is present, which implies that, in this case, adopting reference pricing would be particularly advantageous. Under an alternative interpretation of our results, if a pseudo-generic is present, this suggests a more pressing need for (headline) price regulation within a FPR scheme if RP has not or cannot be adopted. Third, efforts to assure patients that branded and generic drugs are equally effective have differentiated impacts across reimbursement schemes: whilst under FPR such efforts ultimately lead to a reduction in government expenditure, that is not so under RP.

This analysis can be extended to a third possible, and to the best of our knowledge yet under-researched, reimbursement scheme: asymmetric fixed percentage reimbursement, through which the reimbursement rates are different for different types of pharmaceuticals, with generics typically attracting higher reimbursement (lower copayment) rates. This type of scheme has been used, for instance, in Belgium, Portugal and Romania (Tele and Groot, 2009) in order to help increase generic penetration. Whilst this type of scheme introduces more complexity in the analysis, it may also have the merit to uncover more intricate details of firms' pricing incentives.

In addition, when a pseudo-generic is present, we have assumed that transportation costs (or product substitutability) are equal for all generics (including the pseudo-generic). But, generally, the identity of the producer is visible in the product and the pseudo-generic may thus be considered, by consumers, to be 'better' (closer to the branded product) than other generics. Also, in our setting, we have assumed the location of the pseudo-generic in the product space to be fixed, i.e., it is not endogenously determined by the branded producer. Again, a possible extension to the model encompasses a setting where the branded producer, both through information visible on the product and/or marketing campaigns, may try to locate the pseudo-generic closer to the branded drug or to the generic producer's variety. These are likely to be the next steps in our research.

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A Appendix - Detailed pricing calculations

A.1 The market with no pseudo-generics

A.1.1 Fixed percentage reimbursement

Under a FPR scheme, the "marginal consumer", $c_{b.g}^F$, who is indifferent between buying the branded (b) or generic (g) pharmaceuticals is found by solving $\gamma - \theta p_g^F - t \times c_{b.g}^F = \beta - \theta p_b^F$:

$$c_{b.g}^F = \frac{\theta(p_b^F - p_g^F) - (\beta - \gamma)}{t} \tag{23}$$

Let $\mathbf{p}^F = \left(p_b^F, p_g^F\right)$ represent the headline price vector. As the total number of consumers is assumed to be equal to 1, the demand functions are given by:

$$\begin{aligned} B\left(\mathbf{p}^F\right) &= 1 - c_{b.g}^F = 1 - \frac{\theta(p_b^F - p_g^F) - (\beta - \gamma)}{t} \\ G\left(\mathbf{p}^F\right) &= c_{b.g}^F = \frac{\theta(p_b^F - p_g^F) - (\beta - \gamma)}{t} \end{aligned} \tag{24}$$

The profit functions are given by $\Pi_{BP}\left(\mathbf{p}^F\right) = p_b^F \times B\left(\mathbf{p}^F\right)$ and $\Pi_{GP}\left(\mathbf{p}^F\right) = p_g^F \times G\left(\mathbf{p}^F\right)$. Profit maximization with respect to p_b^F and p_g^F respectively yields the best-response functions:

$$\begin{aligned} p_b^F &= \frac{1}{2\theta}t + \frac{1}{2\theta}(\beta - \gamma) + \frac{1}{2}p_g^F \\ p_g^F &= \frac{1}{2}p_b^F - \frac{1}{2\theta}(\beta - \gamma) \end{aligned} \tag{25}$$

In a Nash equilibrium, we obtain the following equilibrium prices:

$$\begin{aligned} p_b^F &= \frac{2}{3\theta}t + \frac{1}{3\theta}(\beta - \gamma) \\ p_g^F &= \frac{1}{3\theta}t - \frac{1}{3\theta}(\beta - \gamma) \end{aligned} \tag{26}$$

