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CHE Research Paper 25

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April 2007

Background

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Acknowledgements

This article has been strongly improved with comments by Hugh Gravelle, Matteo Galizzi, Michael Kuhn, Pau Olivela, Peter C. Smith, Xavier Martinez Giralt and participants of the iHEA World Congress (held in 2005 in Barcelona) to whom I am grateful. This paper was written with financial support from the *Sub-Programa Ciência e Tecnologia do 2o Quadro Comunitário de Apoiodo Ministério da Ciência e Tecnologia* and *Fundação Calouste Gulbenkian,* both in Portugal.

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Abstract

Within a horizontally differentiation model, we analyse the relative effects of reference pricing and copayment reimbursement on firms pricing and quality strategies as well as on market coverage under different market structures: competitive market, local monopolies and exogenous full market coverage. Results allow us to shed some light on the welfare and total drug expenditure implications of different drug reimbursement policies.

Keywords: Reference Pricing; Co-payment; Product Differentiation
JEL classification: D40; I11; O33

1 Introduction

In this paper we aim at comparing two of the most common drug financing mechanisms: reference pricing and co-payment trying to clarify the broadly acclaimed positive aspects of reference pricing against co-payment systems. Reference Pricing (RP) is a regulatory mechanism aimed at controlling pharmaceutical expenditure in terms of their impact on quality, market coverage and prices. The mechanism consists of clustering drugs according to some equivalence criteria (chemical, pharmacological or therapeutic) and defining a reference price for each cluster. The third party payer, then, will just reimburse not more than that price for each drug on that cluster. If a consumer buys a drug with price lower or equal to the reference price of that cluster, then the co-payment he faces is null. Otherwise, if the drug bought is priced higher than the reference price, the consumer will pay the difference between the reference price and the drug price.

Even though its formulation varies from country to country, RP is generally seen as an efficient mechanism in cutting drug prices by encouraging self restraint, in controlling relative demand of highly priced drugs and in encouraging the appropriate use of drugs. Based on this premise, third party payer's pharmaceutical expenditure would be controlled. However, the effectiveness of this mechanism strongly depends on its ability in enhancing competition in the drug market and on the promotion of financial responsibility by consumers and pharmaceutical firms.

In our opinion, there are two crucial points concerning RP regulation: its efficacy in achieving the goals it aims for, and its discriminatory effects. Concerning the first, it is important to identify the cause of high pharmaceutical expenditure. Indeed, drug expenditure is driven by two factors: high prices and high consumption Lopez-Casasnovas and Puig-Junoy [5] state that RP as a procurement mechanism would indeed be effective if the market fulfils a specific structure, namely, a large buyer, wide product coverage and low demand elasticity. If RP ends up reducing prices, it might not end up reducing pharmaceutical expenditure if drug consumption is very high.

Furthermore, by clustering drugs that might not be perfect substitutes one can expect that due to patient characteristics RP might lead to undesirable effects such as discrimination against firms and patients[1]. If patients select one of the drugs priced below the RP just to avoid the co-payment, we might expect a lower level of treatment effectiveness and even an increase in expenses if, afterwards, the patient needs complementary treatment[2].

[1] Zammit-Lucia and Dasgupta [9] cite the case of a patient suffering different averse affects when using different drugs in the same cluster. The patient suffered severe averse effects from one calcium antagonism with one drug but tolerated the other drug classified in the same cluster.

[2] This situation is aggravated if one considers that patients are not perfectly informed about different drugs. If this is the case, clustering drugs, and attributing a RP to each cluster, distorts even further patients' perception of the adequacy of a drug relatively to another in the same cluster, makes the selection of an adequate drug even more difficult and, therefore,

Weak substitutability between drugs in the same cluster is quite likely to occur due to a wide range of drugs' characteristics: differences in drug quality, performance, differences in chemical preparation, in application form, bio-availability, number and type of indications, side effects, to name some [6]. These drug specifications can be of higher or lower relevance depending on the specific patient to whom the drug will be administrated. If, from a specific patient point of view, there is no interchange-ability then the co-payment becomes non avoidable and, consequently, RP discriminates against the patient whenever opting for a drug whose price is higher than the RP level. Therefore, unjustified inequalities between patients might then arise if RP fails to take into account patient heterogeneity.

The literature on RP is scarce and not all the subjects addressed above have been covered. It urges the development of theoretical set ups in order to better understand incentives of this policy and, even more importantly, to develop optimal Reference Pricing policies.

The studies by Mestre Ferrandiz and Merino-Castelló deserve special attention ([8], [7]). The generic paradox arises on the work by Mestre-Ferrandiz [8]. The author compares the impact of a reference price and a co-payment system in a pharmaceutical market with generic competition. Using a horizontal differentiated model where two firms compete *á la Bertrand*, the author concludes that, just for some RP level, a RP policy can control pharmaceutical expenditure and reduce drug prices. Even though some welfare analysis is developed, the author doesn't explicitly solve for optimal reference pricing.

Merino-Castello [7], studies the impact of RP on the price setting strategies of pharmaceutical firms (generic and branded) on a vertical product differentiated model. The author concludes that RP is indeed effective in enhancing price competition as, after RP had been implemented, branded prices decrease while generic prices remain constant. Nevertheless, this price competition increases the usage of branded drugs in detriment of generics.

We believe, however, that, when patients are heterogeneous, the effect of RP on price competition would be lower because of a market segmentation effect. In fact, if there exists consumer heterogeneity in terms of price elasticity, drugs that are not perfectly substitutable will benefit from some market power even after RP has been introduced, and hence firms will keep on pricing above the reference price level. If this is the case, a subset of consumers would not be able to avoid the co-payment, thus being indeed discriminated by RP. On the contrary, it might also be the case that due to lack of information part of the demand ends not buying the drug that better matches his specifications, switching to a less-than optimal cheaper drug in order to avoid the co-payment. If this is the case, RP might lead to patients being prescribed drugs not perfectly suitable for their health condition, leading to a lower health outcome, or, if patients need complementary treatment, or drugs, even to increases in health care costs. Clearly, to fully take into account patients' heterogeneity, it would be necessary

increases the probability of the need of supplementary treatment. Nevertheless, our model assumes perfect information and therefore this analysis goes beyond the scope of this analysis.

to consider both horizontal and vertical differentiation. In fact, our analysis differs from the two above mentioned contributions in several aspects.

Firstly, in order to capture the effects of both quality and consumers' specificities on the decision of buying a drug, we complement a model of vertical differentiation with an horizontal dimension[3] and for consumer heterogeneity along the horizontal dimension. Thus, while letting each patient have their best-preferred drug, we assume that patients are homogeneous in what concerns their preferences for quality[4]: everything else equal, all the consumers prefer higher to lower quality drugs. As the inclusion of a two dimensional differentiation might be a controversial subject in the pharmaceutical market modelling, a deeper justification may be useful before proceeding.

We intend as *quality* of a pharmaceutical product, all the characteristics affecting its efficacy. Differences in quality might arise from differences in coating, in the production process (for instance, rates of agitation and pH during the production process), in the degrees of purity of the active compound, just to name some. These differences may affect the efficacy of a drug, for instance, by affecting the rate of absorption of the active compound. Despite this homogeneity, consumers differ on their most preferred drug, because of consumers' individual specificities. This assumption can be exemplified in several ways. For example, when faced with the choice of two drugs, clustered in the same group, consumers might be constrained to buy one specific drug due to adverse side effects that arise when combining the second drug with the already active medication, or even because of the side effects of the drug when administrated alone.

Another example is patient intolerance or "neutrality" to a specific active compound. In fact, differences in metabolism, existence of concurrent diseases, gastric pH, bacterial flora, among others, influence the tolerability and efficacy of a specific drug.

To provide a general example, two drugs are said to be horizontal differentiated when, for a specific patient, one has side adverse affects and the other not. On the other hand, the same drugs are said to be vertically differentiated if, for all patients, their efficacy is different due to different rates of absorption caused by drugs' characteristics (e.g. different coatings). Therefore, two consumers that differ on their most preferred drug, when deciding between two drugs with the same active compound (i.e. zero horizontal differentiation), will base their choice on the drugs' levels of quality. This case is well illustrated when we confront generic and branded drugs. As we have claimed before, these drugs might not have the same quality, or, maybe better, consumers might perceive their qualities as different. On the other hand, if the same consumers have to choose between drugs with different active compounds, their choice will depend on

[3] Note that we do not solve for drugs locations, we simply assume that drugs are horizontally differentiated but that the location of each firm having been chosen in a previous stage not contemplated in our model.

[4] One can think of it as quality (vertical differentiation) or perceived quality (virtual differentiation). In the remainder of the paper we will always refer to quality (hence vertical differentiation) as the results from both set-ups are qualitatively equivalent

the trade off between higher (lower) quality and lower (higher) substitutability between the drugs.

In the former case, we might expect RP policies to have a discriminatory effect against firms if quality differences are not accounted for: by reimbursing the same amount for all the qualities, the government is in fact favouring low quality firms and providing incentives to lower the level of quality produced. In the latter case, the discriminatory effects are also against consumers if RP fails to account for patients' heterogeneity[5]. Consequently, it is important to distinguish between the two differentiation dimensions. Even though both have implications on consumers' utility, the source of those effects differs: as concerns *vertical* differentiation, the implications for patients' utility are exclusively due to the drug characteristics, while, concerning *horizontal* differentiation, those effects depend on the consumer specificities. We argue that this is a crucial point to be taken into account in the design of drugs' reimbursement policies.

Moreover, and contrary to the existing literature, we assume patients to have the same finite willingness to pay for quality.

Finally, we also make some considerations on optimal reference pricing policies. Brekke, Nuscheler and Straume [2] have developed a set up that includes some of these features. They study, in a model of spatial competition, the effect of a price regulation mechanism, where the regulator sets the prices, on the quality and location variables. However, in their model patients are homogeneous on their tastes and RP is not analysed.

There are several questions that are worthwhile analysing: If patients do indeed have different degrees of substitutability between two drugs, is it optimal to settle a unique reference price level for those two drugs, independently of patients' degree of substitutability between those same drugs? What are the effects of such a policy on the quality of the drugs in the market? How does this affect welfare? Is it efficient in the control of health expenditure? If yes, who is paying the cost reduction? To answer these questions, we analyse the effect of RP on equilibrium outcomes, having as a benchmark a co-payment system, in a model where drugs are horizontally differentiated and where firms also decide on optimal quality. Firms choose prices and quality, and patients are assumed to be heterogeneous, in that each patient has its best-preferred drug. Within this framework we analyse the impact of co-payment reimbursement and reference pricing on drugs prices, quality and market coverage under different market structures, namely, competitive market, local monopolies and exogenous market coverage, highlighting welfare and cost control implications.

[5] Assuming that patients stil buy their most preferred drug even when its price is higher than the reference price level. Otherwise, if consumers opt for the cheaper drug to avoid the copayment, RP is discriminatory towards these consumers as the healing process is slower or, even worse, these consumers might suffer from negative adverse effects.

