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On insurance and the cost-sharing of pharmaceutical R&D

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Abstract

Ramsey pricing has been proposed in the pharmaceutical industry as a principle to price discriminate among markets while allowing to recover the (fixed) R&D cost. However, such analyses neglect the presence of insurance or the fund raising costs for drug reimbursement. By incorporating these new elements, we aim at providing some building blocks towards an economic theory merging Ramsey pricing, equity concerns by governments and the strategic incentives, as governments also determine the reimbursement level in countries with a NHS-like system. This will have important implications to the application of Ramsey pricing principles to pharmaceutical products across countries.

Keywords: Ramsey pricing, coinsurance.

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1 Introduction.

An old debate being developed since the late 1950s, concerns the link between the level of profits of a company (and thus, its monopoly power in the market) and the source of funding of R&D activities. The recent years have witnessed the uprising of the globalization of economic activities in the developed world. Together with globalization, increasing costs associated with the pace of technological change force companies to review their R&D organization and spending. DiMasi *et al.* (2003) estimate the total R&D cost per new drug in 2001 at $802 million.[1] The Tufts Center for the Study of Drug Development (2003), increases the estimate further to $897 million in 2003. Domínguez *et al.* (2005) argue that in recent years pharmaceutical companies have oriented their R&D efforts towards small innovations rather that more drastic (and risky) ones. Two reasons justify such behavior. First, the lack of demand sensitivity to price changes induced by insurance; and second, the fact that small innovations are more profitable than large ones as they are directed to the more inelastic part of the demand. In a complementary view, Pavcnik (2002) finds that pharmaceutical corporations pricing policies are sensitive to the patient out-of-pocket expenses. In particular, prices are lower the more exposed are patients to prices. Zeller (2004) looks at the role of R&D strategies of multinatioanl pharmaceutical companies to conclude that those companies embed in knowledge-rich regions thus reinforcing a "pharmabiotech spider's web economy".

The sharp increase in R&D expenses combines in the case of the pharmaceutical industry, with the traditional differences of drug prices across countries due to a number of factors. Among them, different regulatory regimes and insurance systems, together with the fact that governments are usually monopsony buyers of drugs.

In reply to this new environment, companies have reacted developing partnerships as a way to cope with (i) the rising cost and risk of R&D activities, (ii) the appropriation of the full array of applications to capture a greater return on tech-

[1] See Frank (2003) for an assessment on how to interpret this estimation.

nology investment, (iii) the bridging of the gap between technology creators and technology users, and (iv) the complex and multidisciplinary new technologies. Partnerships arise in many forms: among companies, between companies and research universities, as strategic alliances within a supply chain, and, of course, partnerships with governments.

On their part, governments in high price countries have also reacted by introducing these prices differences as an element in their negotiations with pharmaceutical corporations in the so-called reference pricing system and/or allowing for parallel imports under the argument that trade normally increases consumer welfare. Danzon (no date) argues against these practices as they are harmful to R&D efforts. Her argument relies on two facts. On the one hand, R&D is a fixed cost once the new product is developed, and on the other hand, "(...) as R&D costs cannot be rationally allocated as a direct cost of serving a specific country or consumer group, there is a strong incentive for each country to free-ride, leaving others to pay for the joint R&D costs." To complicate matters, R&D costs are difficult to track because they span over a period of 15 to 20 years (see Toole, 2005), and include many failed attempts, so that defining a sharing rule to allocate the joint R&D costs is not an easy task.

Firms, in turn, aim at setting a single price. At least within the European Union such an objective is often found. According to Danzon and Towse (2003) external referencing and parallel trade lie at the heart of this objective.[2] Danzon (no date) stresses the fallacy of uniform prices associated to parallel imports and external referencing: if all consumers face the same high price, then low income countries will be unable to afford innovative medicines. But if everyone pays the same low price, "(...) in the long run, consumers will be deprived of innovative drugs that they would have been willing to pay for, had differential pricing been permitted." In this line, Maynard and Bloor (2003) conclude that price controls must be supplemented with volume controls to constrain overall spending.

