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On the relationship between the negotiated prices of pharmaceuticals and the patients' co-payment

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Abstract

In this paper, we give a new insight on the relationship between the patients' co-payment for buying pharmaceuticals and the price of a patented pharmaceutical. We consider that the price of a pharmaceutical is the outcome of a negotiation between a health authority and a pharmaceutical monopoly producer. We use a model based on bargaining theory to represent this negotiation. The negotiated price is shown to be increasing in the degree of the patients' co-payment. This positive relationship is thus opposite to the negative one prevailing when the price is set by a monopoly without any negotiation. We further analyze the negotiation on the co-payment itself, and show that the optimal degree of the negotiated co-payment is the lowest one.

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1. Introduction

Pharmaceuticals account for almost a fifth of all health spending on average across OECD countries. Since 2000, average spending on pharmaceuticals has risen by almost 50% in real terms and about 60% of the total pharmaceutical expenditure are publicly reimbursed (OECD 2011). The need to control health expenditures has led governments, particularly in Europe, to adopt some kind of cost-containment policies. Among the widely used cost-containment policies is the imposition of higher co-payments for drugs, the use of a list defining the drugs eligible for reimbursement, and the active role of governments in negotiating drug prices product-by-product.

The aim of this paper is to investigate the interaction between these cost-containment policies. More precisely, we analyze the influence of the degree of patients' co-payment for buying pharmaceuticals, on the price of a patented pharmaceutical. We consider that the price of a pharmaceutical product is the outcome of a negotiation between a health authority and a pharmaceutical monopoly producer. To represent this negotiation, we use a model based on bargaining theory, in which the gains from bargaining are explicitly defined. In particular, we consider that when the price is negotiated, the drug is listed for patients' reimbursement. On the contrary, in case of negotiation failure, the drug is not listed for reimbursement, and patients pay the full price of it.

The features captured in our model are prevalent in the pharmaceutical sector, and some of them have been widely discussed in the literature (see Scherer 2000). On the demand-side, consumers' purchases of prescription drugs, like their purchases of health care services, are often reimbursed in whole or in part by insurance. This causes a divergence between the demand curve derived from consumers' income and the full price and the (higher) demand curve reflecting quantities consumed at prices net of insurance payments. This divergence of demand functions leads to reduced demand elasticity and increased purchase of the insured item. Empirical evidence on this relationship between the demand and the level of reimbursement is widespread (see Stuart et al. 2000 and the references therein, and the studies based on data from the Rand Health Insurance Experiment). This led many governments to decrease the level of reimbursement for cost-containment motives, expecting a lower drugs utilization and thereby lower expenses associated with it. These reductions in reimbursement levels have been observed especially in Europe, where reimbursement levels have been traditionally generous.

To have a more complete understanding of the effects of a change in reimbursement on the drug consumption and on the costs and benefits associated with it, it is important to analyze how the reimbursement affects not only the demand but also the pricing of pharmaceuticals. Since we focus on the case of new drugs, the analysis recognizes that on the supply-side, the wide use of patent protection gives monopoly power to the pharmaceutical producers. Microeconomic theory states that a monopolist maximizes its profits by setting a price that is negatively related to the price elasticity of demand. Given that, on the demand-side, insurance reimbursement leads to a reduced price elasticity of demand, we expect that the price set by a monopolist depends positively on the level of reimbursement, that is, negatively on the level of patients' co-payment. This would hold for the pricing of pharmaceuticals if there was no price control on pharmaceutical products imposed by governments, as it is the case in only a few countries such as the US and Germany. To illustrate this point, Pavcnik (2002) provides empirical evidence on the link between patient out-of-pocket expenses and pricing behavior by pharmaceutical firms. She finds that, in Germany, producers significantly reduce prices as the change in patient co-payment directly exposes patients to prices.

However, as noted by Scherer, "the perception, correct or incorrect, that pharmaceutical prices and profits have been excessive, the taxpayer burdens from rising public health care costs, and the belief, especially in smaller nations, that reducing drug prices and profits will at best have a minor impact on R&D expenditures by companies oriented toward serving worldwide markets, have led many governments to impose more or less thoroughgoing price controls on pharmaceutical products". Item-by-item negotiation and control is one of the five categories of drug prices government regulations, cited by Scherer. According to Danzon (1997), a government has a significant monopsony power since it negotiates the drug prices on behalf of an entire country. Our question is then, how does this monopsony power interact with the reimbursement level? In other words, how does the reimbursement affect the pricing of pharmaceuticals when there is negotiation?

