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Reference pricing and cost-sharing: Theory and evidence on German off-patent drugs

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Abstract

This paper evaluates the impact of reference pricing on prices and co-payments in the (German) market for off-patent pharmaceuticals. We present a theoretical model with price-sensitive and loyal consumers that shows that a decrease in the reference price affects the consumers' co-payments in a non-monotonic way: For high reference prices, a marginally lower reference price may lead to lower co-payments. However, for low reference prices a further reduction may result into higher consumer co-payments. We use quarterly data on reference priced drugs covered by the social health insurance in Germany over the period 2007 - 2010 to analyze the empirical effects of reference price reductions. We find that, while prices decrease due to the reduction, co-payments behave non-monotonically and indeed increase if the reference price is sufficiently low.

JEL Classification: L13, I18, I11

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1 Introduction

Since decades, medical expenditures are increasing and many policy debates surrounding health care markets center around cost containment policies while still preserving incentives for providing quality and innovation. This is in particular true for pharmaceutical markets where expenditures have also risen considerably. Additionally, pharmaceutical markets are characterized by a low price sensitivity of consumers due to generous health insurance coverage.

Reference pricing has become an established tool to control pharmaceutical expenditures (Kanavos, 2001) and is now applied in many countries, in particular, in many European countries. The basic idea of reference pricing is that firms can set any drug price, but the maximal amount covered by the health plan is limited to a certain reference price. The potentially positive difference between the price and the reference price has to be covered by the consumer, additionally to other possible co-payments. This policy targets to increase the price elastic behavior of insured individuals, foster substitution to cheaper drugs and thus increase price competition across the pharmaceutical firms.[1]

Another important aspect is how consumer expenses are affected by reference pricing. One concern is that reference pricing shifts pharmaceutical expenditures from health care systems to consumers. Such an unintended effect may realize if firms only react mildly to reference pricing so that consumers simply carry a larger share of the expenses than without reference pricing. Thus, for the impact on consumers it is important to evaluate the size of price effects of reference pricing so as not to increase their burden.

On the empirical side, the effects of reference pricing can be summarized as follows. On average, prices decrease both for brand-name and generic drugs, for example, compared to no regulation for selected German drugs for 1989 and 1994 (Pavcnik, 2002) or compared to a price-cap regulation in Norway in 2003 (Brekke et al., 2009, 2011). Moreover, Brekke et al. (2011) also report that consumers benefit by lower co-payments.

[1] Indeed, the famous RAND Health Insurance Experiment (HIE) with 2000 US families conducted over the years 1974-1979 showed that the demand for pharmaceuticals behaves price-elastic: individuals reduce health care expenditure when co-insurance rates increase (Gruber, 2006).

Recently, how to design reference pricing has received some interest. Kaiser et al. (2013) study the effects of a policy change in Denmark from external reference pricing, where the reference price is set according to an international price comparison, to internal reference pricing where the reference price is based on comparable domestic products. Herr and Suppliet (2012) analyze the effects of introducing co-payment exemption levels, an additional and complementary tool to further increase consumers' price sensitivity.

While a lot is known about the introduction of reference pricing (and related measures), much less is known about reference pricing in a longer-term perspective. Typically, after reference pricing has been introduced, reference prices are adjusted over time so that the relevant reference price is decreasing over time. The important policy question is whether the gains from the introduction of reference pricing are one-time or whether a continued downward adjustment of the reference prices continuously lead to better terms for health care providers and consumers. Augurzky et al. (2009) explore adjustments of reference prices in Germany. They report significant negative effects of a reference price decrease on prices but do not analyze co-payments.

The aim of this paper is to evaluate the effects of a continued adjustment of reference prices. In particular, we do not only analyze prices but, foremost, we focus on the surcharges to be paid by consumers (the co-payments). On the theoretical side, our paper is closest to Brekke et al. (2007) and Brekke et al. (2011) who predict that prices and co-payments are lower if reference pricing is in place. However, we use a price dispersion modeling framework and put less restrictive assumptions on the pricing behavior by brand-name and generic firms.

We present a theoretical model with two drug producers (either two-brand name producers or one-brand name and one generic firm) competing for price-sensitive and loyal consumers. In this model, lower references prices are associated with lower prices. However, the model also shows that a lower reference price affects the consumers' co-payments in a non-monotonic way: For high reference prices, a marginally lower reference price decreases co-payments. However, for sufficiently low reference prices a further reduction increases the consumers' co-payments. Intuitively, consumers only benefit from stricter reference prices if the price effect is sufficiently strong so that it compensates consumers' increased exposure to higher surcharges above the new reference price.

In the second part of the paper we evaluate the impact of reference pricing on prices and co-payments in the (German) market for off-patent pharmaceuticals. We use quarterly data on reference priced drugs covered by the social health insurance in Germany over the period 2007 - 2010 to analyze the empirical effects of reference price reductions. Using a linear fixed-effects approach, we find that, while prices decrease due to the reduction, co-payments indeed increase if the reference price is sufficiently low already before the decrease.

The paper is structured as follows: The theoretical analysis is divided into two parts. Section 2 introduces the general price dispersion modeling framework for two homogeneous products, discusses the main assumptions and derives the base equilibrium. Comparative statics with respect to the reference price show the policy's impact on co-payments, prices, profits, and public expenditures. Section 2.3 then introduces an asymmetric setup with a brand-name drug and a generic drug in a similar modeling framework, where one firm (the incumbent) serves all loyal consumers, and the generic firm only competes for price-sensitive consumers. Evaluating some of the theoretical predictions, the empirical analysis with German data can be found in Section 4. Here, we analyze the adaptation processes of co-payments and prices with respect to reference prices and their reductions. Section 5 finally concludes.