We propose to focus on the issue of how to impute the overall R&D costs

[2]External referencing occurs whenever a country uses (low) prices in other countries to regulate prices at home.

in the pharmaceutical industry across countries in the presence of insurance. We depart from Danzon and Towse (2003) who propose to use the principle of Ramsey pricing to define the price differentials across markets to cover the (fixed) R&D costs. Their main concern is to have richer countries paying enough to allow for the recovery of R&D costs associated with new drugs, while keeping prices low in developing countries, to ensure wide access to pharmaceuticals. Direct application of Ramsey pricing principles lead to this sort of differential pricing rules as long as consumers in low-income countries have a more price-elastic demand.

This is a controversial issue because, Ramsey (discriminatory) prices assume firms obtaining "normal" profit returns, allowing for recovering fixed costs. This contrasts with the periodic announcements by pharmaceutical corporations of profit returns far beyond normal levels. Love (2001) or Raghavan (2001) are examples of the critical view of the use of Ramsey prices, as regulators look at the price discrimination argument but forget about the budget constraint. In contrast, Scherer (2001) assesses the evidence on the link between profits and R&D effort in the US pharmaceutical industry. He concludes that "(...) as profit opportunities expand, firms compete to exploit them by increasing investments, primarily in R&D, until the increases in costs dissipates most, if not all, supranormal profit returns." Also Danzon and Towse (2003) argue in favor of Ramsey prices as "(...) in the long run with unrestricted entry and exit of firms offering competing but differentiated products, dynamic competition will reduce *expected* profits to normal levels at the margin." Besides, Ramsey pricing assumes that the social value of an extra dollar of consumption of an individual is the same across markets. In western economies this may not be a difficulty, but when different markets are located in developed and developing countries, such an assumption is hard to maintain. To overcome this difficulty, Diamond (1975) proposed the so-called *many-person Ramsey rule* as a generalization of the Ramsey pricing to allow for distributional concerns. Jack and Lanjouw (2003) apply this generalized rule to the cost-sharing of pharmaceutical innovation in an international context where world income distribution is used to adjust international pharmaceutical prices. They conclude that (i) with those ad-

justments, poor countries should not necessarily share in any of the costs of R&D, and (ii) the pricing structure is not related to that which would be chosen by a monopolist in a simple (proportional) way.

The argument for sustaining price differentials is reinforced by the simulation study of Dumonliu (2001), where access to pharmaceuticals would be seriously impeded under a global uniform price. Felder (2004, 2006) studies the welfare effects of different pricing policies (uniform prices, two-part tariffs, and third-degree discriminatory prices) under monopoly and moral hazard.

Although these authors and others, emphasize the welfare enhancement from price discrimination across countries, arguing for higher prices in richer countries, we believe they miss a central ingredient. Even if we take price elasticities of demand to be higher in low income countries, the analysis neglects the role of insurance. Actually, Danzon and Towse (2003) do comment on the role of insurance in making demand faced by pharmaceuticals to be more or less price sensitive. However, they do not investigate further the changes in the Ramsey pricing rule that result from differences between the price paid by consumers (net of insurance) and the value received by the firm.

To see intuitively why the level of insurance makes a difference, consider two markets (countries) with the same (constant) price elasticity of demand but distinct insurance levels. For the sake of the argument, assume that in one country there is no insurance while in the other there is full insurance. Efficient pricing *à la* Ramsey determines a higher price in the country that distorts less the quantity consumed. This means that the country where full insurance prevails should pay all the R&D costs, since no distortion in consumption seems to result. Besley (1998) finds that the design of optimal (second-best) insurance policies is driven by the trade-off between the economic losses from moral hazrd and the gains from risk sharing.