To our knowledge, no theoretical prediction exists on the relationship between the level of patients' co-payment and the drug prices, when these are negotiated for the drug to be listed for reimbursement. Only the following observation reported by Scherer (2000) gives some insight about our problem: to control the rising costs of prescription drugs, many Health Maintenance Organizations (HMOs) and traditional hospitals in the US began establishing formularies listing the drugs suitable for use against particular illnesses. As the use of formularies gained acceptance, health care organizations drug procurement personnel realized that they could use the threat of a drug's exclusion from their formulary as a lever to elicit discounts from pharmaceutical manufacturers.

The main conclusion of our paper is that the drug prices resulting from the government-producer bargaining process are generally increasing with the level of patients' co-payment for buying drugs. This conclusion contrasts with the negative relationship between the co-payment and the price, when the price is set by the monopolist without any negotiation. Our result can be explained as follows. The threat faced by the monopolist of failing the negotiation (thus, of having the drug not listed for reimbursement) is stronger when the level of co-payment is lower. Indeed, the monopolist has more at stake in the negotiation when the resulting patients' demand is less price elastic, thus when the level of co-payment is lower. This implicitly gives more bargaining power to the government. This ultimately results in lower negotiated prices, if we consider that the government aims at lower payments for drugs, both with respect to its public finances and on behalf of the patients.

As many European governments negotiate both the price and the level of reimbursement for new drugs, this paper also provides an analysis of the negotiation outcome on the level of the co-payment itself. Given that the negotiated price is shown to be increasing in the co-payment, we show that the optimal negotiated co-payment is the lowest one. This result contributes to the ongoing debate on the pros and cons of patients' co-payment. As already mentioned, the main motive for increasing the level of co-payment refers to the control of drugs utilization, and to the containment of the costs. This argument against full insurance is reinforced by the presence of moral hazard in the consumption of health care services in general, and of drugs in particular. The disadvantage of such an increased co-payment is obviously the increased financial risk faced by the potential consumers of drugs. This shift of financial responsibility to the potential consumers also decreases the access to expensive medicines for the less wealthy, if there is no system of co-payment exemptions. Our results advocates for a lower level of co-payment for another reason: its effect on the negotiated price. Even though the consumption of drugs is expected to be higher with a lower co-payment, the effect on the overall drug expenses is not clear-cut since this higher consumption is accompanied with a lower negotiated price.

Even if price and reimbursement negotiations are common in EU countries, other policy measures exists there to control health care expenditures: International referencing to set prices, internal reference pricing to promote price competition, and positive lists for reimbursement (See Barros 2010 and Kanavos et al. 2011). Many authors have analyzed the relationship between co-payments and outcomes such as expenditure, use, and health, but few have explicitly linked reimbursement to prices. Exceptions are the empirical analyses by Pavcnik (2002) and by Duggan and Scott Morton (2010). As already mentioned, Pavcnik (2002) provides empirical evidence of a negative relationship between co-payment and prices in Germany where prices are set without negotiation. Conversely, Duggan and Scott Morton (2011) report evidence for what they consider a surprising outcome: In the case of the new prescription drug program for Medicare enrollees, moving consumers from cash-paying status to membership in an insured group lowers optimal prices for branded prescription drugs below what they otherwise would be. They mention the possible role of negotiation to explain this result. They actually provide an empirical proof for the main result of our paper.

Turning to other policy measures to control health care expenditures, a large body of the empirical literature repeatedly report evidence that reference pricing policies lead to lower drug prices (see Augurzky *et al*. 2009, Brekke *et al*. 2009, Brekke *et al*. 2011, Dylst *et al*. 2011, Galizzi *et al*. 2011, Puig-Junoy 2004, and Stargardt 2011). Garcia-Mariñoso *et al*. (2011) also provide a theoretical analysis relating drug prices to reimbursements under international reference pricing and Jelovac and Bordoy (2005) do so when parallel imports of drugs are permitted. Looking at the broader picture, Barros and Martinez Giralt (2008) show how insurance coverage affects the optimal prices to pay for the R&D investment. They also show that under certain conditions, there is no strategic incentive by governments to set insurance rates in order to shift the financial burden of R&D to other countries. This will have important implications to the application of Ramsey pricing principles to pharmaceutical products across countries.