2 The model

2.1 A specific model for pharmaceuticals

While the main qualitative results by Economides (1984) [3] clearly still apply to our model, however, in order to better fit the very nature of pharmaceuticals markets, we introduce three important innovations which require particular attention.

First, in our model varieties are treated, unlike Economides [3], as exogenously given. Therefore, our model is clearly unable to provide an equilibrium location choice comparable with Economides result against the acclaimed *"Principle of Minimum Differentiation"*.

Secondly, and crucially, we introduce a second, vertical, dimension in the analysis. In fact, firms endogenously choose the quality levels at which they provide the differentiated drug. This, in turn, directly affects consumers utility, by the new element q_i^{rp}, and therefore substantially drives patients' choice whether, and, if so, what to buy.

Finally, and most importantly, our main objective is to investigate the above *quality-then-price* duopoly game in presence of a *reimbursement policy.* In fact, in most of the pharmaceutical markets in Europe patients are partially subsidized by *third party* payers, such as the national health service or the insurance companies, according to some specific reimbursement rule.

In particular, two principal health care financing schemes have been largely adopted with regards to private expenditure on drugs. On the one hand, the traditional *co-payment* system reimburses the patients a proportional fraction of all drugs' prices. On the other hand, the more recent *reference pricing* system refunds patients a lump sum amount independently of the price of the drugs actually bought.

We argue, however, that different reimbursement policies may have an impact on patients' demand, thus affecting firms' strategies and equilibrium qualities and prices. To better illustrate the role of co-payment and reference pricing in the *quality-then-price* duopoly game are considered in the next sections.

2.2 Firms and products

There are *two firms*, each producing a drug at an identical marginal cost c, for simplicity normalized to zero. Firm 1 produces drug 1 and Firm 2 produces drug 2. Drugs are horizontally differentiated à la Hotelling [4], being located in an unidimensional characteristics space as represented by the unit interval $[0, 1]$. In particular, we assume that varieties $\{x_1, x_2\} \in [0, 1]$ have already been chosen, by firm 1 and 2 respectively, as outcomes of a previous decision process, and that they are therefore treated as exogenously given in our model.[6]

Varieties can be thought as associated each to a specific composite need for a specific health treatment. Equivalently, the unit interval $[0, 1]$ can be interpreted

[6] Locations are assumed to be exogenous since a model with endogenous locations as well as qualities would be intractable

as a cluster containing all the different, but related, drug varieties designed for a close family of comparable health dysfunctions: for instance, any drug treating flue, or gastritis, or throat cancer and so on. On the other hand, drugs are also vertically differentiated in that, for each variety, a continuum of possible quality specifications is possible. Given a specific variety, higher quality drugs are most effective in treating the relative health disease, and are then preferred by any patient having that specific horizontal characteristic. Furthermore, each firm select a *quality-price* strategy in order to maximize its profit function, within a two-stages non-cooperative game.

2.3 Timing

In fact, we assume the *timing* of the model being as follows. Before the game starts, a given pair of drug varieties $x_1, x_2 \in [0,1]$ has been exogenously selected by firms. By a standard convention, $x_1 \leq x_2$.

In the *first stage*, given drug varieties, each firm $i = 1, 2$ chooses, independently and simultaneously, the quality specification q_i^{rp} of its own drug x_i.

In the *second stage*, being both varieties and qualities common knowledge, each firm $i = 1, 2$, again simultaneously and independently, chooses its price p_i.

After the two stages of strategic decisions by the firms, all the consumers just choose which preferred drug variety to buy, if any, and all the payoffs are consequently worked out.

We believe such a timing can fit quite well the genuine essence of competition in drugs markets.

In fact, most of the times, the decision to undertake the production of a specific drug variety implies *long-run* investments, both in *R&D* and in technology, which are planned and implemented long in advance to the consideration of a possible market structure. Indeed, long-run scientific progress, technological advancements, research outcomes and patents are much more likely to represent explanatory factors for the entry into a drugs line, than strategic considerations in terms of actions and reactions by potential competitors.

On the other hand, given the long-run decision of locating at a specific drug variety, *medium-run* adjustments in the relative qualitative level are certainly possible. Moreover, such a decision can hardly be thought as being independent from the consideration of the strategies by competitors already active in the production of the same drug, or of close varieties.

Finally, in the *short-run,* given the varieties and the quality levels produced in the market, each firm can compete by setting its price at an optimal level, given the competitors' pricing behaviour.

2.4 Strategies

The *actions* by each firm $i = 1, 2$ consist of the choice of a quality level $q_i^{rp} \in Q_i = \left[0, \overline{Q}\right]$, in the first stage, and of a price $p_i \in P_i = [0, k]$ in the second stage. We may define $\overline{Q}$ as the maximum attainable quality, the frontier at the state of the art, and $Q = Q_1 \times Q_2$.[7]

A *strategy* for firm $i = 1, 2$ is then represented by a *quality-price* pair $\sigma_i \in \Sigma_i = Q_i \times P_i^Q$, where $P_i^Q : Q \longrightarrow P_i$ is a correspondence from the space of the chosen quality levels to some price.

Finally, no explicit strategic behaviour is described for consumers, who just choose whether to buy or not, and if so, which drug to buy, taking as given varieties, qualities and prices set by firms.

2.5 Equilibrium Solution

The model being a game of perfect information with sequential stages of simultaneous moves, the relevant solution concept for the game is clearly the *Subgame Perfect Nash Equilibrium.*

In particular, finiteness in the number of stages allows us to proceed by *backward induction.* First, we will look for the equilibrium price configurations associated to generic pairs of qualities (q_1, q_2) in the price subgame, then, we will solve for the mutually optimal qualities in the first stage, and we will describe the *equilibrium quality* and *price* strategies of the overall game.

For simplicity, in the analysis we will only focus on *pure strategies* Subgame Perfect Nash Equilibrium.

2.6 Consumers Utility Function and Demand

Consumers are heterogeneous in their tastes for drugs. Each consumer is assumed to have a most preferred drug z that is given by his location on the $[0, 1]$ line segment. In particular, we assume a mass of consumers standardized to 1 and *uniformly distributed* along the unit interval.

Importantly, consumers are endowed with a *finite* instant utility k when consuming one of the drugs, equal across all individuals. Each consumer is assumed to be restricted to buy just one unit from one single drug variety, or none and, in a first instance, we further assume that there are always possible non buyers in the market.

In fact, given drugs' varieties, qualities and prices, patients decide whether to buy one unit of drug x_1, one unit of drug x_2, or, finally, not to buy any drug at all.

In absence of any reimbursement policy, the model closely resembles the one by Economides [3] . In fact, denote, for $i = 1, 2$, x_i the drug i variety, q_i^{rp} the drug i quality, p_i the drug i price, and t the *disutility transportation cost.*

As in Economides (1984), we assume that the consumers' preferences parameter k is finite, and that the disutility incurred by a consumer located at z consuming drug x_i is linear in the distance between the horizontal characteristics, $t\,|z - x_i|$.[8]

[7] This assumption will, further in the chapter, allow us to define an equilbrium for the local monopolies case.

[8] Note that linear transportation costs might lead to the non-existence of a price equilibrium in pure strategies when firms locations are close. Locations must be at most at $\frac{1}{4}$ of distance

Therefore, in our model with *no reimbursement policy*, consumer z utility by consuming drug i, for $i = 1, 2$ is given by

$$U(z; x_i) = k + q_i^{rp} - p_i - t|z - x_i|$$

If the consumer does not buy any of the drugs his utility is assumed to be $U(z; 0) = 0$.

As shown by Economides (1984), the level of k is in fact crucial in the determination of demand and of the consequent market structure. Indeed, for high enough instant utility from treatment, consumers always buy some of the differentiated products and consequently the market is fully covered. This case indeed encompasses the equivalent analysis by D'Aspremont, Gabszewicz and Thisse [1] with an infinite instant utility from treatment. However, for medium levels of the instant utility from treatment parameter, consumers at the edges of the market choose to not consume any of the differentiated commodities, so that the market is only partially covered. Finally, for sufficiently low instant utilities from treatment, also consumers whose horizontal dimension preferences are close to the centre of the market, might be better off by not buying any of the differentiated products. In this case firms behave as local monopolists, selling only to their relative neighborhoods.

3 Co-payment Reimbursement

We first investigate the case where the expenses in pharmaceuticals are reimbursed through a co-payment system: patients are reimbursed a fraction $0 \leq \alpha \leq 1$ of drug prices.

3.1 Demand

By assuming, without loss of generality, unitary transportation cost $t = 1$, the utility derived by a consumer located at z from buying drug i is given by

$$U = k + q_i^{rp} - (1 - \alpha)p_i - |z - x_i| \qquad i = 1, 2 \tag{1}$$

As mentioned above, the finite instant utility from treatment for patients (k) plays a crucial role in the determination of the market coverage.

The level of market coverage, in turn, has an important impact on the degree of competition between firms. Also in presence of a co-payment reimbursement, in fact, depending on market coverage, competition might be tighter or softer.

In particular, market configuration might be such that *duopoly competition* occurs: the two firms actively compete for serving the demand located in the centre of the market. Within this *competitive scenario*, it may also happen that *all* the consumers buy some drugs. In fact, the market is *fully covered* whenever patients show sufficiently high willingness to pay. However, for an intermediate instant utility from treatment k, consumers at the edges of the

to the extremes for a price equilibrium to exist. For a full discussion on this topic see [1] market choose to not consume any of the differentiated commodities. In fact, even in a competitive scenario, the market can also be only *partially covered*. In such a case, reimbursement policy may be seen as not fully effective. Finally, it might also occur that the two firms behave as *natural monopolies*. In fact, for low willingness to pay, also patients located around the centre of the market may opt out of not buying anything. In this case firms behave as local monopolists, selling only to their relative neighborhoods.

The market in the three cases can be represented in the following diagram,

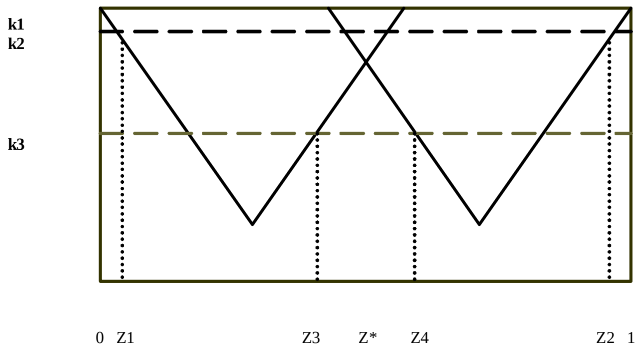


Figure 1: Market structures

Therefore, it can be noticed that demand has a kinked structure and, consequently, is not continuously differentiable everywhere. As this implies that profit functions are also not continuously differentiable everywhere, computing firms' best response functions may be not straightforward. To deal with this, in our model of co-payment scheme, we need to define, for each demand segment, the respective profit function. These demand segments depend both on firms strategies and on the level of consumers' treatment instant utilities.