This, some would say, just acknowledges that price elasticity of demand does still matter. However, this simple intuition fails to take into account an additional aspect. Because insurance exists (and indeed full insurance was assumed) in one country, that country will have the usual moral hazard problem of excessive con-

sumption (as the price faced by consumers at the moment of consumption is zero). Therefore, a benevolent planner, as implied by the Ramsey optimal pricing problem, will actually want to take this into account. Naturally, under full insurance nothing can be done, but under less than full insurance, the social planner may want to increase more the price in the market with higher co-insurance rate to counteract on the moral hazard effect. In addition, since there is some extra consumption under more insurance, the financing constraint is less binding than otherwise, allowing for a lower price in the country with a less generous welfare policy. The price setting problem will make a balance between the distortions needed to allow for recovery of the fixed cost and the compensation of the moral hazard effect. Together with the moral hazard problem generated by insurance, the way countries define copayments has to take into account the equity and access issues underlying the design of differential prices.

In terms of discussion of high prices in rich countries/low prices in poor countries, as long as insurance coverage is more generous in richer countries, our point reinforces the efficiency argument for international pricing differentials. Our contribution in this literature is to provide some building blocks towards an economic theory merging Ramsey pricing, equity concerns by governments and the strategic incentives, as governments also determine the reimbursement level in countries with a NHS-like system. Of course, what arrangement be actually implemented influences the incentives of firms to perform R&D. The paper is organized in the following way: next section presents the basic model and the intuition of how Ramsey prices are distorted by the presence of two coinsurance schemes (copayment and reference prices). Section 3 provides a more general characterization allowing for a comparison of the two coinsurance policies. A section with a discussion of the analysis and its implications closes the paper.

2 The model

We consider a set I of countries where a pharmaceutical company sells a (patented) drug. We assume, for simplicity, that countries are identical and that individuals

within each country are also identical and summarized by a representative consumer.

Health care insurance reimbursement schemes are typically based either on a copayment rate or on a reference price. Let p_i be the price of a particular drug in country i. A *copayment rate* $s_i \in [0,1]$ in country i means that the insurer bears a proportion $s_i p_i$ of the cost of the health care treatment, and the patient pays the remaining amount $(1-s_i)p_i$. A *reference price* $\widehat{p}_i$ in country i is defined as the price level above which the patient is fully responsible for the payment. For prices below the reference price, the insurer bears the cost of the health care provided.

In general, the price paid by the patient in country i, p_i^c, is given by

$$p_i^c = p_i - \overline{p}_i(p_i), \quad \text{with} \quad \overline{p}_i(p_i) = (1-\delta)\hat{p}_i + \delta s_i p_i \tag{1}$$

where $\overline{p}_i$ is the coinsurance in case of need of medical care. For $\delta = 1$ we obtain the copayment setting while for $\delta = 0$ the reference pricing scheme arises. Values of $\delta \in (0,1)$ define mixed systems.

Let $D_i(p_i^c)$ be the demand for the relevant drug in country $i \in I$. The pharmaceutical company has to recover R&D costs, given by F, and has production costs given by a constant marginal cost c. We assume the existence of a supra-national entity that will define prices as to maximize social welfare over a set I of countries. All countries are valued equally.

From the point of view of the supra-national entity, the problem of determination of optimal prices, while recovering the cost of research and development expenditures, takes into account consumers' surplus, producers' surplus, and the payments made for drug reimbursement. This last element, introduces a public funds distortion cost in the case of a public insurer, or the insurance loading in the case of private insurance companies. We denote such distortion cost of funds by η. Thus, the social welfare function can be written as

$$W = \sum_{i \in I} \left(\int_{p_i^c}^{\infty} D_i(p)dp - (1+\eta)s_i p_i D_i(p_i^c) + (p_i - c_i)D(p_i^c) \right) - F \tag{2}$$

2.1 Copayment

The consumer's price at the moment of consumption/health need is net of any insurance the consumer may have:

$$p_i^c = p_i(1 - s_i), \tag{3}$$

where s_i is the co-insurance rate and p_i the price received by the pharmaceutical company, as described above ($\delta = 1$).

The pharmaceutical company has to recover R&D costs, given by F, and has production costs given by a constant marginal cost c.

We assume the existence of a supra-national entity that will define prices as to maximize social welfare. All countries are valued equally.