Therefore, equilibrium quantities are given by:

$$\begin{aligned} B^F &= \frac{2}{3} + \frac{1}{3t}(\beta - \gamma) \\ G^F &= \frac{1}{3} - \frac{1}{3t}(\beta - \gamma) \end{aligned} \tag{27}$$

and equilibrium profits are:

$$\begin{aligned} \Pi_{BP}^F &= \frac{1}{\theta}\left(\frac{4}{9}t + \frac{4}{9}(\beta - \gamma) + \frac{(\beta - \gamma)^2}{9t}\right) \\ \Pi_{GP}^F &= \frac{1}{\theta}\left(\frac{1}{9}t - \frac{2}{9}(\beta - \gamma) + \frac{(\beta - \gamma)^2}{9t}\right) \end{aligned} \tag{28}$$

Consumer surplus is given by the sum of the surplus of buying the branded and generic pharmaceuticals (in equilibrium, $c_{b.g}^F = \frac{t+\gamma-\beta}{3t}$):

$$\begin{aligned} CS^F &= \int_0^{\frac{t+\gamma-\beta}{3t}} \left(\gamma - \theta p_g^F - t \times c\right) dc + \int_{\frac{t+\gamma-\beta}{3t}}^1 \left(\beta - \theta p_b^F\right) dc \\ &= \frac{(\beta - \gamma)^2 - 11t^2 + 10\beta t + 8\gamma t}{18t} \end{aligned} \tag{29}$$

Total profits, which are equivalent to total pharmaceutical expenditure, are given by:

$$\begin{aligned} \Pi^F &= \Pi_{BP}^F + \Pi_{GP}^F \\ &= \frac{1}{\theta}\left(\frac{5}{9}t + \frac{2}{9}(\beta - \gamma) + \frac{2}{9}\frac{(\beta - \gamma)^2}{t}\right) \end{aligned} \tag{30}$$

Government (or other third-party payers) expenditure with pharmaceuticals is a proportion $(1 - \theta)$ of total pharmaceutical expenditure:

$$\begin{aligned} G^F &= (1 - \theta)\Pi^F \\ &= \frac{1 - \theta}{\theta}\left(\frac{5}{9}t + \frac{2}{9}(\beta - \gamma) + \frac{2}{9}\frac{(\beta - \gamma)^2}{t}\right) \end{aligned} \tag{31}$$

Parameter restrictions Two restrictions must hold for these results to be valid. Firstly, $0 < c_{b.g}^F < 1$, i.e., both the branded and the generic varieties are sold in equilibrium. $c_{b.g}^F < 1$ is always verified, whilst for $c_{b.g}^F > 0$ to be verified, the following condition must hold:

$$\beta < t + \gamma \tag{32}$$

Secondly, $\beta \geq \hat{p}_b^F$, i.e., consumer surplus must be positive (in equilibrium) for both product varieties. In order for this to be verified, the following must hold:

$$\beta \geq t - \frac{\gamma}{2} \tag{33}$$

These restrictions are similar to those of Rodrigues et al. (2014).[22]

A.1.2 Reference pricing

When a reference pricing scheme is in place, the consumer who is indifferent between purchasing a generic or a branded pharmaceutical is found by setting $\gamma - \hat{p}_g^R - t \times c_{b.g}^R = \beta - \hat{p}_b^R$, which yields:

$$c_{b.g}^R = \frac{(p_b^R - p_g^R) - (\beta - \gamma)}{t} \tag{34}$$

Note that $c_{b.g}^R = c_{b.g}^{NR}$, that is, the marginal consumer under reference pricing has the same location as the marginal consumer when no reimbursement scheme exists (found by setting $\theta = 1$ in equation (23)). Therefore, demand, profit functions, equilibrium quantities and prices are equal in these two scenarios: $p_k^R = p_k^{NR}$, with $k = b, g$.