2 Reference pricing with two brand-name pharmaceuticals: A model

In this section, we present a model for reference pricing with two homogeneous firms and with loyal and price-sensitive consumers. We derive the equilibrium prices and co-payments and present comparative statics with respect to changes in the reference price. In Section 3, we extend this baseline model and assume that the two drugs differ such that a brand-name drug competes with a generic drug.

2.1 The model setup

Consider a market with two firms, $i = 1, 2$, that offer a homogeneous prescription drug with the same active ingredient at constant marginal costs. For simplicity and without loss of generality, these costs are normalized to zero. There is a unit mass of consumers demanding one unit of the product each if the reservation price v is not exceeded. Consumers divide into two groups. A share μ of the consumers is price-sensitive and buys from the producer with the lower co-payment. The remaining share $1-\mu$ of loyal consumers only considers to buy from one firm (as long as the co-payment does not exceed their reservation value). Reasons for the existence of loyal market segment may be brand loyalty, asymmetric information such as perceived quality differences or other switching costs (see, e.g., Grabowski and Vernon, 1992; Frank and Salkever, 1997). Loyal consumers equally split up between the two firms such that each firm attracts a share of $(1-\mu)/2$.[2]

The consumer's health insurance covers the drug's price, but the insureds have to pay a co-payment when consuming a drug. Furthermore, there is a reference price system in place. A consumer's co-payment c_i is defined as follows:[3]

$$c_i(p_i) = \begin{cases} \gamma p_i & \text{if} \quad p_i \leq p_r \\ \gamma p_i + (p_i - p_r) & \text{if} \quad p_i > p_r, \end{cases} \tag{1}$$

where $\gamma \in (0,1)$ is the co-payment rate and p_r is the reference price. If the drug price p_i of firm i is less than the reference price, consumers pay a co-payment share (γp_i). Otherwise, consumers have to cover this difference ($p_i - p_r$) in addition to the general share.

We make the following assumption on the reference price:

Assumption 1

$$p_r \in \left(\frac{v(1-\mu)}{\gamma(1+\mu)+2\mu}, \frac{v}{\gamma} \right)$$

Assumption 1 ensures that the reference price matters in the sense that firms price above the reference price as well as below the reference price both with positive probability.

[2]In Section 3 we study an asymmetric version where one firm (the brand-name firm) receives all loyal consumers, and the generic firm competes for price-sensitive consumers only.

[3]The co-payment system is given analogously to the German market. This formulation is also considered in other theoretical contributions (e.g., Miraldo, 2009; Brekke et al., 2011). In practice there is, however, a wide range of reference price systems which differ in the detail, see, e.g., Kanavos (2001).

2.2 The market equilibrium with reference prices

We start by stating the demand function for firm i depending on its consumers' co-payment:

$$D_i(c_i(p_i), c_j(p_j)) = \begin{cases} \mu + \frac{1-\mu}{2} & \text{if } c_i < c_j \\ \frac{\mu}{2} + \frac{1-\mu}{2} & \text{if } c_i = c_j \\ \frac{1-\mu}{2} & \text{if } c_i > c_j \end{cases} \tag{2}$$

A firm's demand depends on whether the co-payment for its drug is lower or higher than the competitor's co-payment. When it is lower, a firm can attract all price-sensitive consumers and its share of loyal consumers. When its co-payment is higher, a firm only sells to its loyal consumers.

As co-payments strictly increase in prices (see Eq. (1)), we can re-write the demand function as follows:

$$D_i(p_i, p_j) = \begin{cases} \mu + \frac{1-\mu}{2} & \text{if } p_i < p_j \\ \frac{\mu}{2} + \frac{1-\mu}{2} & \text{if } p_i = p_j \\ \frac{1-\mu}{2} & \text{if } p_i > p_j \end{cases} \tag{3}$$

A firm's profit function then is defined by

$$\Pi_i(p_i, p_j) = \begin{cases} p_i \left[\mu + \frac{1-\mu}{2}\right] & \text{if } p_i < p_j \\ p_i \left[\frac{\mu}{2} + \frac{1-\mu}{2}\right] & \text{if } p_i = p_j \\ p_i \left[\frac{1-\mu}{2}\right] & \text{if } p_i > p_j \end{cases} \tag{4}$$

This price game is similar to Varian (1980). The main difference lies in the assumption that consumers do not pay the price p_i the firm charges, but only the co-payment c_i. However, as the co-payment is strictly monotonic in the price p_i, the price game can be solved by similar methods as in Varian (1980). The equilibrium is in mixed strategies:

Lemma 1 *There exists a unique Nash equilibrium in which firms price according to the cumulative distribution function*

$$F(p) = \frac{1}{2}\left(\frac{1+\mu}{\mu} - \frac{1-\mu}{p\mu}\frac{v+p_r}{1+\gamma}\right) \tag{5}$$

on $p \in [\underline{p}, \overline{p}]$, *where* $\bar{p} = \frac{v+p_r}{1+\gamma}$ *and* $\underline{p} = \frac{(1-\mu)(v+p_r)}{(1+\mu)(1+\gamma)}$.