3.1.1 Intermediate treatment instant utilities: the competitive scenario with partial coverage

For *intermediate* values of k, there are consumers at the edges of the market that do not buy any of the drugs. From now on we will refer to this case, illustrated in Figure 1 (for k_2), as the *competitive scenario* with *partial coverage.* Denote $\overline{z}$ as the location of the consumer who is indifferent between buying the drug produced by firm 1 and the drug produced by firm 2. Moreover, denote as z_1 the location of the consumer indifferent between buying drug 1 or not buying any of the differentiated drugs existing in the market and as z_4 the location of the consumer indifferent between buying drug 2 or not buying any of the differentiated drugs existing in the market. As patients derive disutility from the distance between their most preferred drug and the drug they buy, we have that for $z \in [0, z_1[$ we have $U(z; x_2) < U(z; x_1) < U(z; 0)$. On the other hand, for $z \in]z_1, \overline{z}[$ we have that $U(z; 0) < U(z; x_2) < U(z; x_1)$: consumers located in the interval $z \in \left]z_1, \overline{z}\right[$ prefer buying firm's 1 drug than buying drug 2 or than not buying any drug at all. For $z \in \left]\overline{z}, z_4\right[$ we have that $U(z; x_1) < U(z; 0) < U(z; x_2)$. Finally, also all the consumers located in the segment $z \in \left]z_4, 1\right]$, are better off by not buying any drug at all: $U(z; x_1) < U(z; x_2) < U(z; 0)$. Thus, z_1, z_4 and $\overline{z}$ will be the solutions of $U(z; 0) = U(z; x_1), U(z; x_2) = U(z; 0)$ and $U(z; x_2) = U(z; x_1)$ respectively. Therefore, from the expression for the utility function, we may immediately work out z_1, z_4 and $\overline{z}$ as functions of prices, varieties and qualities:[9]

$$\begin{aligned} z_1(p_1, q_1) &= (1-\alpha) p_1 + x_1 - k - q_1 \\ \overline{z}(p_1, q_1; p_2, q_2) &= \frac{(1-\alpha)(p_2 - p_1) + (x_1 + x_2) + q_1 - q_2}{2} \\ z_4(p_2, q_2) &= k + q_2 + x_2 - (1-\alpha) p_2 \end{aligned} \tag{2}$$

As each consumer demands just one unit of drug and is assumed to be endowed with sufficient income to afford its price, total demand is given by $D = \int_{z_1}^{z_4} f(z)\, dz$ with $D_1 = \int_{z_1}^{\overline{z}} f(z)\, dz$ being served by firm 1 and the remaining $D_2 = \int_{\overline{z}}^{z_4} f(z)\, dz$ consumers by firm 2. Thus, with z uniformly distributed on the support $[0, 1]$, firms demands are given by,

$$\begin{aligned} D_1 &= \overline{z} - z_1 \\ D_2 &= z_4 - \overline{z} \end{aligned} \tag{3}$$

It can be seen that firms' demands depend positively on the consumers' instant utility from treatment k. Moreover, each firm's demand increases in the competitor price and decreases in its own price. The impact of α on firms' demand depend on the pricing strategies

$$\begin{aligned} \frac{\partial D_i}{\partial p_i} &< 0, \quad \frac{\partial D_i}{\partial p_j} > 0 \\ \frac{\partial D_i}{\partial \alpha} &= \frac{1}{2}(p_i - p_j) + p_i \quad i, j = 1, 2 \ i \neq j \end{aligned}$$

The effect of the reimbursement rate α in demand can be decomposed into two effects. Indeed, α affects both the consumers choosing to always buying from one of the firms and the consumers deciding whether to buy one unit of the differentiated product, or no product at all. Then, an increase in α increases the number of the second type consumers and, depending on firms' prices difference,

[9] This assumption will be kept throughout the article

might increase or decrease the number of consumers that switch from one drug to the other.

If firms set equal prices, the impact of α on demand boils down to $\frac{\partial D_i}{\partial \alpha} = p_i$: therefore, the reimbursement rate α has no impact on the allocation of consumers between firms, and only affects, positively, the number of consumers facing the decision of whether to buy something or not to buy at all. If a firm sets a higher price, say $p_2 > p_1$ then an increase in α allows not only the consumers currently not purchasing anything to buy from firm 1, but also the ones currently buying from firm 2 to switch to firm 1 instead.

3.1.2 High instant utility from treatment: the competitive scenario with full coverage

For k sufficiently *high* all consumers buy one of the drugs. In such a case, illustrated in figure 1 (for k_1), for any $z \in [0, 1]$, $U(z; x_i) > U(z; 0)$: all consumers are better off by buying one of the drugs. We refer to this case as the *competitive scenario* with *full coverage*. The market is fully covered and firms' demand functions are given by,

$$D_1 = \overline{z}, \quad D_2 = 1 - \overline{z}$$

Notice that, here, demand does not depend on the instant utility from treatment k. Indeed, in this case, the instant utility from treatment k is assumed to be so big that the market is fully covered, and all consumers buy the differentiated product.

The effect of the reimbursement rate α on one firm's demand depends on the its own price and the price of its competitor,

$$\frac{\partial D_i}{\partial \alpha} = \frac{p_i - p_j}{2} \quad i, j = 1, 2, \, i \neq j$$

While in the previous case the reimbursement rate had an impact on both the choice of whether to buy or not and on the decision from which firm to buy, in this case the reimbursement rate only affects the allocation of consumers between drugs.

Concerning the effect of pricing strategies on firms' demands we have that

$$\frac{\partial D_i}{\partial p_i} < 0, \ \frac{\partial D_i}{\partial p_j} > 0 \quad i, j = 1, 2, \, i \neq j$$

Again, firm's demand is a decreasing function of its own price and increases in the competitor price.

3.1.3 Low instant utility from treatment k: local monopolies

Finally, for sufficiently *low* treatment instant utilities, consumers located close to the centre are better off by not participating in the market and, consequently, firms behave as *local monopolists*. That is, for any $z \in \,]z_2, z_3[$, $U(z; x_i) <$

$U(z;0)$. By referring to Figure 1 (for k_3), let $z_1(p_1)$ and $z_3(p_1)$ be the consumers indifferent between buying from firm 1 while $z_2(p_2)$ and $z_4(p_2)$ be the consumers indifferent between buying from firm 2 or not buying any of the drugs: in such a case we have that for $z \in \{z_1, z_3\}$, $U(z;x_1) = U(z;0)$ and for $z \in \{z_2, z_4\}$, $U(z;x_2) = U(z;0)$. Therefore, from the expression for the utility function, we may immediately work out z_1, z_2, z_3 and z_4 as functions of prices, varieties and qualities:

Each firm demand is then given by,

$$\begin{aligned} D_1 &= z_3(p_1, q_1) - z_1(p_1, q_1) \\ D_2 &= z_4(p_2, q_2) - z_2(p_2, q_2) \end{aligned} \tag{4}$$

Therefore, it can be seen that firms demands are increasing in both the instant utility from treatment k and the reimbursement rate α. Moreover, the magnitude of the effect of α on one firm's demand depends only on its own pricing strategy: $\frac{\partial D_i}{\partial \alpha} = 2p_i$ for $i = 1, 2$. Under local monopolies, the reimbursement rate has no effect on the distribution of consumers between firms. Indeed, under this market structure, firms do not compete for consumers, acting instead as a monopolist for a demand segment.

Demand does not depend on the competitors' price and decreases in firm's own price,

$$\frac{\partial D_i}{\partial p_i} < 0, \ \frac{\partial D_i}{\partial p_j} = 0 \quad i, j = 1, 2, \ i \neq j$$

Naturally, the above described demand structure will imply a step profit function for both firms, that we will describe in depth later.

3.1.4 Market coverage

Finally, let M $(0 \leq M \leq 1)$ be the number of consumers buying the differentiated product, i.e., the market coverage. Generally M is given by

$$M = \min\{z_4, 1\} - \max\{z_2, \overline{z}\} + \min\{z_3, \overline{z}\} - \max\{z_1, 0\} \tag{5}$$

Hence, when the market is served by two local monopolists $M = z_4 - z_2 + z_3 - z_1$. In a competitive market with partial coverage $M = z_4 - z_1$. Finally under full coverage $M = 1$.[10]

Depending on the exogenous parameters k, x_1 and x_2 the market configuration will differ. Indeed we can have a competitive scenario, local monopolies or

[10] Furthermore, for sake of completeness, we should mention that, besides the three scenarios described above, a last case is in theory possible. Indeed, it may potentially occur that the endogenous market structure would be characterized by just a single firm acting as a monopolist over all the demand, while the other firm is pushed out of the market, earning zero profits. However, such a market structure will never arise as the equilibrium outcome of the above two-stages game. Clearly, the reason is a standard undercutting argument: the firm out of the market will always have incentives to undercut on the monopolist's price strategy in order to gain at least some of the market.

exogenous full market coverage. In a competitive scenario and in local monopolies there are several possible sub configurations namely:

- There are non buyers in both extremes of the market (Figures (a) and (e))
- Both extremes of the market are endogenously fully covered in (Figures (b) and (f))
- There are non buyers on the left extreme of the market but on the right extreme all consumers buy (Figures (c) and (g))
- There are non buyers on the right extreme of the market but on the left extreme all consumers buy (Figures (d) and (h))

Graphically and for the competitive scenario,

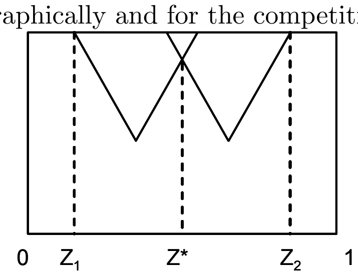


Figure (a)

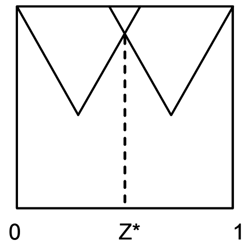


Figure (b)

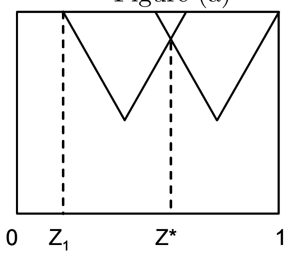


Figure (c)

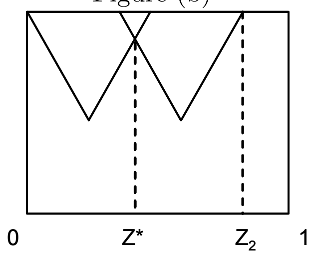


Figure (d)

In the local monopolies scenario,

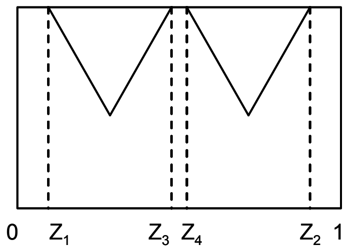


Figure (e)

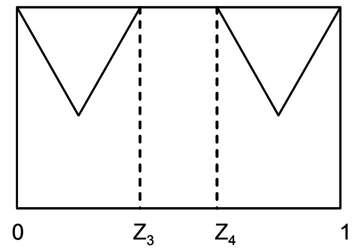


Figure (f)

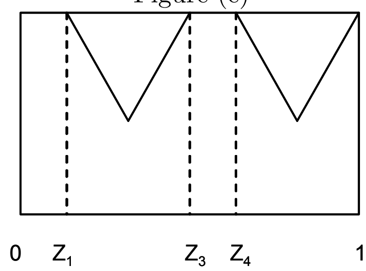


Figure (g)

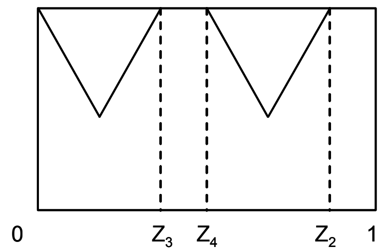


Figure (h)

In the following sections, then, we will analyse in greater details the duopoly two-stages game for the three above scenarios: competitive with full or partial coverage, and local monopolies. However in the main text we focus only on the cases illustrated in figures (a), (b), (e) and (f). The remaining cases can be found in appendix.