Consumer surplus under a RP scheme is given by:[23]

$$\begin{aligned} CS^R &= \int_0^{\frac{t+\gamma-\beta}{3t}} \left(\gamma - \theta p_g^R - t \times c\right) dc + \int_{\frac{t+\gamma-\beta}{3t}}^1 \left(\beta - p_b^R + (1-\theta)\, p_g^R\right) dc = \\ &= \frac{(\beta-\gamma)^2 - (5+6\theta)\, t^2 + (6\theta+4)\, \beta t + (14-6\theta)\, \gamma t}{18t} \end{aligned} \tag{35}$$

Total profits are given by:

$$\begin{aligned} \Pi^R &= \Pi_{BP}^R + \Pi_{GP}^R \\ &= \frac{5}{9}t + \frac{2}{9}(\beta - \gamma) + \frac{2}{9}\frac{(\beta-\gamma)^2}{t} \end{aligned} \tag{36}$$

Government expenditure is a proportion $(1-\theta)$ of the reference price (because the total number of consumers is equal to one):

[22] For a graphical representation of these restrictions, see Rodrigues et al. (2014).

[23] In equilibrium, the marginal consumer is located at $c_{b.g}^R = \frac{t+\alpha-\beta}{3t}$.

$$\begin{aligned} G^R &= (1-\theta)\left(B^R + G^R\right) p_g^R \\ &= (1-\theta)\, p_g^R \\ &= (1-\theta)\left(\frac{1}{3}t - \frac{1}{3}(\beta-\gamma)\right) \end{aligned} \tag{37}$$

Parameter restrictions As outlined earlier, two conditions must be verified: $0 < c_{b.g}^R < 1$ and $\beta \geq \hat{p}_b^R$. In the first case, the same restriction outlined earlier must also hold: $\beta < t + \gamma$. As for the second case, the following must hold: $\beta \geq t - \gamma\frac{(2-\theta)}{(1+\theta)}$. This latter condition is less restrictive than the previous second restriction given by equation (33)) for any $\theta \in [0,1]$; therefore, it is always satisfied when equation (33) holds.

A.2 The market with a pseudo-generic

A.2.1 Fixed percentage reimbursement

Under FPR and with a pseudo-generic in the market, we assume that it is located sufficiently close to the generic so that consumer $c_{g.pg}^F$ is indifferent between the two. Solving $\gamma - \hat{p}_g^F - tc_{g.pg}^F = \gamma - \hat{p}_{pg}^F - t\left(f_{BP} - c_{g.pg}^F\right)$ we find:

$$c_{g.pg}^F = \frac{f_{BP}}{2} + \frac{\theta\left(p_{pg}^F - p_g^F\right)}{2t} \tag{38}$$

In addition, provided the pseudo-generic does not fully cannibalize the sales of the branded variety, consumer $c_{b.pg}^{r,F}$ will be indifferent between the two (r indicates that this consumer is located to the right of f_{BP}). Solving $\gamma - \hat{p}_{pg}^F - t\left(c_{b.pg}^{r,F} - f_{BP}\right) = \beta - \hat{p}_b^F$ we find:

$$c_{b.pg}^{r,F} = f_{BP} - \frac{\beta-\gamma}{t} + \frac{\theta\left(p_b^F - p_{pg}^F\right)}{t} \tag{39}$$

Let $\underline{\mathbf{p}}^F = \left(p_b^F, p_{pg}^F, p_g^F\right)$ be the headline price vector under a FPR scheme. Demand functions are thus given by:

$$\begin{aligned} B\left(\underline{\mathbf{p}}^F\right) &= 1 - c_{b.pg}^{r,F} = 1 - f_{BP} + \frac{\beta-\gamma}{t} - \frac{\theta\left(p_b^F - p_{pg}^F\right)}{t} \\ PG\left(\underline{\mathbf{p}}^F\right) &= c_{b.pg}^{r,F} - c_{g.pg}^F = \frac{f_{BP}}{2} - \frac{\beta-\gamma}{t} + \frac{\theta\left(p_b^F - p_{pg}^F\right)}{t} - \frac{\theta\left(p_{pg}^F - p_g^F\right)}{2t} \\ G\left(\underline{\mathbf{p}}^F\right) &= c_{g.pg}^F = \frac{f_{BP}}{2} + \frac{\theta\left(p_{pg}^F - p_g^F\right)}{2t} \end{aligned} \tag{40}$$