In the next section, we move on to model our problem, defining the objectives of the parties involved in the negotiation. In Section 3, we present the bargaining model, and its Nash bargaining solution price, after computing the disagreement point (i.e. the outcome when the drug is not listed for reimbursement). In Section 4, we perform some comparative statics to derive the relationship between the negotiated price and the co-payment. In Section 5, we analyze some policy implications of our results. Section 6 completes the analysis of the negotiation by deriving the Nash bargaining solution co-payment. Section 7 concludes. Proofs are in the Appendix.

2. The model

In this model, the price of a pharmaceutical product affects the objectives of three parties: the patients, the government, and the pharmaceutical monopoly producer. We focus on the case where the amount paid by the patients for buying a pharmaceutical product is proportional to its price. However, the main results obtained in this paper can be easily replicated for the case of a fixed charge co-payment instead of a proportional one. We assume that the patients' total demand for the drug is $q = a - \alpha p$, where α is the proportion of the price paid by the

consumer, i.e. the degree of co-payment, with $\alpha \in [0,1]$, and p is the price of the drug.[1] The resulting consumers' surplus is then $CS = (a - \alpha p)^2 / 2$.

The government is assumed to have as an objective to maximize the consumers' surplus, net of the public expenses, denoted *PE*, associated with the partial reimbursement of drug expenses, where $PE = (1-\alpha)pq = (1-\alpha)p(a-\alpha p)$. Therefore, the objective function of the government can be written as $OF = CS - PE = (a - \alpha p)(a - (2-\alpha)p)/2$.

We assume that the objective of the monopoly producer of drugs is to maximize its profits $\Pi = pq - F = p(a - \alpha p) - F$, where F stands for the fixed costs of R&D, safety approval process and marketing. Given that the pharmaceutical industry is characterized by high fixed costs and low marginal costs, we assume in this model that the marginal cost of producing the drug is zero.

3. The price negotiation

We first discuss the case with no negotiation. If there is neither negotiation nor any other form of control on the drug price, then the profit-maximizing monopolist chooses the monopoly price $p^m = a / 2\alpha$, which is decreasing in the level of patients' co-payment, α. The resulting monopoly profit, consumers' surplus, public expenses, and government's objective, are summarized in the following lemma.

Lemma 1.

If there is neither negotiation nor any other form of control on the drug price, then:

$$p^m = \frac{a}{2\alpha}, \quad \Pi^m = \frac{a^2}{4\alpha} - F, \quad CS^m = \frac{a^2}{8}, \quad PE^m = \frac{1-\alpha}{\alpha}\frac{a^2}{4}, \quad OF^m = \frac{3\alpha - 2}{\alpha}\frac{a^2}{8}.$$

If a drug is not listed for reimbursement, then its price is set by the monopolist without any negotiation, and the patients pay the full price of the drug: $\alpha = 1$. Hence, the outcome derived previously for the case of monopoly pricing can be adapted, using $\alpha = 1$, to reflect the outcome that would be achieved if no agreement on the drug price is reached during a negotiation. This outcome is summarized in the following lemma, and it illustrates the disagreement point to be considered when analyzing the negotiation process.

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[1] This demand is compatible with a patients' utility maximization, each patient having a utility additively separable in the consumption of one or zero unit of the drug, $x \in \{0,1\}$, and the consumption of a numeraire composite good, z. Each patient has an income I, and a valuation for consuming the drug characterized by the parameter θ, with θ ~U[b, a]. Therefore, the demand $q = a - \alpha p$ comes from the following program:

$\underset{\{x,z\}}{Max}\ U = z + \theta x$ subject to $z + \alpha p x \leq I$ and $x = \{0, 1\}$, with $\theta \sim U[b, a]$.