From the point of view of the supra-national entity, the problem of determination of optimal prices, while recovering the cost of research and development expenditures, is given by

$$\begin{aligned} \max_{\{p_i\}} W &= \sum_{i \in I} \left(\int_{p_i^c}^{\infty} D_i(p)dp - (1+\eta)s_i p_i D_i(p_i^c) + (p_i - c_i)D_i(p_i^c) \right) - F \\ s.t. &\sum_{i \in I} (p_i - c_i)D_i(p_i^c) - F = 0. \end{aligned} \tag{4}$$

The first-order conditions of this problem are:

$$\begin{aligned} \frac{\partial \mathcal{L}}{\partial p_i} &= -D_i(p_i^c)(1 + s_i\eta) - s_i(1 - s_i)(1+\eta)p_i \frac{\partial D_i}{\partial p_i^c} + \\ &\quad + (1+\lambda)\left[D_i(p_i^c) + (p_i - c_i)(1 - s_i)\frac{\partial D_i}{\partial p_i^c} \right] = 0, \ i \in I \end{aligned} \tag{5}$$

$$\frac{\partial \mathcal{L}}{\partial \lambda} = \sum_{i \in I} (p_i - c_i)D_i(p_i^c) - F = 0 \tag{6}$$

Rearranging the first-order conditions, we can write

$$\frac{p_i - c_i}{p_i} = \frac{\lambda}{1+\lambda}\frac{1}{\varepsilon_i} + \frac{s_i}{1+\lambda}\kappa_i, \ \ \kappa_i \equiv 1 - \eta\left(\frac{1 - \varepsilon_i}{\varepsilon_i}\right) \tag{7}$$

where λ is the Lagrange multiplier associated with the zero-profit constraint, and $\varepsilon_i = -\partial D/\partial p \times p/D$ denotes demand elasticity.

The introduction of the distortion cost η has an upper bound smaller than one. Most estimates put this value in a range around 0.2.[3] Also, the presence of insurance is likely to make demand inelastic with values in co-insurance contexts around 0.2 (Newhouse, 1993; Ringel *et al*, 2005). For those values κ_i takes positive values. Thus, heretofore, we will assume $\kappa_i > 0$.

The equilibrium pricing rule obtained differs from the standard Ramsey pricing rule in the last term: for equal demand elasticities, Lagrange multiplier, and given distortion cost of funds, a country with a higher co-insurance rate will have a higher price as well. This is due to the well-known ex-post moral hazard problem of health insurance. Since insurance implies a lower price at the moment of consumption, consumers tend to overspend, in the sense of marginal benefit being smaller than social marginal cost at the equilibrium. This effect is larger the higher the co-insurance rate, which motivates a higher p_i as to partially correct it.

This additional motive for price differentials may, or may not, reinforce price dispersion across countries. Whenever on top of lower price elasticity of demand, richer countries also have a higher insurance coverage, then they should face higher prices than low-income countries for efficiency reasons alone.

This result also implies that assessment of international price dispersion cannot be made on the basis of marginal cost and price elasticity of demand differences. One must also look at co-insurance rate variations.

It is also noteworthy that Ramsey pricing is still not supportive of a policy of uniform prices across countries. It may accidentally occur that ε_i and s_i are such that price-cost margins are equal across countries, but a small perturbation in the fixed cost F would destroy such uniform prices.

The existence of insurance has actually another indirect effect. Holding mill prices constant, increasing the co-insurance rate means more revenues to the company as consumption expands. This helps to finance the fixed costs. Therefore, λ also varies, in equilibrium, with exogenous shifts in the co-insurance rate.

The comparison of prices for distinct levels of the co-insurance rate cannot be

[3] For more details, see, inter alia, Allgood and Snow (2006) and Fullerton (1991).

fully assessed from the mere statement of first-order conditions. A full comparative statics exercise must be performed, which we report below for the two-country case.