3.2 The price game

In this stage firms compete simultaneously in prices. With p_i the drug price of firm i, and D_i the demand faced by firm i, the duopolists profit functions π_i are given by,

$$\pi_i = p_i D_i - \frac{q_i^2}{2} \qquad i = 1, 2 \tag{6}$$

As mentioned before, as the demand function is kinked, firms' profit functions are segmented. Thus, given (4), if

$$0 \leq p_1 \leq p_2 + \frac{q_1 - q_2}{(1-\alpha)} + \frac{x_1 - x_2}{(1-\alpha)} \tag{7}$$

the firm will be a monopolist and the profit function is given by,

$$\pi_1 = p_1 (z_4 - z_1) - \frac{q_1^2}{2}$$

Otherwise, if

$$p_2 + \frac{q_1 - q_2}{(1-\alpha)} + \frac{x_1 - x_2}{(1-\alpha)} \leq p_1 \leq \frac{q_1 + q_2 + x_1 - x_2 - (1-\alpha) p_2 + 2k}{1-\alpha} \tag{8}$$

the market structure will be competitive and the firm 1 profit is given by,

$$\pi_1 = p_1 (\overline{z} - z_1) - \frac{q_1^2}{2}$$

Finally, if

$$\text{if} \quad \frac{q_1 + q_2 + x_1 - x_2 - (1-\alpha) p_2 + 2k}{1-\alpha} \leq p_1 \leq \frac{k + q_1 + x_1}{1-\alpha} \tag{9}$$

the market structure will be characterized by local monopolies and firm 1 profit function is given by,

$$\pi_1 = p_1 (z_3 - z_1) - \frac{q_1^2}{2}$$

We will now look for the Nash Equilibria in pure strategies (*NE*) of the simultaneous moves price game played by the two firms in the last stage of the overall game.

A price p_i such that $0 \leq p_i \leq p_j + \frac{q_i^{rp} - q_j}{(1-\alpha)} + \frac{x_i - x_j}{(1-\alpha)}$ $i, j = 1, 2$ and $i \neq j$, can never constitute a pure strategies Nash Equilibrium of the price subgame. The proof consists of a standard undercutting argument. Within this price range one of the firms will be a monopolists and the second firm would be out of the market, earning zero profits. The latter will always have incentives to undercut on the monopolist price strategy in order to gain the whole demand.

Having ruled out the monopolist case as a candidate Nash equilibrium in the price subgame, we will then focus on the two polar cases: *competitive scenario,* either with partial or full coverage, and the *local monopolists scenario.* Maximizing profits with respect to prices and solving the first order conditions, the Nash Equilibrium in the price game for these two cases is summarized in the propositions that follow,

Proposition 1 *For $k < x_2 - x_1 - \frac{q_1+q_2}{2}$[11] with $i, j = 1, 2$ and $i \neq j$ the market is characterized by two local monopolists and the Nash Equilibrium in the price stage is given by*[12],

$$p_i^{*lm} = \frac{k + q_i^{rp}}{2(1-\alpha)} \qquad i = 1, 2 \tag{10}$$

For $q_1 - q_2 > \frac{7}{11}(x_2 - x_1)$ and $k > \frac{5}{6}x_2 - \frac{3}{2}x_1 + \frac{1}{3} - \frac{q_2+q_1}{2}$[13] the market is

[11] This inequality ensures that $p_i \in \left[\frac{q_i+q_j+x_i-x_j-(1-\alpha)p_j+2k}{1-\alpha}, \frac{k+q_i}{1-\alpha}\right]$ and can be easily computed by plugging the equilibrium prices and solving for k.

[12] Second order conditions are always satisfied. Indeed, $\frac{\partial^2 \pi_i}{\partial p_i^2} = -4 + 4\alpha < 0$.

[13] These are market structure conditions. For reservation prices that satisfy these conditions the market will be competitive. They are easily obtained by plugging the equilibrium prices in the condition $p_i \in \left[p_j + \frac{q_i - q_j}{(1-\alpha)} + \frac{x_1 - x_2}{(1-\alpha)}, \frac{q_i+q_j+x_1-x_2-(1-\alpha)p_j+2k}{1-\alpha}\right]$

competitive and the Nash Equilibrium in the price stage is [14]

$$\begin{aligned} p_1^{c*} &= \frac{7(x_1 - x_2) + 3q_2 - 17q_1 - 14k}{35(\alpha - 1)} \\ p_2^{c*} &= \frac{7(x_1 - x_2) + 3q_1 - 17q_2 - 14k}{35(\alpha - 1)} \end{aligned} \tag{11}$$

For $p_i \in \left[\frac{q_i^{rp}+q_j+x_1-x_2-(1-\alpha)p_j+2k}{1-\alpha}, \frac{k+q_i^{rp}}{1-\alpha}\right]$ with $i, j = 1, 2$ and $i \neq j$[15] firms do not compete for the marginal consumer. There are consumers in the centre of the market that are better off by not buying any of the drugs. Hence, firms behave like local monopolists.

Notice, however, that if, for some parameters' configuration, $\frac{k+q_i^{rp}}{2(1-\alpha)}$ does not fall in the interval $\left[\frac{q_i^{rp}+q_j+x_1-x_2-(1-\alpha)p_j+2k}{1-\alpha}, \frac{k+q_i^{rp}}{1-\alpha}\right]$, then the local monopolist Nash equilibrium can not exist in the price subgame.

In such a case, having ruled out the existence of a NE where just one firm covers the whole market, a Nash Equilibrium of the price subgame, if any, needs to be in the last, competitive scenario.

The latter occurs whenever $p_i \in \left[p_j + \frac{q_i^{rp}-q_j}{(1-\alpha)} + \frac{x_1-x_2}{(1-\alpha)}, \frac{q_i^{rp}+q_j+x_1-x_2-(1-\alpha)p_j+2k}{1-\alpha}\right]$, firms profit functions being $\pi_1 = p_1(\overline{z} - z_1) - \frac{q_1^2}{2}$ and $\pi_2 = p_2(z_4 - \overline{z}) - \frac{q_2^2}{2}$

Equilibrium prices increase with the degree of horizontal and vertical differentiation, the instant utility from treatment k and with the co-payment rate α.

3.3 The Quality Game

Plugging the above found NE prices for each scenario in the relative range of the firms' profit functions, and maximizing with respect to qualities, we obtain the optimal quality levels for the given prices. Substituting back these optimal qualities in the Nash Equilibrium prices, we are then able to fully characterize the subgame perfect NE of the two-stage quality-then-price game. The sub game perfect Nash Equilibrium will depend on the co-payment rate. For low treatment instant utilities (low k), the market will be served by two local monopolists and the SPNE is described in the proposition that follows.

Proposition 2 *For sufficiently low treatment instant utilities firms behave as local monopolists and the SPNE will depend on the level of the preferences parameter k. For $k < 2x_1 - \overline{Q}$ and $k < x_2 - x_1 - \overline{Q}$ the market is partly covered with non buyers on both extremes of the market and the SPNE is characterized by,*

$$q_i^* = \overline{Q}, \quad p_i^* = \frac{k + \overline{Q}}{2(1-\alpha)} \quad i = 1, 2 \tag{12}$$

[14] Second order conditions always satisfied indeed, $\frac{\partial^2 \pi_i}{\partial p_i^2} = -3 + 3\alpha < 0$.

[15] From the market structure conditions

Finally, for $k > 2 - 2x_2 - \overline{Q}$ and $x_1 \leq x_2 - \frac{1}{2}$ the market is partly covered with consumers located around the centre of the market being the only non buyers. The SPNE is given by,

$$\begin{aligned} q_1^* &= 2x_1 - k \\ q_2^* &= 2 - 2x_2 - k \\ p_1^* &= \frac{x_1}{1-\alpha} \\ p_2^* &= \frac{1-x_2}{1-\alpha} \end{aligned} \tag{13}$$

Proof. Proof in Appendix A ■

When the market is served by two local monopolists, for low instant utilities from treatment, i.e., $k < 2x_1 - \overline{Q}$, firms pricing and quality strategies are equal and the market is partly covered with consumers on both sides of the market not consuming any of the drugs. The market coverage is given by $M^c = 2k + 2\overline{Q}$.

Finally, also for $k > 2 - 2x_2 - \overline{Q}$ drugs' prices and qualities differ among firms. Indeed,

$$\begin{aligned} \Delta p^* &= p_1^* - p_2^* = \frac{x_1 + x_2 - 1}{(1-\alpha)} \\ \Delta q^* &= q_1^* - q_2^* = 2(x_1 + x_2 - 1) \end{aligned}$$

For $x_1 + x_2 < 1$ (> 1) drug 1 is sold at a lower (higher) price and quality than drug 2, i.e., $\Delta p^* < 0$ (> 0) and $\Delta q^* < 0$ (> 0). Market coverage is given by $M^c = 2 - 2x_2 + 2x_1$.

In a *competitive scenario* given that the second order conditions are satisfied for $\alpha \in [0, 0.29]$[16] the analysis will be done within this range. More precisely, we will have two sets of results one for $\alpha \in [0, 0.16]$ and other for $\alpha \in [0.16, 0.29]$. Therefore for $\alpha \in [0, 0.16]$ equilibrium will be characterized by full market coverage. Note that a equilibrium with partial market coverage will never arise. The thresholds of k that define the different equilibria are very long expressions, therefore in the propositions that follow we use a label for each of these expressions and relegate the full expression for the appendix.

Proposition 3 *For $k \in [k_{2c}, k_{3c}]$, $x_1 \in \left[x_2 - \frac{1}{2}, \frac{1}{2}\right]$ and $x_2 \in \left[\frac{1}{2}, 1\right]$, the market is fully covered and the subgame perfect Nash equilibrium qualities and prices*

[16] This condition arises by a direct computation of the second order condition.

are[17]

$$q_1^* = \frac{5x_1 + 2x_2 - 1 - 3k}{3} \quad (14)$$
$$q_2^* = \frac{6 - 3k - 2x_1 - 5x_2}{3} \quad (15)$$
$$p_1^* = \frac{2x_1 + 2x_2 - 1}{3(1-\alpha)}$$
$$p_2^* = \frac{3 - 2x_1 - 2x_2}{3(1-\alpha)} \quad (16)$$

Proof. Proof in Appendix A ■

For high instant utilities from treatment, i.e. $k \in [k_{2c}, k_{3c}]$, the market is (endogenously) *fully covered ($M^c = 1$)* and, by standard comparative statics analysis, it immediately follows that,

$$\frac{\partial q_i^*}{\partial \alpha} = 0, \quad \frac{\partial p_i^*}{\partial \alpha} > 0, \quad \frac{\partial q_i^*}{\partial k} < 0, \quad \frac{\partial p_i^*}{\partial k} = 0 \quad i = 1, 2$$

the effect of the reimbursement rate on quality is null, but is positive on equilibrium prices. Furthermore, the preferences parameter k has a negative effect on quality but a nil effect on prices.