In this scenario, the branded producer produces both the branded and the pseudo-generic products. Hence, its profit function is given by $\Pi_{BP}\left(\underline{\mathbf{p}}^F\right) = p_b^F \times B\left(\underline{\mathbf{p}}^F\right) + p_{pg}^F \times PG\left(\underline{\mathbf{p}}^F\right)$, whilst the generic producer's profit function is given by $\Pi_{GP}\left(\underline{\mathbf{p}}^F\right) = p_g^F \times G\left(\underline{\mathbf{p}}^F\right)$. Maximizing the former

with respect to p_b^F and p_{pg}^F and the latter with respect to p_g^F, we find the best-response functions which lead to the following Nash equilibrium prices:

$$\begin{aligned}
\underline{p}_b^F &= \frac{11}{6\theta}t - \frac{5}{6\theta}tf_{BP} + \frac{1}{2\theta}(\beta-\gamma) \\
\underline{p}_{pg}^F &= \frac{4}{3\theta}t - \frac{1}{3\theta}tf_{BP} \\
\underline{p}_g^F &= \frac{2}{3\theta}t + \frac{1}{3\theta}tf_{BP}
\end{aligned} \tag{41}$$

At these prices, we obtain the equilibrium quantities:

$$\begin{aligned}
\underline{B}^F &= \frac{1}{2}(1-f_{BP}) + \frac{\beta-\gamma}{2t} \\
\underline{PG}^F &= \frac{1}{6}(1+2f_{BP}) - \frac{\beta-\gamma}{2t} \\
\underline{G}^F &= \frac{1}{3} + \frac{1}{6}f_{BP}
\end{aligned} \tag{42}$$

And the equilibrium profits are:

$$\begin{aligned}
\underline{\Pi}_{BP}^F &= \frac{1}{36\theta}\left(t(41 - f_{BP}(34 - 11f_{BP})) + 18(1-f_{BP})(\beta-\gamma) + \frac{9(\beta-\gamma)^2}{t}\right) \\
\underline{\Pi}_{GP}^F &= \frac{1}{18\theta}t(2+f_{BP})^2
\end{aligned} \tag{43}$$

Consumer surplus is given by:[24]

$$\begin{aligned}
\underline{CS}^F &= \int_0^{\frac{f_{BP}}{6}+\frac{1}{3}} \left(\gamma - \theta\underline{p}_g^F - t\times c\right)dc + \int_{\frac{f_{BP}}{6}+\frac{1}{3}}^{f_{BP}} \left(\gamma - \theta\underline{p}_{pg}^F - t\times(f_{BP}-c)\right)dc + \\
&\quad + \int_{f_{BP}}^{\frac{(1+f_{BP})t-(\beta-\gamma)}{2t}} \left(\gamma - \theta\underline{p}_{pg}^F - t\times(c-f_{BP})\right)dc + \int_{\frac{(1+f_{BP})t-(\beta-\gamma)}{2t}}^{1} \left(\beta - \theta\underline{p}_b^F\right)dc \\
&= \frac{9(\beta-\gamma)^2 + (18\beta+54\gamma)t - 18(\beta-\gamma)tf_{BP} - \left(115 - 86f_{BP} + 61f_{BP}^2\right)t^2}{72t}
\end{aligned} \tag{44}$$

Total profits are given by:

$$\begin{aligned}
\underline{\Pi}^F &= \underline{\Pi}_{BP}^F + \underline{\Pi}_{GP}^F \\
&= \frac{1}{36\theta}\left(t(49 - f_{BP}(26 - 13f_{BP})) + 18(1-f_{BP})(\beta-\gamma) + \frac{9(\beta-\gamma)^2}{t}\right)
\end{aligned} \tag{45}$$

[24] In equilibrium, $c_{g.pg}^F = \frac{f_{BP}}{6} + \frac{1}{3}$ and $c_{b.pg}^{r,F} = \frac{(1+f_{BP})t-(\beta-\gamma)}{2t}$.