2.1.1 Comparative statics in a two-country market

Assume that we have two countries, $I = \{1, 2\}$. Total differentiation of first-order conditions yields, for a change in s_1,

$$\frac{\partial^2 \mathcal{L}}{\partial p_1^2} dp_1 + \frac{\partial^2 \mathcal{L}}{\partial p_1 \partial \lambda} d\lambda + \frac{\partial^2 \mathcal{L}}{\partial p_1 \partial s_1} ds_1 = 0, \tag{8}$$

$$\frac{\partial^2 \mathcal{L}}{\partial p_2^2} dp_2 + \frac{\partial^2 \mathcal{L}}{\partial p_2 \partial \lambda} d\lambda = 0, \tag{9}$$

$$\frac{\partial^2 \mathcal{L}}{\partial \lambda \partial p_1} dp_1 + \frac{\partial^2 \mathcal{L}}{\partial \lambda \partial p_2} dp_2 = 0, \tag{10}$$

where $\mathcal{L}$ denotes the Lagrangian function of the optimization problem.

We solve this system for dp_i/ds_1 and $d\lambda/ds_1$. The comparative statics exercise establishes:[4]

$$\frac{dp_1}{ds_1} \lesseqgtr 0, \quad \frac{dp_2}{ds_1} < 0, \quad \frac{d\lambda}{ds_1} < 0. \tag{11}$$

These results imply the following. An increase in the co-insurance rate in country 1 increases overall consumption and allows to finance more easily the R&D costs (the amount F). This alleviates the constraint faced ($d\lambda/ds_1 < 0$), which in itself would allow for a reduction of prices in both countries. In country 2 there are no further effects and an increase in the co-insurance rate in country 1 should decrease the optimal Ramsey price in country 2 ($dp_2/ds_1 < 0$). On country 1, however, an increase in the co-insurance rate also increases the moral hazard issue (the subsidy must also be paid, and at the margin consumption occurs where marginal benefit is already below marginal costs). To control for this, the price in country 1 should increase. Therefore, in country 1 we have conflicting effects and the equilibrium price may actually increase or decrease.

[4] On top of the usual regularity conditions stated previously, we also make use of the assumption of a concave or not too convex demand function to ensure $\partial^2 \mathcal{L}/\partial p_1 \partial s_1 > 0$.

Finally, it is relevant to note that in our setup the co-insurance rate s_1 is overall welfare decreasing ($d\mathcal{L}/ds_1 < 0$), as

$$\frac{\partial \mathcal{L}}{\partial s_1} = p_1^2 \frac{\partial D_1}{\partial p_1^c} \frac{\lambda}{\varepsilon_1} < 0 \tag{12}$$

where we have made use of (7).

This is not surprising as the co-insurance rate plays only the role of a price subsidy here. This is so because we have not modeled the costs of bearing risk, and the welfare gains of insurance, which would work in the opposite direction in what respects the total effect.

2.2 Reference price

A reference price $\widehat{p}_i$ as defined above means that $p_i^c = p_i - \widehat{p}_i$. The welfare measure of the supra-national authority is given by the lagrangian function of the welfare maximization problem, that is,

$$\max_{\{p_i\}} W = \sum_{i \in I} \left(\int_{p_i^c}^{\infty} D_i(p)dp - (1+\eta)\widehat{p}_i D_i(p_i^c) + (p_i - c_i) D_i(p_i^c) \right) - F \tag{13}$$

$$s.t. \sum_{i \in I} (p_i - c_i) D_i(p_i^c) - F = 0$$

The corresponding first-order conditions for welfare maximization are

$$\begin{aligned} \frac{\partial \mathcal{L}}{\partial p_i} &= -D_i(p_i^c) - (1+\eta)\hat{p}_i \frac{\partial D_i}{\partial p_i^c} + \\ &\quad + (1+\lambda) \left[D_i(p_i^c) + (p_i - c_i) \frac{\partial D_i}{\partial p_i^c} \right] = 0, \ i \in I \end{aligned} \tag{14}$$

$$\frac{\partial \mathcal{L}}{\partial \lambda} = \sum_{i \in I} (p_i - c_i) D_i(p_i^c) - F = 0 \tag{15}$$

From these expressions, we can easily obtain the comparative statics of an increase in $\hat{p}_1$ in a two-country world. Similar to what happens with the co-insurance arrangement,

$$\frac{dp_1}{d\widehat{p}_1} \lesseqgtr 0; \qquad \frac{dp_2}{d\widehat{p}_1} < 0; \qquad \frac{d\lambda}{d\widehat{p}_1} < 0 \tag{16}$$

Therefore, the qualitative effects are the same as under the co-insurance arrangement.