Or, equivalently: $U = I + Max\ \{\theta - \alpha p;\ 0\}$, with $\theta \sim U[b, a]$. The consumers' surplus is then:

$$CS = I + \int_{\alpha p}^{a} (\theta - \alpha p) d\theta = \frac{1}{2}(a - \alpha p)^2.$$

The income parameter (*I*) plays no role in the analysis. We therefore omit it.

Lemma 2.

If the drug is not listed for reimbursement, then:

$$p^n = \frac{a}{2}, \qquad \Pi^n = \frac{a^2}{4} - F, \qquad CS^n = \frac{a^2}{8}, \qquad PE^n = 0, \qquad OF^n = \frac{a^2}{8}.$$

Denoting the negotiation power of the government and of the monopoly producer as β and $1-\beta$, respectively, the Nash bargaining program corresponding to the government-monopolist negotiation on the price of a drug can be written as:[2]

$$\underset{\{p\}}{Max} \quad (1-\beta)\ln\left(\Pi - \Pi^n\right) + \beta\ln\left(OF - OF^n\right). \tag{1}$$

The first-order condition associated with this program is:

$$(1-\beta)\frac{\Pi_p'}{\Pi - \Pi^n} + \beta\frac{OF_p'}{OF - OF^n} = 0, \tag{2}$$

where "prima" denotes the first derivative, and the subscript refers to the variable with respect to which the function is derived. This first-order condition (2) gives us the Nash bargaining solution price, denoted p^*, since the second-order condition is satisfied (see Appendix A).

4. The influence of the patients' co-payment

We now move on to the main proposition of this paper.

Proposition 1

The price of a patented drug increases with the degree of patients' co-payment, when it is the outcome of a negotiation between a profit-maximizing monopoly drug producer and a government aiming at maximizing the consumers' surplus net of its public expenses:

$$\left.\frac{dp^*}{d\alpha}\right|_{[FOC]} > 0.$$

Proof. See Appendix B

The main rationale behind this result is the following. When the degree of co-payment is high, then the price elasticity of demand does not vary much from a non-negotiated outcome to a negotiated one. In that case, the monopolist does not have much at stake with the

[2] See Muthoo (1999) for detailed information on the Nash bargaining solution.

negotiation, and he would rather fail the negotiation than accept a low price. Therefore, if any price is agreed upon during the negotiation, it has to be a high one. Conversely, when the degree of co-payment is low, the price elasticity of demand is much lower under a negotiated outcome. The monopolist would then rather go for a negotiated price, even low, than failing the negotiation.

Even if all countries normally care both for patients' welfare and for controlling health care expenditure, they associate different priorities to each objective. To account for this difference, we extend the basic model, assigning weights λ and $1-\lambda$ to *CS* and to *PE*, respectively, within the regulator's objective function: $OF = \lambda\ CS - (1-\lambda)\ PE$. Using for simplicity a fixed co-payment k rather than a proportional one, we can easily show that our main result continues to hold whenever λ and β are not both too high:

$$\frac{\partial p^*}{\partial k} > 0 \Leftrightarrow \lambda < \frac{8-6\beta}{13-11\beta}. \tag{3}$$

Only very high values of both λ and β lead to the converse result. In this case, the negotiation greatly prioritize patients' welfare over both public expenses and firm's profits. The negotiation stake is therefore inversed: When the co-payment increases, the patients' welfare decreases. Only a lower negotiated price can compensate for the loss in patients' welfare. The remaining of the paper considers the basic setting, with equal weights on both *CS* and *PE*.

5. Implications for reimbursement policies

Many governments rise the degree of patient co-payment as a mean to decrease the expenses associated with drug utilization. Therefore, it is important to analyze to what extent total expenses decrease when the co-payment increases.

Governments often increase co-payments with the aim of controlling the demand for pharmaceuticals but ignoring a possible change in the drug pricing. Obviously, when we ignore the possible effect on pricing, the total expenses decrease as the co-payment increases.

Another view, with empirical evidence provided by Pavcnik (2002) for the case of Germany, is that the pharmaceutical producers adapt their pricing behavior to the increased co-payment. When there is no price control on pharmaceutical products, as it is the case in only a few countries, then the pharmaceutical producers decrease their price as a response to an increased co-payment. Therefore, the expected effect of an increased co-payment on the total expenses is negative again because both demand and prices are expected to decrease.