Moreover, optimal firms' prices and qualities might differ. These differences are a function of both locations and the reimbursement variable α:

$$\Delta p^* = p_1^* - p_2^* = \frac{4(x_1 + x_2 - 1)}{3(1-\alpha)} \quad (17)$$
$$\Delta q^* = q_1^* - q_2^* = \frac{7}{3}(x_1 + x_2 - 1)$$

Analysing these quality and price gaps, between firms, we have that $\frac{\partial(p_1^* - p_2^*)}{\partial \alpha} = \frac{(1-x_1+x_2)(3+\alpha)}{(\alpha-1)^3}$ and $\frac{\partial(q_1^* - q_2^*)}{\partial \alpha} = \frac{2(x_1+x_2-1)}{(\alpha-1)^2}$. Hence, for $x_1 + x_2 < 1$ (> 1) the drug produced by firm 1 is less (more) expensive and has lower (higher) quality than the drug produced by firm 2. Moreover, the price gap is decreasing (increasing) in the reimbursement variable α.

We will now describe the results for the remaining range of co-payment rates, i.e. for $\alpha \in [0.16, 0.29]$. For higher co-payment rates, i.e. $\alpha \in [0.16, 0.29]$, the above described competitive equilibrium with full market coverage will still hold (even though the range of the preferences parameter k for which it exists will differ) but the local monopolies equilibria will no longer exist[18]. Additionally,

[17] Second order conditions satisfied for $\frac{\partial \pi_i^2}{\partial q_i^2} = \frac{1225\alpha - 35}{1225(1-\alpha)} < 0 \Longrightarrow \alpha < 0.29$

[18] Note that for some parameter configurations we could have that by increasing k the market structure would switch from competitive to local monopolies. Nevertheless, allowing for this possibility would lead to further sub-cases that would not bring further insight on the qualitative results despite of complicating even further the analysis. Therefore we have restrained the analysis from these cases and focus on the range of parameters for which they will not arise.

the existence of an equilibrium with partial market coverage will depend on the relation between firms locations, namely on whether $x_1 > \frac{x_2}{3}$ or $x_1 \leq \frac{x_2}{3}$ holds. Therefore, the SPNE in this case is given by,

Proposition 4 *For $k \in [k_{1c}, k_{3c}]$ and under condition*

$$\Omega_1 = \begin{cases} x_1 \in \left[x_2 - \frac{1}{2}, \frac{1}{2}\right] \\ x_2 \in \left[\frac{1}{2}, 1\right] \\ x_1 + x_2 > \frac{1}{2} \end{cases}$$

the market is fully covered and the SPNE is given by (14)

Proof. Proof in Appendix A ■

On the other hand we will now describe a situation where multiple equilibria can arise.

Proposition 5 *For $\frac{x_2}{3} < x_1 < 0.46x_2$, for $k \in [0, k_{6c}]$ we have multiple equilibria. The sub game perfect Nash equilibrium with partial market coverage is given by,*

$$\begin{aligned} q_i^* &= \frac{51\,(x_1 - x_2 - 2k)}{175\alpha - 73} \\ p_i^* &= \frac{35\,(x_1 - x_2 - 2k)}{175\alpha - 73} \end{aligned} \tag{18}$$

Within the same range of locations, $\frac{x_2}{3} < x_1 < 0.46x_2$, but for $k \in [k_{1c}, k_{3c}]$ instead, there still exists a SPNE with full market coverage characterized by (14).

Proof. Proof in Appendix A ■

Hence, for such range of locations we have two separate equilibria each arising within a specific interval of the preferences parameter k.

Finally, results remain qualitatively the same for $x_1 > 0.46x_2$ with the only prominent difference that there is an interval of (low) values of k within which only an equilibrium with partial market coverage exists.

Proposition 6 *For $x_1 > 0.46x_2$ and $k \in [0, k_6c]$ there is a unique SPNE characterized by symmetric partial coverage (18). Finally for $k \in [k_{1c}, k_{3c}]$ the market is fully covered and the SPNE is given by (14).*

Proof. Proof in Appendix A ■

Analysing the results described in the propositions, for $k \in [k_{1c}, k_{3c}]$ and Ω_1[19] the market is endogenously fully covered ($M = 1$) and the price and quality gaps are given by (17). For $x_1 > \frac{x_2}{3}$ a new equilibrium exists (under the conditions specified in propositions 6 and 7). When this equilibrium holds

[19] Recall that $\Omega_1 = \begin{cases} x_1 \in \left[x_2 - \frac{1}{2}, \frac{1}{2}\right] \\ x_2 \in \left[\frac{1}{2}, 1\right] \\ x_1 + x_2 > \frac{1}{2} \end{cases}$

firms pricing and quality strategies are equal, implying null quality and price gaps, i.e. $\Delta p^* = \Delta q^* = 0$. The market is partially covered and the number of consumers buying a drug is given by,

$$M^c = \frac{105\,(2k + x_2 - x_1)\,(1-\alpha)}{73 - 175\alpha} < 1$$

Finally, results remain qualitatively the same for $x_1 > 0.46x_2$ with the only prominent difference that there is an interval of (low) values of k within which only the equilibrium with partial market coverage exists.

Proposition 7 *For $x_1 > 0.46x_2$ and $k \in [0, k_6c]$ there is a unique SPNE characterized by symmetric partial coverage (18). Instead, for $k \in [k_{1c}, k_{3c}]$*[20] *the market is fully covered and the SPNE is given by (14).*

Proof. Proof in Appendix A ■

4 Reference Pricing

In this section we address the analysis of the effects of reference pricing on firms quality and price strategies. The model structure follows closely the one used in the previous section, only differing in the reimbursement system.

Expenses in pharmaceuticals are reimbursed through a reference pricing system: patients are reimbursed a lump sum amount p_r independently of the drug bought. Therefore, with respect to the Co-payment reimbursement, the reference pricing simply changes the utility function and consequently the indifferent consumers and demand functions.

The utility derived by a consumer located at z from buying drug i is then now given by

$$U = k + q_i^{rp} - (p_i - p_r) - t\,|z - x_i| \qquad i = 1, 2$$

Proceeding in the same way as in the previous section, within a *competitive market* the marginal consumers are

It follows that the demand of firm 1 and 2 are given by

$$\begin{aligned} D_1 &= \frac{3q_1 - q_2 - 3p_1 + p_2 + x_2 - x_1 + 2\,(p_r + k)}{2} \\ D_2 &= \frac{3q_2 - q_1 - 3p_2 + p_1 + x_2 - x_1 + 2\,(p_r + k)}{2} \end{aligned} \qquad (19)$$

Firm i demand increases on firm j prices and decreases on its own price. The reference price and the instant utility from treatment k have a positive impact on demand. Accordingly,

[20] With k_{1c} and k_{3c} standing, respectively, for the treshold k that solves the cosntraint associated with the non negativity of the indifferent consumer location and $q_1 = 0$.

$$\frac{\partial D_i}{\partial p_i} < 0,\ \frac{\partial D_i}{\partial p_j} > 0,\ \frac{\partial D_i}{\partial k} = \frac{\partial D_i}{\partial k} > 0 \quad i,j = 1,2 \quad i \neq j$$

An interesting point, is that these effects do not depend on the reference price value. A variation on p_r has quantitatively the same impact on both firms' demand, and is independent of pricing strategies, and does not affect the allocation of consumers between firms. Moreover, notice that the effect of the pricing strategies on firms' demand is higher than under the co-payment policy.

In the *local monopolists* scenario each firm demand is now given by,

$$\begin{aligned} D_1 &= z_3(p_1, q_1) - z_1(p_1, q_1) \\ D_2 &= z_4(p_2, q_2) - z_2(p_2, q_2) \end{aligned} \tag{20}$$

Also here, we observe that demand is not affected by the competitor's price and is decreasing in firm's own price. Both reference price and the preferences' parameter k have a positive impact on firms' demand: in fact they both increase the number of buyers in the market.

In the three possible market configurations, both firms' demand depend positively on preferences parameter, k, and on the reference price p_r. Moreover the impact of these two parameters on the demand is exactly the same and its magnitude does not depend on firms's strategies.

4.1 The price game

We now look for the pure-strategies subgame perfect Nash Equilibria of the two stages quality-then-price game. As usual, by backward induction, we first describe the Nash equilibria of the simultaneous moves price game in the second stage.

Maximizing profits with respect to prices and solving the system of first order conditions, the Nash Equilibria in the price game will be analysed under each of the three different market structures: monopoly, competitive equilibria and local monopolists.

Once again, for $p_1 \in [0, p_2 + q_1 - q_2 + x_1 - x_2]$ and $p_2 \in [0, p_1 + q_2 - q_1 + x_1 - x_2]$ no Nash Equilibrium in the price game can ever exist. In fact, within this price range one of the firms will be a monopolist and the other would be out of the market. The latter will always have incentives to pick up a different strategy in order to improve profits. Hence we will focus on the two polar cases: competitive scenario and the local monopolists scenario.

Proposition 8 *Under a competitive market, the Nash Equilibrium in the price* *stage is*[21]

$$p_1^{rp*} = \frac{2(p_r+k)+x_2-x_1}{5}+\frac{17q_2-3q_1}{35} \quad (21)$$
$$p_2^{rp*} = \frac{2(p_r+k)+x_2-x_1}{5}+\frac{17q_1-3q_2}{35}$$

Proof. Proof in Appendix B ■

In this case we have that prices are increasing in the reference price and in the instant utility from treatment k.

Proposition 9 *Within the local monopolists scenario* $(x_j - x_i) > \frac{q_i^{rp}}{2} - q_j$ *and* $k > x_j - x_i - p_r - \frac{q_i^{rp}+q_j}{2}$ [22] *with* $i, j = 1, 2$ *and* $j \neq i$ *the Nash Equilibrium in the price stage is*[23]

$$p_i^{lm} = \frac{k+p_r+q_i^{rp}}{2} \quad (22)$$

Proof. Proof in Appendix B ■

Again, it can be noticed that both the instant utility from treatment k and the reference price have a positive effect on the price level.

For $p_i \in [p_j + q_i^{rp} - q_j + x_1 - x_2,\ q_i^{rp} + q_j + x_1 - x_2 - p_j + 2(k+p_r)]$ firm 1 and firm 2 do not compete for the marginal consumer. There are consumers in the centre of the market that are better off by not buying any of the drugs. Hence, firms behave like local monopolists. If p_i^m does not fall in that interval, then the local monopolist equilibrium does not exist, and the only price game Nash equilibrium is the one under the competitive scenario.