Government expenditure is given by:

$$\begin{aligned}\underline{G}^F &= (1-\theta)\,\underline{\Pi}^F \\ &= \frac{(1-\theta)}{36\theta}\left(t\left(49-f_{BP}\left(26-13f_{BP}\right)\right)+18\left(1-f_{BP}\right)\left(\beta-\gamma\right)+\frac{9\left(\beta-\gamma\right)^2}{t}\right) \qquad (46)\end{aligned}$$

Parameter restrictions Five conditions must hold for these results to be valid. Firstly, $0 < c_{b.g}^{r,F} < 1$, which is equivalent to requiring that:

$$\gamma+\left(\frac{1}{3}-\frac{7}{3}f_{BP}\right)t<\beta<\gamma+\frac{7}{3}\left(1-f_{BP}\right)t \qquad (47)$$

Secondly, $c_{b.pg}^{r,F} > c_{b.g}^{F}$ and $\gamma-\underline{\hat{p}}_{pg}^{F}-tf_{BP}<\gamma-\underline{\hat{p}}_{g}^{F}$, i.e., the pseudo-generic is sold in equilibrium. The latter is satisfied provided $\underline{\hat{p}}_{pg}^{F} > \underline{\hat{p}}_{g}^{F}$, which holds in equilibrium. The former is satisfied provided:

$$f_{BP} > 2/5 \qquad (48)$$

If this condition holds, the first inequality in equation (47) is always satisfied for any $\beta > \gamma$.

Thirdly, $f_{BP} < c_{b.pg}^{r,F} < 1$, so that the branded product is sold in equilibrium. $c_{b.pg}^{r,F} < 1$ is always satisfied, but in order for $f_{BP} < c_{b.pg}^{r,F}$ the following must hold:

$$\beta<\gamma+\left(1-f_{BP}\right)t \qquad (49)$$

Fourthly, $c_{b.g}^{F} > c_{b.pg}^{l,F}$ so that the pseudo-generic is sold in equilibrium. This is equivalent to requiring that:

$$\beta<\gamma+\left(\frac{5}{3}-\frac{8}{3}f_{BP}\right)t \qquad (50)$$

This condition is more restrictive than the second inequality in equation (47) and the inequality in equation (49). In addition, this condition sets an upper boundary for f_{BP}, because by assumption $\beta > \gamma$. Hence, for this assumption to hold, $f_{BP} < 5/8$. Together with equation (48), this implies that:

$$2/5 < f_{BP} < 5/8 \qquad (51)$$

Finally, all product varieties must provide positive surplus, which is equivalent to requiring that $\beta \geq \underline{\hat{p}}_{b}^{F}$. This is verified provided the following condition holds:

$$\beta \geq \frac{t\left(11-5f_{BP}\right)}{3}-\gamma \qquad (52)$$

Therefore, equations (50), (51) and (52) must hold for our results to be verified.[25]

A.2.2 Reference pricing

Under RP, the location of the consumer who is indifferent between the branded and pseudo-generic products and between the pseudo-generic and the generic products is equivalent to the NR scenario: solving $\gamma-\hat{p}_{g}^{R}-tc_{g.pg}^{R}=\gamma-\hat{p}_{pg}^{R}-t\left(f_{BP}-c_{g.pg}^{R}\right)$ we obtain the latter ($c_{g.pg}^{R}=\frac{f_{BP}}{2}+\frac{p_{pg}^{R}-p_{g}^{R}}{2t}$), whilst solving $\gamma-\hat{p}_{pg}^{R}-t\left(c_{b.pg}^{r,R}-f_{BP}\right)=\beta-\hat{p}_{b}^{R}$ we find the former ($c_{b.pg}^{r,R}=f_{BP}-\frac{\beta-\gamma}{t}+\frac{p_{b}^{R}-p_{pg}^{R}}{t}$). Hence, equilibrium quantities, prices and profits are equal to those in that scenario (in particular, $\underline{p}_{k}^{R}=\underline{p}_{k}^{NR}$, with $k=b,pg,g$, and the latter can be found by setting $\theta=1$ in equation (41)).