As this paper focuses on cases where the drug price is the outcome of a negotiation between the producer and the health authority as it is the case in many countries, we now analyze the effect of an increase in the co-payment on the total expenses accordingly. Proposition 1 states that in this case, the price of a drug increases with the degree of patients' co-payment, while the demand is still expected to decrease. Therefore, the expected total effect of an increased co-payment on the total expenses is not so clear-cut anymore. We can show that the possible decrease in total expenses due to an increase in the co-payment is lower when the drug price is negotiated.

6. The co-payment negotiation

Given that in some countries the negotiators agree not only on the price of pharmaceuticals but also on the level of reimbursement, we now complete our analysis providing the Nash bargaining solution co-payment. It is the solution to the following program:

$$\underset{\{\alpha\}}{Max} \quad (1-\beta)\ln\left(\Pi - \Pi^{n}\right) + \beta\ln\left(OF - OF^{n}\right). \tag{4}$$

Whether the negotiation on the price and the one on the co-payment are simultaneous or sequential does not make any difference in theory since the parties involved in the negotiation are always the same. The next proposition gives the Nash bargaining solution co-payment.

Proposition 2.

When a pharmaceutical monopoly producer and a health authority negotiate upon both the price of a drug and the co-payment rate for purchasing the drug, then the Nash bargaining solution co-payment is the lowest possible one: $\alpha^* = 0$. *Accordingly,*

$$p^* = \frac{(3-\beta)a}{8}, \qquad \Pi^* = \frac{(3-\beta)a^2}{8} - F,$$

$$CS^* = \frac{a^2}{2}, \qquad PE^* = \frac{(3-\beta)a^2}{8}, \qquad OF^* = \frac{(1+\beta)a^2}{8}.$$

Proof. See Appendix C

The rationale for the negotiated co-payment to be the lowest one is that, it results in the highest patients' welfare, the highest firm's profits and the highest government's objective all together, even tough public expenses are the highest:

$$\frac{\partial\Pi(\alpha, p^*(\alpha))}{\partial\alpha} < 0; \quad \frac{\partial CS(\alpha, p^*(\alpha))}{\partial\alpha} < 0; \quad \frac{\partial OF(\alpha, p^*(\alpha))}{\partial\alpha} < 0; \quad \frac{\partial PE(\alpha, p^*(\alpha))}{\partial\alpha} < 0.$$

Therefore, a low co-payment that results in a relatively low price (in our basic case) is compatible with several key issues in balance: controlling pharmaceutical expenditures, ensuring access for patients, rewarding industry for valuable innovations, and maintaining pharmaceutical production, which is associated with employment and income-generation. A low price combined with a low co-payment (and thereby a high demand) allows reconciling all these seemingly conflicting objectives.

Last, we notice that a negotiated outcome, as described in Proposition 2, compared to the outcome obtained without negotiation and described in Lemma 1, leads to the following: a lower price, a higher consumers' surplus, higher public expenses, and a higher level of the government's objective, for any level of co-payment applied to the non-negotiated outcome.

Furthermore, the monopolist earns a higher profit under a negotiated outcome only if its negotiation power, $1 - \beta$, is high enough.

7. Conclusions

In this paper, we demonstrate that the price of a new pharmaceutical product generally increases with the degree of patients' co-payment, when it is the outcome of a negotiation between a profit-maximizing monopoly drug producer and a government aiming at maximizing the consumers' surplus net of its public expenses. This result is obtained using a model of Nash bargaining, in which the gains from bargaining are explicitly defined. In particular, we consider that when the price is negotiated, the drug is listed for patients' reimbursement. On the contrary, in case of negotiation failure, the drug is not listed for reimbursement, and patients pay the full price of it. The main rationale for our result is the following: the lower the patients' co-payment, the lower the price elasticity of demand, the higher the monopolist's profits if the drug is listed for reimbursement, and the more the monopolist has to gain with a negotiated outcome.

Our result suggests that when governments use several policies simultaneously to control the costs corresponding to the consumption of pharmaceutical products, they should carefully weight the possible interactions between the different policies. In particular, when a government uses item-by-item negotiation, and decides to rise the level of co-payment to contain the costs related to drug consumption, it should take into account that a higher co-payment would result in higher negotiated prices, thus countervailing the cost-containment effects of the changed reimbursement policy.