3 General characterization

The previous sections presented the basic intuition of the additional effects of Ramsey pricing introduced by existence of insurance arrangements. We proceed now to a more general characterization allowing for comparing the two insurance copayment schemes presented.

Let us recall previous notation,

$$p_i^c = p_i - \overline{p}_i(p_i), \qquad \overline{p}_i(p_i) = (1-\delta)\hat{p}_i + \delta s_i p_i \tag{17}$$

To compare both systems note that moving from $\delta = 0$ to $\delta = 1$ we move from the reference price system to the copayment one. If the infinitesimal changes, along the path from $\delta = 0$ to $\delta = 1$ keep the same sign effect upon each of the endogenous variables, the same will be true of the full effect. For this comparison, we maintain the assumption of two countries.

Total differentiation of the first-order conditions yields, for a change in δ,

$$\frac{\partial^2 \mathcal{L}}{\partial p_1^2} dp_1 + \frac{\partial^2 \mathcal{L}}{\partial p_1 \partial \lambda} d\lambda = -\frac{\partial^2 \mathcal{L}}{\partial p_2 \partial \delta} d\delta \tag{18}$$

$$\frac{\partial^2 \mathcal{L}}{\partial p_2^2} dp_2 + \frac{\partial^2 \mathcal{L}}{\partial p_2 \partial \lambda} d\lambda = -\frac{\partial^2 \mathcal{L}}{\partial p_2 \partial \delta} d\delta \tag{19}$$

$$\frac{\partial \Pi}{\partial p_1} dp_1 + \frac{\partial \Pi}{\partial p_2} dp_2 = -\frac{\partial \Pi}{\partial \delta} d\delta \tag{20}$$

given that $\partial^2 \mathcal{L}/\partial p_1 \partial p_2 = 0,\ \partial^2 \mathcal{L}/\partial p_1 \partial \lambda = \partial^2 \mathcal{L}/\partial p_2 \partial \lambda = \partial \Pi/\partial p_i = \Pi_i$, and $\Pi = \sum_{i \in I} (p_i - c_i) D(p_i^c) - F$.

Solving this system of equations,

$$\frac{dp_1}{d\delta} = \frac{\partial \Pi/\partial p_2}{H} \left(\frac{\partial \Pi}{\partial p_2} \frac{\partial \mathcal{L}}{\partial p_1} \delta - \frac{\partial \Pi}{\partial p_1} \frac{\partial \mathcal{L}}{\partial p_2} \delta \right) \tag{21}$$

$$\frac{dp_2}{d\delta} = \frac{\partial \Pi/\partial p_1}{H} \left(\frac{\partial \Pi}{\partial p_1} \frac{\partial \mathcal{L}}{\partial p_2} \delta - \frac{\partial \Pi}{\partial p_2} \frac{\partial \mathcal{L}}{\partial p_1} \delta \right) \tag{22}$$

$$\frac{d\lambda}{d\delta} = -\frac{\partial \Pi}{\partial \delta} \frac{\partial^2 \mathcal{L}}{\partial p_1^2} \frac{\partial^2 \mathcal{L}}{\partial p_2^2} + \frac{\partial^2 \mathcal{L}}{\partial p_1 \partial \delta} \frac{\partial \Pi}{\partial p_1} + \frac{\partial^2 \mathcal{L}}{\partial p_1^2} \frac{\partial^2 \mathcal{L}}{\partial p_2 \partial \delta} \frac{\partial \Pi}{\partial p_2} \tag{23}$$

where H denotes the determinant of the corresponding hessian matrix. It is also

the case that

$$\frac{\partial \Pi}{\partial \delta} = \sum_{i \in I} (p_i - c_i) \frac{\partial D_i}{\partial p_i^c} (\hat{p}_i - s_i p_i) \tag{24}$$

$$\frac{\partial \Pi}{\partial p_i} = D(p_i^c) + (p_i - c_i) \frac{\partial D_i}{\partial p_i^c} (1 - \delta s_i) > 0 \tag{25}$$

(if this last inequality does not hold, the monopoly price would prevail).