4.2 The quality game

Plugging the above found NE prices for each scenario into the relative range of the firms' profit functions, and maximizing with respect to qualities, we obtain the optimal quality levels for the given prices. Substituting back these optimal qualities in the Nash Equilibrium prices, we are then able to fully characterize the subgame perfect NE of the two-stage quality-then-price game.

Proposition 10 *For sufficiently high preferences' parameter k the market is* competitive. *In particular, for* $k \in [k_{ii2}, k_{11}]$[24] *the market is partly covered, and the subgame perfect Nash equilibrium, prices and qualities are given by,*

$$q_1^* = q_2^* = \frac{51\,[2k+2p_r+1-2x_1]}{73} \quad (23)$$
$$p_1^* = p_2^* = \frac{35\,[2k+2p_r+1-2x_1]}{73}$$

[21] Second order conditions always satisfied as $\frac{\partial^2 \pi_i}{\partial p_i^2} = -3 < 0$.

[22] These are market structure conditions. For k's satisfying this condition the market will be served by two local monopolists. Can be easily obtained by plugging the equilibrium prices in the conditions $p_i \in [p_j + q_i - q_j + x_1 - x_2,\ \ q_i + q_j + x_1 - x_2 - p_j] + 2(k+pr)$

[23] Second order conditions always satisfied indeed, $\frac{\partial^2 \pi_i}{\partial^2 p_i} = -4 < 0$.

[24] With k_{ii2} and k_{11} standing, respectively, for the treshold k that ensures, respectively, a competitive market structure and the non-negativity of the indifferent consumers' location.

Finally, for $k \in [k_{2p}, k_{3p}]$ *and under condition* Φ *with,*

$$\Phi = \begin{cases} x_1 \in \left[x_2 - \frac{1}{2}, \frac{1}{2}\right] \\ x_1 + x_2 > 0.66 \end{cases}$$

the market is (endogenously) fully covered and the SPNE is characterized by,

$$\begin{aligned} q_1^* &= \frac{5}{3}x_1 + \frac{2}{3}x_2 - \frac{1}{3} - (p_r + k) \\ q_2^* &= 2 - k - p_r - \frac{5}{3}x_2 - \frac{2}{3}x_1 \\ p_1^* &= \frac{2(x_1 + x_2) - 1}{3} \\ p_2^* &= \frac{3 - 2(x_1 + x_2)}{3} \end{aligned} \tag{24}$$

Proof. Proof in Appendix B ■

For low preferences' parameter $k'$the market will be served by two local monopolies and the SPNE will depend on the state of art of quality, i.e. $\overline{Q}$.

Proposition 11 *If the preferences' parameters ks are sufficiently low the market is served by two local monopolists. For* $k < 2x_1 - k - p_r$[25] *the SPNE is characterized by,*

$$\begin{aligned} q_i^* &= \overline{Q} \\ p_i^* &= \frac{k + \overline{Q} + p_r}{2} \end{aligned} \tag{25}$$

Finally, for $k > 2x_1 - k - p_r$[26] *by,*

$$\begin{aligned} q_1^* &= q_2^* = 2x_1 - k - p_r \\ p_1^* &= p_2^* = x_1 \end{aligned} \tag{26}$$

Proof. Proof in Appendix B ■

For $k \in [k_{ii2p}, k_{11p}]$, the level of market coverage under a competitive market with partial coverage is given by

$$M_{RP}^{pc} = \frac{105}{72}\left[2(k + p_r) + x_2 - x_1\right] \tag{27}$$

Comparing the firms pricing strategies we have,

$$\begin{aligned} \Delta q^* &= q_1^* - q_2^* = 0 \\ \Delta p^* &= p_1^* - p_2^* = 0 \end{aligned} \tag{28}$$

[25] This condition ensures that the constraint $q_i \leq \overline{Q}$ for $i = 1, 2$ is binding.
[26] This condition ensures that the constraint $q_i \leq \overline{Q}$ for $i = 1, 2$ is slack.

Drugs are sold at the same price and have the same quality.

One can see that under a competitive market with partial coverage prices and qualities are increasing in the reference price and in the instant utility from treatment k. However, under a competitive scenario with full market coverage, quality is decreasing with the instant utility from treatment (k) and reference price while prices depend neither on k nor on the reference price. In a sense, in terms of utility and therefore demand, quality has the same impact as both the reference and the preferences' parameter k. Once the market is fully covered, an increase in the reference price and/or preferences' parameter k does not further increase demand (as the market is already fully covered). It, nevertheless, allows the firm to (profitably) decrease the quality of the drug supplied, extracting (the extra) surplus from the consumers.

Still on a competitive market structure for $k \in [k_2, k_3]$ the market is fully covered ($M_{RP}^{pc} = 1$). Comparing drugs' prices and qualities

$$\begin{aligned} \Delta q^* &= q_1^* - q_2^* = \frac{7}{3}(x_1 + x_2 - 1) \\ \Delta p^* &= p_1^* - p_2^* = \frac{4}{3}(x_1 + x_2 - 1) \end{aligned} \tag{29}$$

When the market is fully covered, for a competitive market structure, firms' equilibrium strategies might differ. While under a co-payment reimbursement these differences are functions of both locations and reimbursement rate, under reference pricing they are a function of locations only. Only when firms are located symmetrically, $x_1 + x_2 = 1$, are drugs prices and qualities the same in equilibrium. However, this no longer holds for asymmetric locations. In particular, if $x_1 + x_2 > 1$ (< 1) drug 1 has higher (lower) quality but also higher (lower) price than drug 2. The reason is quite intuitive. For asymmetric locations one of the firms serves a larger neighborhood and, therefore, has a privileged position that allows it to sell its drug at higher price and quality.

Concerning local monopolies, by definition of this market structure, the market is always partly covered, as, at least, consumers located in between the two firms do not buy any of the drugs. Nevertheless, the market coverage increases with the preferences parameter k.

For $k < 2x_1 - k - p_r$ market coverage is given by

$$M^{lm} = 2k + 2\overline{Q} + 2p_r < 1$$

Quality and price gaps are given by,

$$\Delta q^* = q_1^* - q_2^* = \Delta p^* = p_1^* - p_2^* = 0$$

For low ks firms pricing and quality strategies are the same. Indeed, for such low instant utilities even with asymmetric locations the sub market faced by each firm has the same structure in the sense that their distance to the ends of the market is sufficiently big to both firms in order to restrain them from choosing qualities and prices that would allow all consumers located at the ends of the market to consume.

Finally, for $k > 2 - 2x_2 - k - p_r$ market coverage is given by

$$M^{lm} = 2x_1 - 2x_2 + 2$$

In this case, the only consumers that opted out from the market are (some of the) consumers located between the two firms while all the others, including the individuals located towards the ends of the market, always buy one of the drugs. The quality and price gaps are given by,

$$\begin{aligned} \Delta q^* &= q_1^* - q_2^* = 2x_1 + 2x_2 - 2 < 0 \\ \Delta p^* &= p_1^* - p_2^* = x_1 + x_2 - 1 < 0 \end{aligned} \tag{30}$$

Also here, for the locational advantage of firm 2 mentioned before, firm 1 will price at a lower level and supply less quality than firm 2.

5 Exogenous Full Market Coverage

The model developed above did not assume full market coverage beforehand, instead, market coverage was endogenous. However one may argue that this might not be the case specially in the market for prescription drugs. Indeed, the trend in the literature has been to follow the model by d'Aspremont and Thisse that assume an inelastic demand, in that consumers' instant utility k is so high that they are always willing to buy some of the drugs. This scenario corresponds to medical conditions in which consumers obtain very high health benefits from taking a drug, or in which patients suffer very hard health consequences when deprived from any drug consumption. Since we are imposing full market coverage we will designate this model by- exogenous market coverage.

Investigating these scenarios emphasizes the role of competition between the two firms and underlines the effects of reimbursement policies on firms' strategies. In the following, we first describe the case of *co-payment reimbursement*, and then the one of reference pricing.

5.1 Co-payment System

The general model adopted above will be just specified by imposing exogenous full market coverage: $z_1 = 0$ and $z_4 = 1$. Implying the following demands,

$$D_1 = \overline{z}, \qquad D_2 = 1 - \overline{z} \tag{31}$$

which do not depend on the instant utility level k, with

$$\overline{z} = \frac{(1-\alpha)(p_2 - p_1) + (x_1 + x_2) + q_1 - q_2}{2}$$

The impact of the reimbursement rate α on firms' demand depends, qualitatively and quantitatively, on firms pricing strategies

$$\frac{\partial D_i}{\partial \alpha} = \frac{p_i - p_j}{2} \qquad i, j = 1, 2 \text{ and } i \neq j.$$

As, by the full market coverage assumption, all individuals buy one unit of the differentiated product, the reimbursement rate only affects the allocation of consumers between drugs.

Concerning the impact of pricing strategies on firms' demand, from

$$\frac{\partial D_i}{\partial p_i} < 0, \frac{\partial D_i}{\partial p_j} > 0 \quad i, j = 1, 2,\, i \neq j$$

it can be seen that a firm demand is a decreasing function of its own price and increasing in the competitor price. The size of these effects is softened by α.

As, for k sufficiently high, all consumers buy a drug from one of the two firms, from (31), firms profit functions with the co-payment reimbursement are

$$\begin{aligned}\pi_1 &= p_1 \left(\frac{(1-\alpha)(p_2 - p_1) + (x_1 + x_2) + q_1 - q_2}{2} \right) - \frac{q_1^2}{2} \\ \pi_2 &= p_2 \left(\frac{2 - (1-\alpha)(p_2 - p_1) - (x_1 + x_2) - q_1 + q_2}{2} \right) - \frac{q_2^2}{2} \qquad (32)\end{aligned}$$

Again, firms maximize their profits in a two-stage game, by first deciding quality strategies and then prices. The equilibrium is summarized the following Proposition.

Proposition 12 *Under a co-payment reimbursement system the subgame perfect Nash Equilibrium prices and qualities are*[27]

$$\begin{aligned}p_1^* &= \frac{6\alpha - 4 - 3(x_1 + x_2)(1-\alpha)}{(1-\alpha)(9\alpha - 7)} \qquad (33) \\ p_2^* &= \frac{12\alpha - 10 + 3(x_1 + x_2)(1-\alpha)}{(1-\alpha)(9\alpha - 7)} \\ q_1^* &= \frac{6\alpha - 4 - 3(x_1 + x_2)(1-\alpha)}{3(1-\alpha)(9\alpha - 7)} \\ q_2^* &= \frac{12\alpha - 10 + 3(x_1 + x_2)(1-\alpha)}{3(1-\alpha)(9\alpha - 7)}\end{aligned}$$

Proof. Proof in Appendix C ■

It follows immediately that the reimbursement rate α has a positive effect on equilibrium prices and quality. Indeed, proceeding with comparative statics analysis we have that,

$$\frac{\partial p_i}{\partial \alpha} > 0, \quad \frac{\partial q_i^{rp}}{\partial \alpha} > 0, \ \ i = 1, 2$$

Equilibrium price and quality differences are functions of both locations and reimbursement rate α, indeed,

[27] Second order conditions in the price stage satisfied for $\alpha \in [0, 1]$ and in the quality stage for $\alpha < \frac{8}{9}$

$$\Delta p_C = p_1^* - p_2^* = \frac{6(1-x_1-x_2)}{(9\alpha-7)} \tag{34}$$
$$\Delta q_C = q_1^* - q_2^* = \frac{2(1-x_1-x_2)}{(9\alpha-7)}$$

Moreover the drug supplied by drug 1 will be sold at a lower price and lower quality, i.e., $\Delta p_C < 0$ and $\Delta q_C < 0$ [28] This result arises from the nature of the asymmetry on locations that we have assumed, i.e., $1 > x_1 + x_2$.