Proof: *see Appendix.*

Due to the presence of loyal and price-sensitive consumers, a price equilibrium can only exist in mixed strategies (Varian, 1980; Narasimhan, 1988). At an intuitive level an equilibrium in pure strategies fails to exist as firms would have an incentive to set a high price for the loyal consumers, but a low price for the price-sensitive consumers. The equilibrium price distribution turns out to be such that each firm is indifferent about all prices in its support. In equilibrium, each firm expects to earn the same as it would earn by selling only to its share of loyal consumers at the reservation price:

$$E(\Pi) = \frac{1-\mu}{2}\overline{p} = \frac{(1-\mu)(v+p_r)}{2(1+\gamma)}. \tag{6}$$

We can now use Lemma 1 to determine average prices and co-payments by consumers. The average price a firm charges can be calculated from the above price distribution as

$$E(p) = \int_{\underline{p}}^{\overline{p}} f(p)p dp, \tag{7}$$

where $f(p)$ denotes the density function associated with the equilibrium distribution function $F(p)$. The average price can be re-written as

$$E(p) = \frac{1-\mu}{2\mu}\frac{v+p_r}{1+\gamma}\ln\left(\frac{1+\mu}{1-\mu}\right). \tag{8}$$

Next, we determine the consumers' co-payments, where we have to take into account that loyal consumers only buy from their preferred firm while price-sensitive consumers choose the firm offering the lower price. The average co-payment of a loyal consumer is

$$E(c_L) = \int_{\underline{p}}^{\bar{p}} (\gamma f(p)p)dp + \int_{p_r}^{\bar{p}} (p-p_r)f(p)dp, \tag{9}$$

where the first part reflects the general co-payment share and the second part adds if the price exceeds the reference price.

Price-sensitive consumers always purchase from the firm that offers the lower price, and hence, the lower co-payment. The relevant price for a price-sensitive consumer comes from the cumulative distribution function $G(p) = 1-(1-F(p))(1-F(p))$. The expected co-payment of a price-sensitive consumer is then

$$E(c_S) = \int_{\underline{p}}^{\bar{p}} (\gamma g(p)p)dp + \int_{p_r}^{\bar{p}} (p - p_r)g(p)dp, \tag{10}$$

where $g(p)$ denotes the density function associated with $G(p)$.

Adding up payments by loyal and price-sensitive consumers and taking the group size into account, we calculate the total co-payments paid to the health insurance:

$$\begin{aligned} COP &= (1-\mu)E(c_L) + \mu E(c_S) \\ &= \frac{(1-\mu)[\gamma(\mu(4+3\gamma)+\gamma)p_r^2 + v\gamma(6\mu+4\gamma\mu-2)p_r + v^2(1-\mu)]}{4\mu(1+\gamma)^2 p_r} \end{aligned} \tag{11}$$

As products in the market are homogeneous, total co-payments form an inverse measure of the consumer welfare in the market. The higher the co-payments, the lower is the consumer surplus. Hence, we can use total co-payments to evaluate the impact of a lower reference price on consumer welfare.

2.3 The impact of a change in the reference price

We are now in a position to analyze the impact of an exogenous decrease in the reference price on firms, consumers and on the expenditures of the health insurance system.

Producer prices and profits

We start by analyzing the impact of a decrease in the reference price p_r on the firms' pricing behavior and their profits. We first note that pricing by firms becomes more aggressive as the reference price is decreased. This can best be seen by differentiating the equilibrium distribution function $F(p)$ with respect to p_r, which gives $-\frac{\partial F(p)}{\partial p_r} > 0$. Hence, the equilibrium distribution function before the decrease in the reference price first order stochastically dominates the one after the reduction in the reference price. This directly implies that the average price decreases and, hence, $-\frac{\partial E(p)}{\partial p_r} < 0$. In addition, as a lower reference price leads to lower prices, the firms' profits also decrease with $-\frac{\partial \Pi}{\partial p_r} < 0$ (Eq. (6)). Thus, we have:

Proposition 1 *A decrease in the reference price leads to lower expected prices and lower expected firms' profits.*

In contrast, Brekke et al. (2011) show that a reference price as such leads to lower prices and profits than no reference price.

Co-payments

To measure the impact of a decrease in the reference price on co-payments, and hence, on consumer surplus, is more complicated. On the one hand, as seen above, a decrease in the reference price, tends to decrease the prices set by the firms, which is beneficial for consumers. On the other hand, for given prices, a larger part of the health care expenditures are shifted from the insurance to the consumers. This effect tends to increase the co-payments paid by consumers. It turns out that either effect can dominate.

By differentiating total co-payments (Eq. (11)), Proposition 2 formally evaluates the impact of a change in the reference price on the consumers:

Proposition 2 *Define* $\bar{p}_r = \sqrt{\frac{v^2(1-\mu)}{4\mu\gamma+(1+3\mu)\gamma^2}}$ *and consider a decrease in the reference price. Then,* $-\frac{\partial COP}{\partial p_r} < 0$ *for all* $p_r > \bar{p}_r$ *and* $-\frac{\partial COP}{\partial p_r} > 0$ *for all* $p_r < \bar{p}_r$*.*

Proof: *see Appendix.*

The Proposition shows that the impact of the reference price on the expected consumer co-payments is non-monotonic. A lower reference price decreases the co-payment for large values of p_r, but increases the consumers' payments if p_r is sufficiently low ($p_r < \bar{p}_r$). The trade-offs for consumers turn out to be as follows: For a high reference price, consumers basically only pay their co-payment rate (γ) as the prices charged by the firms only rarely exceed the reference price. On the negative side, however, prices set by firms are on average higher than if facing a low reference price. A decrease in the reference price decreases prices on average. However, the probability that the lower price exceeds the lower reference price increases. The two effects point in different directions and the overall effect is positive for consumers for moderate and high reference prices, but negative for very low reference prices. Hence, a sufficiently strict regulation may indeed hurt consumers. We illustrate this non-monotonic effect of the reference price on co-payments in Figure 1 with different shares of price-sensitive and loyal consumers.