Starting at $\delta = 1$ (co-insurance regime) and introducing the reference price equal to the reimbursed value at the equilibrium value of the co-insurance regime, $\hat{p}_i = s_i p_i^*$ one obtains

$$\frac{\partial^2 \mathcal{L}}{\partial p_i \partial \delta} = p_1^* s_i \frac{\partial D_i}{\partial p_i^c} \left(s_i - \frac{p_i^* - c_i}{p_i^*} (1 + \lambda) \right) > 0 \tag{26}$$

and from the first-order condition the term in parenthesis has negative value, so the positive value follows. Also, at the same initial point, $\partial \Pi / \partial \delta = 0$, and applying (26) and (27) into (24) implies

$$\frac{d\lambda}{d\delta} < 0 \tag{27}$$

Thus moving from co-insurance rate to reference pricing increases the financial constraint - since at the margin the consumer is more sensitive to the price, the financing of the R&D cost has a higher distortion cost.

The other conclusion is about price movements, as prices will evolve in opposite directions.

3.1 Comparative statics on $\overline{p}$

Another issue that can be addressed in our framework is the desirability of having a co-payment driven by the need to finance the R&D costs, against the alternative of consumers paying the full price. Taking the welfare function,

$$W = \sum_{i=1,2} \left(\int_{p_i^c}^{\infty} D(p) dp - \bar{p}_i D_i(p_i^c) + (p_i - c_i) D_i(p_i^c) \right) - F \tag{28}$$

The impact of an exogenous change in the reference price is

$$\frac{dW}{d\bar{p}_i} = \bar{p}_i \frac{\partial D_i}{\partial p_i^c} + (p_i - c_i) \frac{\partial D_i}{\partial p_i^c} \left(\frac{\partial p_i}{\partial \bar{p}_i} - 1 \right) + (p_j - c_j) \frac{\partial D_j}{\partial p_j^c} \frac{\partial p_j}{\partial \bar{p}_i}, j \neq i \tag{29}$$

Evaluated at $\bar{p}_i = 0$, and given that from the comparative statics results, $\partial p_i/\partial \bar{p}_i < 1, \partial p_j/\partial \bar{p}_i < 0$, one obtains $dW/\bar{p}_i > 0$. Therefore, for positive R&D costs to be financed, under the assumption of unitary social cost of funds, it is welfare improving to have a positive reference price.

We find this result remarkable because, even without considering the welfare effects of insurance, it turns out that a positive coinsurance to finance a fixed R&D cost is welfare enhancing.

4 Discussion

Another interesting implication from explicit consideration of the insurance arrangements is that in the presence of such arrangements, price equal to marginal cost is not optimal even for $\lambda = 0$. That is, even if revenues under normal market conditions are sufficient to cover the R&D costs, it is optimal to have price above marginal cost.

The comparison across systems is a hard one to perform, as the same revenue has to be raised in each case. If $\bar{p}_i = sp_i^*$, does p_i change? To answer this, we need to look at the first-order conditions of both problems. In any case, increasing one price means decreasing the other price, given the same R&D costs that need to be financed. Therefore, a change in the insurance scheme can only imply a reallocation of the financial burden. By comparing the two sets of first-order conditions, it is easy to see that both are satisfied for the very same prices as long as $\bar{p}_1 = s_1 p_1^*$. Therefore, the insurance arrangement is irrelevant - reference pricing or rate of reimbursement yield the same price and allocation of resources.

The analysis has been presented in terms of a representative consumer. Accordingly, there is no room for introducing equity concerns. On the issue the reader is referred to Jack and Lanjouw (2003). As we have mentioned above, introducing different populations (countries), lead them to non-proportional pricing schemes so that poor countries need not share any R&D cost.

We may finally discuss the role of arbitrage across countries. The existence of arbitrage means one more constraint in the choice problem of the Government,

which does not improve with respect to its absence. An immediate implication of perfect arbitrage between countries is that prices will be equal in both countries, which in turn makes the price to the consumer to be fully determined by the financial constraint.

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