5.2 Reference Pricing

We now describe the model with exogenous full market coverage under a *reference pricing* policy. Demands are given by $D_1 = \overline{z}$ and $D_2 = 1 - \overline{z}$, with $\overline{z} = \frac{(p_2-p_1)+(x_1+x_2)+q_1-q_2}{2}$

From these demands, firms' profit functions follow:

$$\pi_1 = p_1\left(\frac{p_2-p_1+(x_1+x_2)+q_1-q_2}{2}\right) - \frac{q_1^2}{2} \tag{35}$$
$$\pi_2 = p_2\left(1-\frac{p_2-p_1+(x_1+x_2)+q_1-q_2}{2}\right) - \frac{q_2^2}{2}$$

A crucial aspect to be noticed is that, under reference pricing, the demand functions are affected neither by the instant utility k nor by the reference price p_r Therefore, firms' strategies will be independent from both of these variables. This result is clearly due to the joint outcome of two hypotheses in force. First, by assuming that the market is fully covered, reference pricing can not have any impact on consumers' choice on whether to buy, or not, some of the differentiated products. Secondly, as the reference pricing is a lump sum reimbursement, it can not affect the distribution of consumers between firms.

Furthermore, firm's demand depends positively on the competitor price and decreases in its own price.

Proposition 13 *Under the reference pricing system the subgame perfect Nash*

[28] Note that for $q_i > 0$ and $p_i > 0$ for $i = 1, 2$ the numerators of the equilibrium prices and qualities in (33) can not be simultaneously (i.e. for both firms) positive. Therefore, for negative numerators, the denominators must be negative for strictly positive equilibrium qualities and prices, implying that $\alpha < \frac{7}{9}$. Consequently, for $1 > x_1 + x_2$, $\Delta p_C < 0$ and $\Delta q_C < 0$

Equilibrium prices and qualities is[29],

$$
\begin{aligned}
p_1^* &= \frac{3(x_1+x_2)+4}{7} \\
q_1^* &= \frac{3(x_1+x_2)+4}{21} \\
p_2^* &= \frac{10-3(x_1+x_2)}{7} \\
q_2^* &= \frac{10-3(x_1+x_2)}{21}
\end{aligned} \tag{36}
$$

Proof. Proof in Appendix C ■

It can be seen that, under reference pricing, price and quality differences depend only on firms' locations,

$$
\begin{aligned}
\Delta p_{RP} &= p_1^* - p_2^* = \frac{6(x_1+x_2-1)}{7} \\
\Delta q_{RP} &= q_1^* - q_2^* = \frac{6(x_1+x_2-1)}{21}
\end{aligned} \tag{37}
$$

Once again, for $x_1 + x_2 > 1$ (< 1) drug 1 (2) is sold at a higher (lower) price and at a higher (lower) quality than drug 2 (1).

When the preferences parameter k is high enough, consumers will always buy the differentiated product. This sort of demand rigidity softens competitive pressure on firms, which no longer need to compete for consumers at the edges of the market. While, with partial market coverage, the reference price has an impact on both demand and profits by reinforcing the effect of the instant utility k, in the fully covered market case, the effect of k is so overwhelming that the reference price has no marginal effect. In other words, in the former case, for a given k, the level of p_r can affect profits by increasing demand. Conversely, in the latter case, demand is already at its maximum, so that p_r has no influence on it. In fact, equilibrium prices and qualities do not depend on its level.

On the other hand, the co-payment rate α has an impact on competition between firms for consumers located towards the centre, namely for the marginal consumer z. It is easy to see that, in this case, reference pricing is nested in the co-payment system. Indeed, we have that whenever $\alpha \to 0$, $p_i^c \to p_i^{RP}$: in other words, the reference pricing system is equivalent, in terms of prices and qualities, to a system where there is no reimbursement. The only role of reference pricing is acting as "reimbursement ceiling" for the third party payer. Therefore, contrary to co-payment rate α, reference price can not be used as a regulatory instrument for the determination of prices, qualities or for market coverage.

Finally, by comparing the price and quality gaps across firms, we observe that the relation between price and quality gaps under the two different reimbursement systems depends not only on firms locations but also on the reimbursement variable α.

[29] Second order conditions always verified

$$\Delta p_C - \Delta p_{RP} = \frac{54\alpha(x_1 + x_2 - 1)}{7(9\alpha - 7)}$$
$$\Delta q_C - \Delta q_{RP} = \frac{18\alpha(x_1 + x_2 - 1)}{7(9\alpha - 7)}$$

Interestingly, the difference in the gaps between the two reimbursement systems is not the same for prices and qualities level, $\Delta p_C - \Delta p_{RP} > \Delta q_C - \Delta q_{RP}$.

6 Reference Pricing vs Co-payment: the case of symmetric locations

We will now compare prices, qualities and market coverage of the two reimbursement systems, for all the above described scenarios assuming symmetric locations, i.e., $x_1 + x_2 = 1$[30]. In order to proceed with the comparisons, under endogenous market coverage, we need to order the equilibria for all values of the instant utility from treatment k. This analysis is done in appendix 3.

6.1 Competitive Market Structure

Since the sub-game perfect Nash equilibrium under a co-payment depends on the level of the co-payment rate the comparison analysis will be done for both cases separately. Therefore, for $\alpha \in [0, 0.16]$ comparing the two reimbursement systems leads to the results described in the following proposition.

The thresholds of p_r that define the different equilibria are very long expressions, therefore in the propositions that follow we use a label for each of these expressions and relegate the full expression for the appendix.

Proposition 14 *A co-payment system leads to higher prices and quality level than a reference pricing system and at least the same, if not higher, market coverage. More precisely, for low and medium reference prices, market coverage is equal under the two reimbursement systems for high preferences parameter and is higher under co-payment for low preferences parameter. Instead, for high reference price levels both systems lead to full market coverage.*

Proof. Proof in Appendix D ■

Note that under these parameters' configurations expenditure in pharmaceuticals is always higher under co-payment but also quality is. Moreover, for low preferences parameter, this policy performs better than reference pricing in terms of access to care.

Instead, for $\alpha \in [0.16, 0.29]$ the comparisons (in quality, prices and market coverage) between a co-payment regime and a reference pricing will depend on the reference pricing level and on the instant utility from treatment .

[30] The analysis remains the same as previously stated. Results can be easily derived by substituiting $x_2 = 1 - x_1$ in the results and conditions found above.

Proposition 15 *For low reference price levels, i.e.* $p_r < p_{r2}$*, the equilibria under reference pricing are described by (24) and (23) while under co-payment by (14). Therefore, quality and prices are always higher under a co-payment regime. Concerning market coverage, for* $p_r < p_{r13}$ *market coverage is higher under co-payment while for* $p_r \in [p_{r13}, p_{r2}]$ *in a reference pricing system there are more consumers buying a drug*[31]*.*

Proof. Proof in Appendix D ■

While it is clear that for $p_r < p_{r13}$ expenditure is higher under co-payment for higher reference prices results are ambiguous. Nevertheless, for $p_r < p_{r13}$, even though expenditure in pharmaceuticals is higher for the co-payment system relatively to a reference pricing system, this policy ensures higher market coverage and consequently is superior in terms of access to care. These results are specific to the range of parameters defined in the proposition . Indeed, as we will show in the following propositions, results are very sensitive to changes in both reimbursement instruments and preferences parameter. For example, in proposition 33 for low reference and preferences parameter quality is higher and pharmaceutical expenditure is clearly lower under co-payment than under reference pricing (due to lower prices and lower market coverage). Nevertheless, note that lower public expenditure, in this case, is achieved through not only lower prices but also lower market coverage. While the former might be desirable from a welfare perspective, the latter might jeopardize public policies targeted at tackling inequalities on access to care.

Additionally, for higher preferences parameter we observe that co-payment performances in terms of quality is weaken and becomes lower relatively to the reference pricing policy.

Proposition 16 *For medium reference price levels, i.e.* $p_r \in [p_{r2}, p_{r7}]$*, results are ambiguous.*

Proof. Proof in Appendix D ■

For low treatment instant utilities, i.e. $k \in [k_{ii2p}, k_{2p}]$, the SPNE under a co-payment regime is characterized by (18) and under reference pricing by (23). Under both systems the market is partly covered but the market coverage is lower under a co-payment. For low treatment instant utilities, i.e. $k \in [k_{ii2p}, k_e]$,co-payment system leads to higher quality and lower prices than a reference pricing system. For medium-low instant utility parameter (k) levels, i.e., $k \in [k_e, k_{2p}]$results are reversed, i.e., under a co-payment system drugs have a lower quality and higher prices than under a reference pricing system. For $k \in [k_{2p}, k_{6c}]$the SPNE under a co-payment regime is characterized by (18) and under reference pricing by (24). While under reference pricing the market is fully covered, under a co-payment policy there are consumers that opt-out from the market. The relation between prices and quality between the two regimes is again ambiguous and depends on the instant utility level.

[31] The conditions on the reference price are obtained by subtracting the equilibrium values of co-payment and reference pricing.

For $k \in [k_{2p}, k_g]$ prices and quality are higher under co-payment. While, for $k \in [k_g, k_{6c}]$ under a co-payment system drugs are still sold at higher prices than under reference pricing, but have also lower quality.

Finally, for $k \in [k_{6c}, k_{3p}]$the market is fully covered under both regimes, and the SPNE is characterized by (14) and (24) for the co-payment and reference pricing respectively. For this range of treatment instant utilities, a co-payment system allows higher quality but also higher prices than a reference pricing policy. Also here expenditure in pharmaceuticals depends on the reimbursement instruments and instant utility.

Proposition 17 *For medium-high reference price levels, $p_r \in [p_{r7}, p_{r3}]$[32], the SPNE will depend on the instant utility.*

Proof. Proof in Appendix D ■

For low treatment instant utilities, i.e. $k \in [k_{ii2p}, k_{2p}]$ the SPNE under reference pricing is given by (23) while under co-payment by (18). The market is partly covered under both policies and the market coverage is higher under reference pricing. Prices are lower and quality higher under a co-payment regime.

For $k \in [k_{2p}, k_{6c}]$ the market is still fully covered under a reference pricing system but under a co-payment regime there are consumers not buying a drug. For low treatment instant utilities, i.e., $k \in [k_{2p}, k_g]$ quality is higher under a co-payment system and prices are lower. For medium treatment instant utilities, i.e., $k \in [k_g, k_h]$ prices are still lower under co-payment than under reference pricing but also quality is. For high treatment instant utilities, i.e., $k \in [k_h, k_{6c}]$ a co-payment system leads to higher prices and lower quality than a reference pricing system.