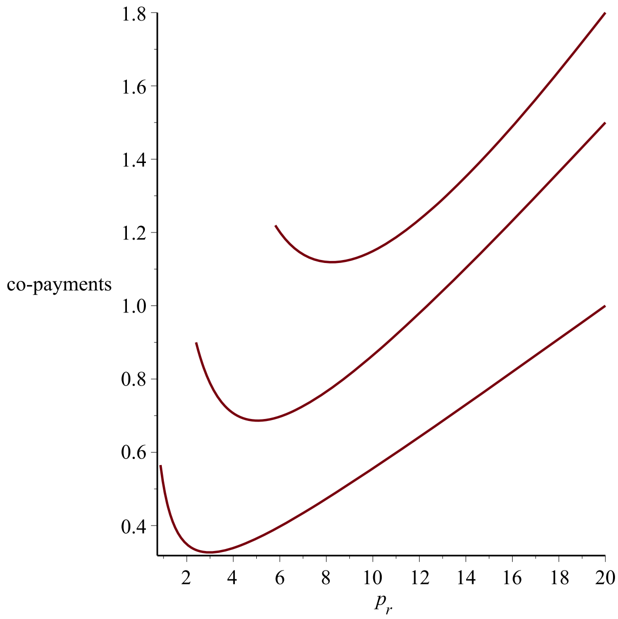


Figure 1: The impact of the reference price on co-payments with parameter values $v = 2$ and $\gamma = 0.1$, and $\mu_1 = 0.1, \mu_2 = 0.25$ and $\mu_3 = 0.5$ from upper right to lower left curve, and $p_r \in (\frac{2-2\mu}{0.1+2.1\mu}, 20)$ (following Assumption 1) .

Additionally to Brekke et al. (2011), who conclude that a reference price leads to unambiguously lower consumers' co-payments than no reference price, we show that within certain parameter ranges co-payments may also increase, since the producer price reduction does not outweigh the burden of the higher cost-sharing. The co-payment increasing effect can be observed at relatively high reference prices, the lower the share of price sensitive consumers μ in the population.

Health care expenditures

Finally, we evaluate how a change in the reference price affects the health insurance expenditures, which are given by:

$$\begin{aligned} EXP &= (1-\mu)\left[\int_{\underline{p}}^{\bar{p}}(1-\gamma)pf(p)dp - \int_{p_r}^{\bar{p}}(p-p_r)f(p)dp\right] \\ &+ \mu\left[\int_{\underline{p}}^{\bar{p}}(1-\gamma)pg(p)dp - \int_{p_r}^{\bar{p}}(p-p_r)g(p)dp\right]. \end{aligned} \tag{12}$$

The first (second) part of the expression reflects the insurance's payments for treating loyal (price sensitive) consumers. This expression simplifies to:

$$EXP = \frac{(1-\mu)}{4\mu(1+\gamma)^2 p_r}\left[(4\mu - \gamma^2 - 3\mu\gamma^2)p_r^2 + 2v(2\mu(1-\gamma^2) + \gamma(1-\mu))p_r - v^2(1-\mu)\right]. \tag{13}$$

Proposition 3 *Consider a decrease in the reference price. Then, the health insurance's expenditures decrease, i.e.,* $-\frac{\partial EXP}{\partial p_r} < 0$.

Proof: *see Appendix.*

Thus, the health insurance always benefits from decreasing reference prices.

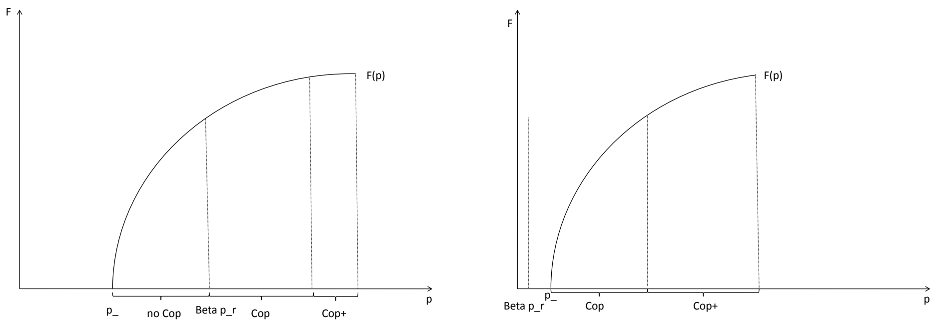
2.4 Co-payment exemptions: An extension

This section considers an extension of the base model where we introduce co-payment exemption levels. In Germany, such exemption levels have been introduced in some selected clusters of reference priced drugs. According to this rule, consumers are exempt from any co-payment if the price of a drug is below a level of 70% of the reference price.

As in the empirical analysis of the German pharmaceutical market in Section 4 this will become highly relevant, we now consider an extension of the base model where consumers are exempt from a co-payment if the price is below a level of βp_r. This new co-payment scheme with exemption levels then reads as follows:

$$c_i(p_i) = \begin{cases} 0 & \text{if} \quad p_i \leq \beta p_r \\ \gamma p_i & \text{if} \quad \beta p_r < p_i \leq p_r \\ \gamma p_i + (p_i - p_r) & \text{if} \quad p_i > p_r. \end{cases} \tag{14}$$

For analytic tractability we impose the assumption that price-sensitive consumers who can choose among several exempt drugs choose the one with the lowest price. This assumption allows us to analyze the price game between the two firms as in the base model. Indeed, the price game is unchanged to the base model as the demand function of the base model (Eq. (3)) still applies, meaning that the price equilibrium, described in Lemma 1, also applies. Obviously, the derivation of equilibrium co-payments to be actually paid by the consumers is different as the co-payment scheme is different.