We also show that the optimal degree of the negotiated patient co-payment is the lowest one. This result contributes to the debate on the pros and cons of full coverage for health care. One argument against full insurance is driven by cost-containment motives, especially in the presence of moral hazard in the consumption of health care services. Arguments in favor of full insurance relate to the protection against financial risk and to a granted access to health care services. Our results give another argument in favor of full insurance: its effect on the negotiated price. Even though the consumption of drugs is expected to be higher with full insurance, the effect on the overall drug expenses, as well as on the objectives of the parties involved in the negotiation, is not clear-cut since this higher consumption is accompanied with a lower negotiated price.

Further research is needed to assess how the results derived in this paper extend to a situation with some degree of competition among pharmaceutical firms. Indeed, as noted by Scherer (2000), "although companies selling new drug chemical entities commonly enjoy patent protection for a number of years after their product is introduced, more often than not they must face competition from chemically differentiated molecules that might be prescribed to treat the same symptoms".

Further research is also needed about the dynamic competition among new pharmaceutical products, the effect of different reimbursement policies on the dynamic competition and the effect of this dynamic competition on the price level and its interaction with patient's copayment, to build an in-depth understanding of certain selected practices as implemented in different countries, particularly regarding set-up, risks, success factors and impact on expenditure, reward for innovation and patient access.

Appendix A

The second-order condition associated to program (1) is:

$$(1-\beta)\frac{\Pi_{pp}''\left(\Pi-\Pi^{n}\right)-\left(\Pi_{p}'\right)^{2}}{\left(\Pi-\Pi^{n}\right)^{2}}+\beta\frac{OF_{pp}''\left(OF-OF^{n}\right)-\left(OF_{p}'\right)^{2}}{\left(OF-OF^{n}\right)^{2}}.$$

This expression is negative since:

$$\Pi_{pp}'' = -2\alpha < 0,$$

and:

$$OF_{pp}''\left(OF-OF^{n}\right)-\left(OF_{p}'\right)^{2}<0 \quad \Leftrightarrow \quad \alpha(2-\alpha)\left(OF-OF^{n}\right)-\left(\alpha(2-\alpha)p-a\right)^{2}<0$$

$$\Leftrightarrow \quad \alpha(2-\alpha)\left(OF+OF^{n}\right)+(1-\alpha)^{2}a^{2}>0.$$

Therefore, program (1) is concave and its first-order condition gives us the Nash bargaining solution.

Q.E.D.

Appendix B

Proof of Proposition 1

We prove that the Nash bargaining solution price, p^*, characterized by the first-order condition (2), is also decreasing in the degree of co-payment, α. To prove that, we apply the Implicit Function Theorem to the first-order condition (2), to obtain the relationship between the Nash bargaining solution price, p^*, and the co-payment, α:

$$\left.\frac{dp^{*}}{d\alpha}\right|_{[FOC]} = -\frac{(1-\beta)\dfrac{\Pi_{\alpha p}''\left(\Pi-\Pi^{n}\right)-\left(\Pi_{\alpha}'\Pi_{p}'\right)}{\left(\Pi-\Pi^{n}\right)^{2}}+\beta\dfrac{OF_{\alpha p}''\left(OF-OF^{n}\right)-\left(OF_{\alpha}'OF_{p}'\right)}{\left(OF-OF^{n}\right)^{2}}}{(1-\beta)\dfrac{\Pi_{pp}''\left(\Pi-\Pi^{n}\right)-\left(\Pi_{p}'\right)^{2}}{\left(\Pi-\Pi^{n}\right)^{2}}+\beta\dfrac{OF_{pp}''\left(OF-OF^{n}\right)-\left(OF_{p}'\right)^{2}}{\left(OF-OF^{n}\right)^{2}}}.$$