Consumer surplus is given by:[26]

$$\begin{aligned}\underline{CS}^{R} &= \int_{0}^{\frac{f_{BP}}{6}+\frac{1}{3}}\left(\gamma-\theta\underline{p}_{g}^{R}-t\times c\right)dc+\int_{\frac{f_{BP}}{6}+\frac{1}{3}}^{f_{BP}}\left(\gamma-\underline{p}_{pg}^{R}+(1-\theta)\,\underline{p}_{g}^{R}-t\times(f_{BP}-c)\right)dc+\\ &+\int_{f_{BP}}^{\frac{(1+f_{BP})t-(\beta-\gamma)}{2t}}\left(\gamma-\underline{p}_{pg}^{R}+(1-\theta)\,\underline{p}_{g}^{R}-t\times(c-f_{BP})\right)dc+\\ &+\int_{\frac{(1+f_{BP})t-(\beta-\gamma)}{2t}}^{1}\left(\beta-\underline{p}_{b}^{R}+(1-\theta)\,\underline{p}_{g}^{R}\right)dc\\ &= \frac{9\left(\beta-\gamma\right)^{2}+\left(18\beta+54\gamma\right)t-18\left(\beta-\gamma\right)tf_{BP}-\left(67+48\theta-110f_{BP}+24\theta f_{BP}+61f_{BP}^{2}\right)t^{2}}{72t}\end{aligned} \tag{53}$$

Total profits are given by:

$$\begin{aligned}\underline{\Pi}^{R} &= \underline{\Pi}_{BP}^{R}+\underline{\Pi}_{GP}^{R}\\ &= \frac{1}{36}\left(t\left(49-f_{BP}\left(26-13f_{BP}\right)\right)+18\left(1-f_{BP}\right)\left(\beta-\gamma\right)+\frac{9\left(\beta-\gamma\right)^{2}}{t}\right)\end{aligned} \tag{54}$$

Recall that total profits under a RP scheme are equivalent to total profits under a NR scheme, i.e., $\underline{\Pi}^{R}=\underline{\Pi}^{NR}$.

Government expenditure is given by:

$$\begin{aligned}\underline{G}^{R} &= (1-\theta)\left(\underline{B}^{R}+\underline{PG}^{R}+\underline{G}^{R}\right)\underline{p}_{g}^{R}\\ &= (1-\theta)\,\underline{p}_{g}^{R}\\ &= (1-\theta)\left(\frac{2}{3}t+\frac{1}{3}tf_{BP}\right)\end{aligned} \tag{55}$$

[25] All these restrictions are similar to those of Rodrigues et al. (2014), where their graphical representation can also be found.

[26] In equilibrium, $c_{g.pg}^{R}=\frac{f_{BP}}{6}+\frac{1}{3}$ and $c_{b.pg}^{r,R}=\frac{(1+f_{BP})t-(\beta-\gamma)}{2t}$.

Parameter restrictions As in the FPR scheme case, equations (50), (51) must hold for our results to be verified. In addition, $\beta \geq \underline{\hat{p}}_b^R$, which is equivalent to requiring that $\beta \geq \frac{[(7+4\theta)-(7-2\theta)f_{BP}]}{3} - \gamma$. This condition is less restrictive than equation (52) for any $\theta \in [0,1]$; therefore, it is always satisfied when equation (52) holds.