(a) moderate p_r (b) strict p_r

Figure 2: Exemption levels and the reference price

Let us now examine, given the firms' equilibrium pricing strategies, under which circumstances consumers may be exempt from co-payments. Obviously this can only happen if firms do charge lower prices than βp_r in equilibrium, that is, if the lower bound of the price support ($\underline{p}$) is lower than the exemption level,

$$\underline{p} < \beta p_r \Leftrightarrow \frac{(1-\mu)(v+p_r)}{(1+\mu)(1+\gamma)} < \beta p_r. \tag{15}$$

This situation is represented in the left panel of Figure 2.

From Eq. (15) it also follows that it depends on the reference price whether consumers are exempt from co-payments. Let $\hat{p}_r = \frac{(1-\mu)v}{(1+\mu)(1+\gamma)\beta-(1-\mu)}$, then consumers can only be exempt if the reference price is sufficiently high ($p_r > \hat{p}_r$). However, if the reference is sufficiently low ($p_r \leq \hat{p}_r$), then the lower bound of the price support exceeds the exemption level and consumers are never exempt from co-payments in equilibrium. This is illustrated in the right panel of Figure 2.

We can now discuss the impact of a reduction of the reference price on the consumers' co-payments. As in the base model, a reduction of the reference price can increase consumer co-payments as consumers are more likely to be charged prices that exceed the reference price (see Proposition 2). However, there is a second effect that works via the exemption level. With stricter reference prices the likelihood of being charged a price lower than the exemption level decreases. Indeed, if the reference is sufficiently low, the exemption never occurs in equilibrium.

The preceding analysis suggests that the impact of a reduction in the reference price can be more negative for the consumers in the presence of exemption levels. Not only do prices above the reference price occur more often, but also prices below the exemption level occur less often.

3 The model with heterogenous firms: Generic competition

In many pharmaceutical markets, after the patent expiry, the former patent-holder faces competition from generic producers. Therefore, in this section, we briefly discuss competition between an incumbent and an entrant of a generic product. Our main aim is to show that also in this case a decrease in the reference price can lead to higher out-of-pocket payments for consumers.

Denote the incumbent by Firm 1 and the generic entrant by Firm 2. As in the base model, there is a fraction μ of price-sensitive consumers who purchase from the firm that offers the lower co-payment (price). In contrast to the base model, however, loyal consumers only buy from the incumbent.[4] The immobility of some of the incumbent's customers can be explained by different switching costs. Alternatively, the brand-name advantage of the incumbent might stem from a perceived quality advantage because of longer experience or because of a higher advertising intensity of the brand-name drug (see e.g., Brekke et al., 2011).

Assumption 1 is replaced by:

Assumption 2

$$p_r \in \left(\frac{(1-\mu)v}{\mu+\gamma}, \frac{v}{\gamma} \right)$$

We start by providing the profit functions of the two firms:

$$\Pi_1^a(p_1, p_2) = \begin{cases} p_1 \left[\mu + (1-\mu)\right] & \text{if } p_1 < p_2 \\ p_1 \left[\frac{\mu}{2} + (1-\mu)\right] & \text{if } p_1 = p_2 \\ p_1(1-\mu) & \text{if } p_1 > p_2, \end{cases} \tag{16}$$

[4] In the base model, each firm attracted half of the loyal consumers.

$$\Pi_2^a(p_1,p_2) = \begin{cases} 0 & \text{if } p_1 < p_2 \\ p_2\frac{\mu}{2} & \text{if } p_1 = p_2 \\ p_2\mu & \text{if } p_1 > p_2. \end{cases} \tag{17}$$

The price game is similar to the one in our base setup with symmetric firms, the only difference being that Firm 1 obtains all loyal consumers. As the co-payment is strictly increasing in the price, we can solve this model by similar methods as in Narasimhan (1988), who analyzes an asymmetric version of Varian (1980). There is a unique equilibrium in mixed strategies and Firm 1 has a mass point at $\bar{p}$:

Lemma 2 *There exists a unique Nash equilibrium in which firms price according to the cumulative distribution functions*

$$F_1^a = 1 - \frac{(1-\mu)(v+p_r)}{(1+\gamma)p} \tag{18}$$

and

$$F_2^a = \frac{1}{\mu} - \frac{(1-\mu)(v+p_r)}{(1+\gamma)\mu p} \tag{19}$$

on $p \in [\underline{p}^a, \overline{p}^a]$*, where* $\underline{p}^a = \frac{(1-\mu)(v+p_r)}{1+\gamma}$ *and* $\overline{p}^a = \frac{v+p_r}{1+\gamma}$.

Proof: *see Appendix.*

One can see that the incumbent's price first order stochastically dominates the price of the entrant, i.e., $F_1^a < F_2^a$ (see, e.g., Narasimhan, 1988). This immediately implies that Firm 1 on average charges a higher price than Firm 2. The intuitive reason is that the opportunity costs for competing for the price-sensitive consumers are higher for Firm 1 than for Firm 2 as Firm 1 would lose revenues from its loyal consumers when lowering the price.