The denominator of this expression coincides with the second-order condition, and it is thus negative (see Appendix 2). Therefore, in order to prove that:

$$\left.\frac{dp^*}{d\alpha}\right|_{[FOC]} > 0,$$

it is enough to prove that the numerator is positive:

$$(1-\beta)\frac{\Pi_{\alpha p}''\left(\Pi-\Pi^n\right)-\left(\Pi_\alpha'\Pi_p'\right)}{\left(\Pi-\Pi^n\right)^2}+\beta\frac{OF_{\alpha p}''\left(OF-OF^n\right)-\left(OF_\alpha'OF_p'\right)}{\left(OF-OF^n\right)^2}>0.$$

This holds true if:

$$\Pi_{\alpha p}''\left(\Pi-\Pi^n\right)\geq\Pi_\alpha'\Pi_p' \qquad \text{and} \qquad OF_{\alpha p}''\left(OF-OF^n\right)>OF_\alpha'OF_p'$$

$$\Leftrightarrow \quad -2p^*\left(ap^*-2p^{*2}-\frac{a^2}{4}\right)\geq -p^{*2}\left(a-2\alpha p^*\right) \qquad \text{and}$$

$$2(1-\alpha)p^*\left(\frac{a^2}{2}-ap^*+\frac{1}{2}\alpha(2-\alpha)p^{*2}-\frac{a^2}{8}\right)>(1-\alpha)p^{*2}\left(-a+\alpha(2-\alpha)p^*\right)$$

$$\Leftrightarrow \quad p^*\leq\frac{a}{2} \quad \text{and} \quad p^*<\frac{3a}{4}.$$

This is always satisfied:

$$p^*\leq p^n=\frac{a}{2}<\frac{3a}{4}$$

(otherwise, the Nash Bargaining Solution would not be Pareto-efficient).

This ends the proof for our proposition stating that the price of a pharmaceutical drug is increasing in the level of patients' co-payment, when the drug price is the outcome of a negotiation between a government and a pharmaceutical monopoly producer.

Q.E.D.

Appendix C

Proof of Proposition 2

To prove the result in Proposition 2, it is enough to show that program (4) is non-increasing in α, i.e., that:

$$(1-\beta)\frac{\Pi_\alpha^{'}}{\Pi-\Pi^n}+\beta\frac{OF_\alpha^{'}}{OF-OF^n}+\left.\frac{dp^*}{d\alpha}\right|_{[FOC]}\left((1-\beta)\frac{\Pi_p^{'}}{\Pi-\Pi^n}+\beta\frac{OF_p^{'}}{OF-OF^n}\right)\leq 0.$$

We know, from first-order condition (2) in Section 3, that:

$$(1-\beta)\frac{\Pi_p^{'}}{\Pi-\Pi^n}+\beta\frac{OF_p^{'}}{OF-OF^n}=0 \quad\Leftrightarrow\quad \frac{(1-\beta)}{\Pi-\Pi^n}=-\frac{\beta}{OF-OF^n}\frac{OF_p^{'}}{\Pi_p^{'}}.$$

Therefore, to have $\alpha^* = 0$, the following inequality must hold:

$$\frac{\beta}{OF-OF^n}\left(OF_\alpha^{'}-\frac{OF_p^{'}\Pi_\alpha^{'}}{\Pi_p^{'}}\right)\leq 0 \;\Leftrightarrow \frac{\beta p^{*2}}{OF-OF^n}\left((1-\alpha)+\frac{-a+\alpha(2-\alpha)p^*}{a-2\alpha p^*}\right)\leq 0$$

$$\Leftrightarrow -\frac{\alpha\beta p^{*2}}{OF-OF^n}\left(1+\frac{\alpha p^*}{a-2\alpha p^*}\right)\leq 0, \text{ which holds for any } \alpha\in[0,1].$$

Therefore, $\alpha^* = 0$ is the solution to program (4).

We can substitute the Nash bargaining solution co-payment $\alpha^* = 0$ into the first-order condition (2) associated with program (1) to derive the final negotiated price, together with the resulting profit, consumers' surplus, public expenses and overall government objective:

$$p^*=\frac{(3-\beta)a}{8},\ \Pi^*=\frac{(3-\beta)a^2}{8}-F,\ CS^*=\frac{a^2}{2},\ PE^*=\frac{(3-\beta)a^2}{8},\ OF^*=\frac{(1+\beta)a^2}{8}$$

Q.E.D.

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