Still for the same range of reference pricing, for $k \in [k_{6c}, k_{3p}]$ the market is fully covered under both regimes, and quality and prices are higher under co-payment.

Proposition 18 *For high reference price levels, i.e., $p_r > p_r$, both reimbursement systems lead to partial coverage. Under a co-payment system drugs are sold at higher quality and lower prices than under reference pricing.*

Proof. Proof in Appendix D ■

Finally, this last proposition clearly describes a scenario where no only co-payment ensures lower pharmaceutical expenditure and higher quality but also full access to drugs.

6.2 Local Monopolies

In the same line as in the competitive scenario also local monopolies show a multiplicity of results. Comparing prices, qualities and market coverage of the

[32] The conditions on the reference price are obtained by subtracting the equilibrium values of co-payment and reference pricing.

two reimbursement systems, results are summarized in the proposition that follows.

Proposition 19 *When firm one is closer to the left end of the market, i.e.* $x_1 < \frac{1}{4}$[33]*,*

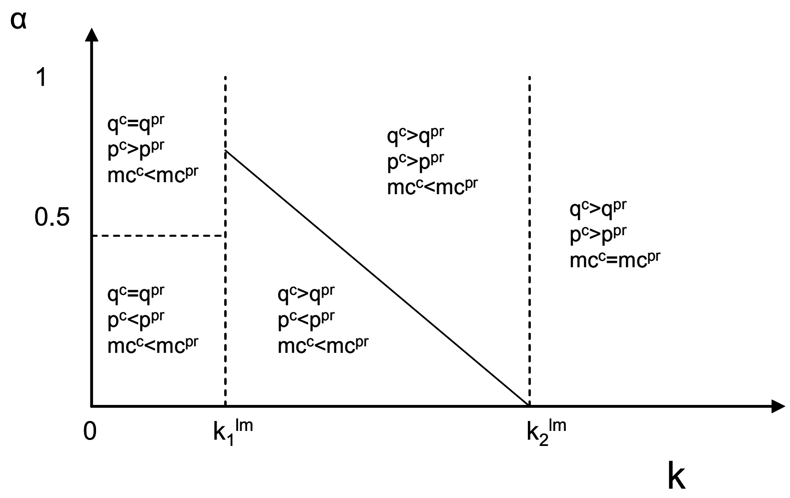
- *For low treatment instant utilities the two systems deliver the same quality and price differences between the two systems depend on the co-payment rate.*
  - *Namely, for a co-payment rate higher than* 0.5*, prices are higher under co-payment*
  - *While for lower co-payment rates, i.e.* $\alpha < 0.5$*, the reverse holds*

  Co-payment system leads to lower market coverage than a reference pricing system.
- *For medium treatment instant utilities a co-payment system delivers higher quality than the reference pricing system but, at maximum, achieves the same market coverage than reference pricing policies. On what concerns prices, for intermediate treatment instant utilities co-payment leads to lower prices than a reference pricing system, while for high instant utility* k *levels prices, are higher under co-payment.*

Proof. Proof in Appendix D ■

The following graph illustrates the results described in the proposition above,

[33] Note that linear transportation costs might lead to the non-existence of a price equilibrium in pure strategies when firms locations are close. Locations must be at most at $\frac{1}{4}$ of distance to the extremes for a price equilibrium to exist. Therefore, under the linear transportation cost assumption in our set up results are confined to the interval $x_1 \in \left[0, \frac{1}{4}\right]$.



Reference Pricing versus co-payment equilibrium qualities and prices for $x_1 < \frac{1}{4}$

7 Welfare

The analysis would not be complete without a welfare analysis. Hence, we will now describe the implications for consumer surplus and total welfare of both reimbursement policies.

Under a *competitive scenario*, with both full and partial coverage the consumer surplus, CS, is given by

$$\begin{aligned} CS &= \int_0^{z_1} U(z,0)f(z)\,dz + \int_{z_1}^{\overline{z}} U(z,x_1)f(z)\,dz \\ &\quad + \int_{\overline{z}}^{z_4} U(z,x_2)f(z)\,dz \int_{z_4}^{1} U(z,0)f(z)\,dz \end{aligned} \tag{38}$$

In fact, the first and the last element represent the utility of the consumers that do not buy any of the drugs, while the second and the third element stand for the utility of the fraction of consumers that buy drug 1 and drug 2 respectively.

Under *local monopolies,* as consumers in the centre of the market do not buy any of the differentiated products, the consumer surplus is represented by

$$CS = \int_{0}^{z_1} U(z,0) f(z)\, dz + \int_{z_1}^{z_3} U(z,x_1) f(z)\, dz \quad (39)$$
$$+ \int_{z_3}^{z_2} U(z,0) f(z)\, dz + \int_{z_2}^{z_4} U(z,x_2) f(z)\, dz + \int_{z_4}^{1} U(z,0) f(z)\, dz$$

The second term corresponds to the utility of the fraction of consumers that buy drug 1, the fourth to the utility of consumers that buy drug 2 and the remaining terms represent the utility of consumers that do not buy any of the drugs.

Using an utilitarian welfare function, social welfare is given by

$$W = CS + \sum_{i=1}^{2} \pi_i - (1+\lambda) R$$

Where R stands for the drug reimbursement paid by the third party payer to the consumers. With (38) and (39) total Welfare in both reimbursement systems for the different market structures can be easily computed by plugging the SPNE found into the welfare function.

Given the diversity of the results described throughout the paper, the comparison between the welfare and surplus of the two reimbursement systems will lead to a multiplicity of cases. Instead of describing the full characterization of these comparisons we will restrict our analysis to two illustrative cases.

We will start with the case for which an equilibrium with full market coverage holds for both reimbursement systems (for the co-payment it is given by (14) and for the reference pricing by (24)). Recall that under this case the prices and qualities were always higher under a co-payment than under a reference pricing system. Then as $\frac{dCS}{dq} > 0$ and $\frac{dCS}{dp} < 0$ and given that,

$$q_i^c - q_i^{rp} = p_r$$
$$p_i^c - p_i^{pr} = \frac{\alpha}{3(1-\alpha)}$$

it is easy to show that the differences in prices perfectly outweigh the differences in quality and, consequently, the two systems lead to the same level of consumer surplus.

On what concerns Welfare there exists a threshold on λ above (below) which the a co-payment system leads to lower (higher) welfare than a reference pricing policy. This threshold is given by $\overline{\lambda}$ and is defined by[34],

$$\overline{\lambda} = \frac{p_r(1+6k-6x_1-3p_r)}{\alpha + 3p_r(\alpha - 1)}$$

[34] The treshold is the level of λ that solves $W^{rp}(p_i^*, q_i^*) = W^c(p_i^*, q_i^*)$

Therefore, we can conclude that, for this illustrative example, even though total expenditure on pharmaceuticals is higher in a co-payment rather than under a reference pricing policy and, for $\lambda < \overline{\lambda}$, welfare is, also, higher than under a reference pricing policy. Therefore, we can conclude that a socially optimal reimbursement system must inevitably account for the trade-off between welfare and cost control.

Consider now the case for which an equilibrium with full market coverage holds for the co-payment system but, under reference pricing, the equilibrium is such that the market is partly covered (the corresponding SPNE are given by, respectively, (14) and (23)). Recall that under this case the prices, quality and market coverage are always higher under a co-payment than under a reference pricing system then as $\frac{dCS}{dq} > 0$ and $\frac{dCS}{dp} < 0$ the relation between the consumer surplus under both regimes depends on the reimbursement variables. Comparing the welfare between the two systems, and proceeding in analogous way than in the previous case, we can conclude that, there exists a cost of public funds threshold that defines which reimbursement system leads to higher welfare. In the same line as in the previous case also here results show that a (socially) optimal reimbursement policy must trade-off the effects on, not only public expenditure (in this case higher under a co-payment) but also on agents surplus. Furthermore, this case raises another crucial consideration that is the implications of a reimbursement policy on access to care. Indeed, since under reference pricing the market is only partly covered, even though public expenditure is lower than under a co-payment definitely this system is weaker in terms of access to care.

8 Conclusions

With the analysis presented we characterized the implications of implementing a reference pricing policy in comparison to a co-payment system, under different market structures. We have been able to show that under a competitive scenario the relation between prices, quality and market coverage between the two reimbursement policies depends not only on the relation between the co-payment rate and the reference price level but also, within the same range of reimbursement variables, on the instant utility k. The multiplicity of the results, shows that neither reimbursement policy can be assumed to be always superior in terms of pharmaceutical expenditure control. Even if drugs prices are lower under such a policy, this might arise at a high welfare cost if quality or market coverage vary negatively by the introduction of such a policy. For asymmetric locations, if firms price asymmetrically and set different quality levels as the competition tightness between the two reimbursement systems differs (at least for some market structures), switching from one policy to the other has significant inequality implications.

Moreover, still from a cost containment perspective, even when prices are lowered by the introduction of, for example, reference pricing, if the market coverage is increased it might be the case that drug expenditure increases. On the other hand, if market coverage is lower, the fact that there are consumers in the market that opt out from buying might increase costs in other types of treatment by, for instance, increasing the number of doctor visits, hospital utilization, among others.

These results focus on absolute comparisons between prices, quality and market coverage for the two reimbursement policies. Nevertheless, for policy design some further considerations on welfare and agents surplus are useful. Concerning this matter, even if a policy does lead to lower expenditure in pharmaceuticals it might do so due to decreased market coverage and/or decreased quality. This stresses the importance of the mechanism behind the design of reimbursement policies. The decision mechanism on drug reimbursement should better encompass access and minimum quality standards policies, in order to achieve the desired effects, both from a cost control and welfare perspective.

Within the set-up where the market is exogenously fully covered results are clear-cut and allow us to derive another important qualitative result. Indeed, under this scenario, competitive pressure on firms is softer in the sense that firms no longer need to compete for consumers at the edges of the market. Under this structure, the effect of the instant utility k is so overwhelming that the reference price has no marginal effect. Indeed, we notice that, in this case, the thresholds defining the area where prices and qualities are higher under one of the two financing schemes, *do not* depend on the reference price level. In fact, as p_r is a lump sum amount, the reimbursement has the same impact on consumers' utility, independently from which firm they buy. Furthermore, as the instant utility k is very high in this case, individuals always choose to buy. Hence the reference price does not influence consumers' decision on whether to opt out from the market. As demand is already at its maximum the reference price has no impact on it. In fact, equilibrium prices and qualities do not depend on its level. On the other hand, the co-payment rate α has an impact on competition between firms for consumers located towards the centre, namely for the marginal consumer z.

We have then shown that the reference pricing is nested in the co-payment system, i.e., reference pricing system is equivalent, in terms of prices and qualities, to a system where there is no reimbursement. The only role of reference pricing is acting as "reimbursement ceiling" for the third party payer. Therefore, contrary to co-payment rate α, reference price can not be used as a regulatory instrument for the determination of prices, qualities or for market coverage.

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