Given the price equilibrium we can now determine the impact of a stricter reference price. We find:

Proposition 4 *i) A decrease in the reference price leads to lower expected prices, profits and health insurance expenditures.*

ii) Define $\hat{p}_r = \sqrt{\frac{v^2(1-\mu)}{2\mu\gamma+(1+\mu)\gamma^2}}$ *and consider a decrease in the reference price. Then,* $-\frac{\partial COP^a}{\partial p_r} < 0$ *for all* $p_r > \hat{p}_r$ *and* $-\frac{\partial COP^a}{\partial p_r} > 0$ *for all* $p_r < \hat{p}_r$.

Proof: *see Appendix.*

This proposition mirrors the results from the symmetric setup. Prices and firm profits decrease with stricter reference prices and also expenditures of the health care insurance are reduced. In addition and analogously to the symmetric case, the non-monotonic effect of a decreasing reference price on the consumer's co-payments carries over to the case with generic competition. However, a comparison with Proposition 2 shows that $\hat{p_r} > \bar{p}_r$. Thus, in a market with a generic firm consumers may already be hurt at higher higher reference price levels. The reason is that competition between two asymmetric firms is less strict than competition between two symmetric firms so that prices react less strictly to changes in the reference price system. As a consequence, co-payments increase more easily.

4 Empirical evidence using German reference price data

This section provides empirical evidence on how changes in the reference price affect prices and co-payments in the German pharmaceutical market. We use German data over the years 2007 to 2010 and differentiate two different firm types. Before presenting the empirical results, we briefly provide an overview of the most important regulations in Germany.

4.1 Institutional background

In Germany, the reference price is set by the Federal Association of Statutory Health Insurance Funds (FASHI) for each reference price cluster. After normalization of prices according to package size, dosage form, and concentration, the reference price has to lie within the smallest 30% of the total price interval. In addition, at least 20% of all packages and of all prescriptions must be available for prices equal to or below the reference price at the time of implementation. Products with a market share of less than 1% are not considered. The FASHI reviews reference prices regularly and adjusts them if necessary. Revision cannot be foreseen by firms but are announced one quarter before the adjustment. We will use these adjustments of the reference prices to test our theoretical results with respect to pricing and co-payments. Note that the pharmaceutical companies can neither negotiate about the drug belonging to a specific reference price group nor about the reference price itself. The whole procedure is exogenous to the producers but the timing may depend on the observed prices within the cluster.

Compared to other European countries and to the US, the fraction of drug co-payments is small in Germany (A. et al., 2008). However, total drug co-payments added up to 1.76 billion euros (2.40 euros per package) in 2010 (ABDA, 2011). Since January 2004, consumers pay 10% of the pharmacy's selling price, p_i, within the minimum of 5 euros and the maximum of 10 euros (plus the difference to the reference price ($p_i - pr_i$), if positive).

Since 2006, the FASHI can also introduce co-payment exemption levels (CELs) in selected clusters of reference priced drugs if it expects savings from this means (§31 (3), 4 SGB V). In general, the maximum price of an exempt drug lies 30% below the respective reference price (p_r). If firms decrease the price below this exemption level, consumers do not need to co-pay for the drug. This selection is important for the empirical analysis since changes in the reference price affect co-payments more heavily in the groups with (also changing) CELs.

We will capture the selection issue by splitting the full population into two samples: Those reference price clusters with a CEL and those without.

4.2 Data and descriptive statistics

We observe quarterly price data at the package level of all drugs belonging to a reference price cluster in Germany for the years 2007 to 2010. This data has been used by Herr and Suppliet (2012) before. By the end of 2010, the reference price drugs covered 71.7% of all drug packages sold and 36.6% of all pharmaceutical expenses in Germany (Pro Generika, 2011). Prices (p), reference prices (p_r) and exemption levels (CEL) are based on the pharmacies' selling prices including VAT and the pharmacist's reimbursement. We trace products by a unique identification number (PZN) by firm name, active ingredient, package size, strength, form of administration, and reference price cluster. Information on reference prices are publicly available (DIMDI, 2011). We augment the data with product-specific co-payment exemption levels, where applicable FASHI (2011).

We restrict our analysis to those drugs for which a reference price had been decreased during the time span of interest. Thus, our final sample includes about 240,000 observations out of the full population of 392,000 observations for the 16 quarters across 2007 to 2010.

Table 1 provides a descriptive overview of the main variables under study over 16 quarters and separates packages[5] by firm type. In the following, we differentiate between the 41,000 observations, which never face an additional CEL and those which can choose to set the price below the co-payment exemption level (191,000 observations) after the introduction of the CEL in their reference price cluster.

Table 1: Descriptive statistics by firm type and availability of CEL, 2007-2010

		Always CEL		Never CEL	
type	variable	mean	sd	mean	sd
Generic	price	43.22	106.91	14.69	6.93
	ref. price	54.92	120.97	15.84	8.95
	co-payment	1.94	4.18	5.11	0.82
	# of firms	102.66	73.81	100.86	72.36
	N	130,245		32,760	
Brand	price	92.50	190.89	18.50	15.42
	ref. price	100.59	214.48	17.54	17.41
	co-payment	7.06	9.17	6.53	5.44
	# of firms	113.67	59.13	128.53	66.52
	N	61,555		9,543	

CEL : Co-payment Exemption Level = $0.7\cdot$ ref. price

Table 1 shows, that branded drugs cost more than generic drugs confirming our first hypothesis from Proposition (**??**). It also becomes clear that more expensive drugs' clusters are selected for the new policy of co-payment exemption levels (CEL), while in low-price clusters the CEL is not necessary as a further means to reduce prices. Furthermore, by construction, average co-payments are much lower for generics when a CEL is available (2.20 EUR versus 5 EUR) due to the high share of exempted packages.

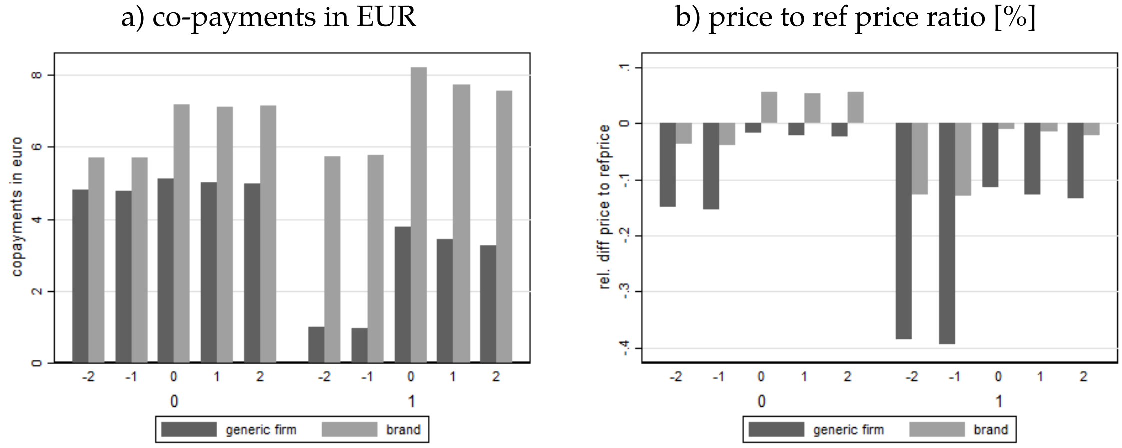
Now, we consider the case that the reference price is decreased.[6]

The most important result of our model concerns the non-monotonic behavior of the co-payments. We showed that due to a reduction of the reference price, co-payments by consumers may increase or decrease. In particular, a moderate decrease in the reference price should lead to a reduction of the co-payment. A large decrease should lead to an increase in the co-payment.

[5]Each combination of a firm and an active ingredient defines a product of which different packages (e.g. different package sizes) may be available.

[6]We do not analyze increases in the reference price, since we only observe 640 events (0.003% of our sample).

Figure 3: Co-payments (and changes) by firm type around the change in the reference price in $t = 0$



Data: prescription drugs with decrease in reference price in quarter 0 between 2007-2010. Left panel (0): a co-payment exemption level (CEL) had been NEVER introduced in the respective reference price cluster, Right panel (1): CEL ALWAYS observed during the 16 quarters

To get more insights, we now compare different bar charts by firm types and CEL status in Figure 3. Figure a) shows that co-payments increase immediately after a decrease of the reference price where this increase fades out for packages of generic firms three quarters after the reduction. Innovators, however, remain on a higher level. Figure 3, chart b), illustrates one way that co-payments may increase with lower reference prices. It shows how the price to reference price ratio evolves over the quarters around the adjustment of the reference price ($t = 0$). It can be easily seen that this ratio is reduced across all firm types and that on average innovators and importers price above the reference price after the adjustment. Furthermore, the price dispersion is also reduced since all firm types price closer to the reference price than before.

Both figures show different patterns for the two samples (with and without co-payment exemption levels (CEL)). If a CEL is not introduced (left, 0), prices are lower and do not change much over time. Co-payments stay fairly constant at around 5 EUR for both drug types. Those groups which face a CEL even before 2007 (right, 1) comprise higher priced drugs and increasing competition. Here, the jump in co-payments is high since prices do not only exceed the lower reference price but also the lower CEL if both are reduced and prices are not adjusted accordingly.

4.3 Estimation strategy and results

The general model is applied to two different outcomes (prices and co-payments) using two different samples. We run log-linear fixed effects estimators for each drug package i at time t

$$\log(y_{it}) = \beta_0 + \sum_{b=1}^{2} \beta_b \log(pr_{it})^b \cdot brand_i + \sum_{b=1}^{2} \gamma_b \log(pr_{it})^b \cdot generic_i \\ + \delta_k \log(firms)_{it} + \alpha_i + \tau_t q_t + \epsilon_{it} \tag{20}$$

where $y \in$ (price, co-payment), pr reference price, firms is number of firms within i's cluster, q the quarter $t \in (2, 16)$, ϵ a normally distributed error, and α_i the unobserved time-constant product-specific heterogeneity. If $b = 2$ we add a quadratic interaction effect of the reference price on prices and co-payments.

4.3.1 Estimation results

We start by considering the impact of decreasing references prices on drugs without any exemption level. Table 2 presents the main results of our study. We find that price changes in response to a change in the reference price are only modest (a 1% reduction leads only to a roughly .03% reduction in the price) if we do not account for a non-linear relation. This is similar for brands and generics. However, for all specifications, we find that co-payments can increase with a reduction in the reference price where the effect is very strong for branded drugs but also significant, though smaller for generics. When we allow for a quadratic relation between the reference price and the price or co-payments, we find a similar u-shaped pattern for co-payments as our theoretical model predicts.

The result regarding price reductions is consistent with empirical evidence. In her empirical analysis of potential consumer out-of-pocket expenses and pharmaceutical pricing in Germany, Pavcnik (2002) concludes that depending on the therapeutic group and specification, price reductions range from 10% to 26%. Brekke et al. (2011) find similar effects for Norway.

If we also consider those drugs where a CEL is always in place, we look at a different and much bigger sample. Table 4 in the Appendix reproduces the regressions from Table 2. Although this sample comprises more expensive drugs on average, the effects

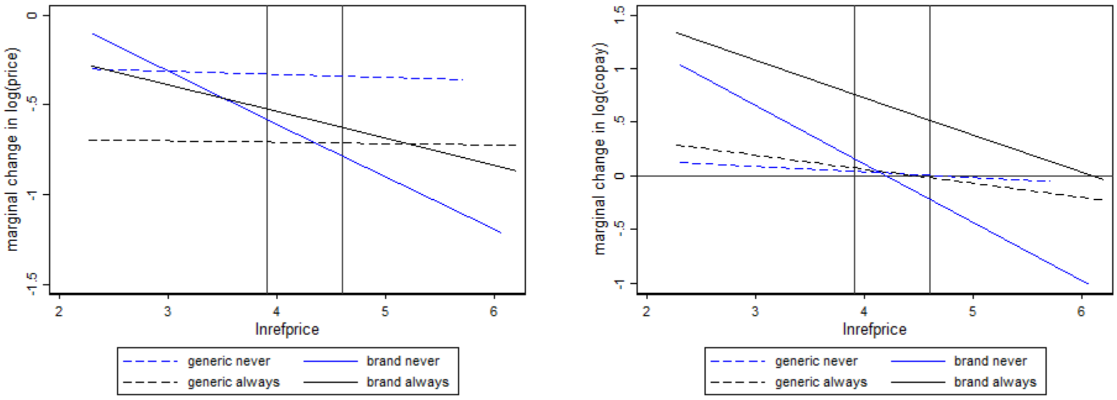
Table 2: Never - CEL: prices and co-payments

	(1) log(price)	(2) log(price)	(3) log(co-pay)	(4) log(co-pay)
log(reference price) x generic	0.315***	0.261**	-0.0854***	-0.245***
	(0.0128)	(0.0864)	(0.0177)	(0.0738)
log(reference price)^2 x generic		0.00855		0.0261*
		(0.0149)		(0.0123)
log(reference price) x brand	0.293***	-0.577**	-0.682***	-2.290***
	(0.0291)	(0.209)	(0.0734)	(0.422)
log(reference price^2) x brand		0.148***		0.273***
		(0.0352)		(0.0728)
log(firms per group)	-0.00343	-0.00172	0.00760	0.0109
	(0.00628)	(0.00655)	(0.00761)	(0.00799)
Constant	1.858***	2.197***	2.233***	2.927***
	(0.0376)	(0.123)	(0.0635)	(0.167)
Observations	41,917	41,917	41,917	41,917
R^2	0.391	0.401	0.199	0.219

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Figure 4: Marginal change of prices and co-payments depending on reference price
a) marginal effect on price b) marg. effect on co-pay



Vertical lines at $\log(50)$ and $\log(100)$.
Sample: ref price cut at 500 EUR (less than 1% of reference prices), co-payment $= 0$ dropped

are quite similar. However, we need to drop those drugs which are actually exempt from co-payments due to a price below the threshold, since the logarithm of zero is undefined (96,000 out of 183,000 observations).

4.3.2 Summary of effects on prices and co-payments across all samples

Figure 4 presents graphs of the cumulative marginal effects in the quadratic model for both samples by drug type. If the reference price is **decreased** by 1%, the price for all drugs always decreases. However, changes in the branded drug's price depend strongly on the level of the reference price and range between -0.1% to over 1.2% while changes in the generic drugs' price are quite stable across all reference prices. Looking at the co-payments in panel b), the reactions differ again by drug type where the branded drugs react more. However, now, co-payments may increase up to 1.3% for a branded drug if the reference price is already low before the 1% decrease, especially if a CEL is available in the reference price cluster.

The intuition behind these strong effects is that, as we also predicted in the extension to our model with exemption levels, reference prices may be exceeded if prices are not decreased sufficiently much. Thus, the consumer carries the absolute difference while the health insurance saves by lower reimbursements.

Since reference prices may be endogenous, we cannot claim our results to be causal.

However, we only measure short term effects and argue that a single firm is probably not strong enough to strategically influence the reference price in a cluster with 13 other firms on average. We also do not observe price increases before the adjustment which would point into the direction of strategic behavior. We also will be controlling for the censoring of the co-payment at 5 EUR. First results show that censoring does not play a role for the discussed effects.

4.4 Extensions

Additionally, we would like to explore how the exempted packages we dropped in Table 4 differ from the non-exempted packages. Table 3 reports regression results on the probability that drugs are actually priced below the CEL (if available). As the reference price becomes smaller this probability increases. In contrast to the case without a CEL, this effect seems to be quite strong for generics since the majority are available at a low price in groups with low reference prices.

Table 3: Always - CEL: Probability that drug package is exempt (=priced below CEL)

	Prob(exempt=yes): Logit	Prob(exempt=yes): FE
log(reference price) x generic	-25.19^{***}	-1.359^{***}
	(0.738)	(0.0783)
log(reference price)^2 x generic	1.090^{***}	0.0507^{***}
	(0.0954)	(0.0102)
log(reference price) x brand	-24.00^{***}	-0.344
	(2.239)	(0.182)
log(reference price)^2 x brand	0.369	-0.0920^{***}
	(0.302)	(0.0238)
log(firms per group)	-0.338^{***}	-0.0339^{*}
	(0.0898)	(0.0142)
Constant		4.293^{***}
		(0.144)
Observations	106,298	106,298
R^2		0.431

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Sample reduced to drugs which switch between exempt and non-exempt at least once

We also extended our analysis by including lags in our preferred model without any exemption level. Table 5 in the Appendix shows that prices and co-payments mostly adjust in the first quarter. Afterwards, they stay stable over time. This is similar to Augurzky et al. (2009) who show that price reductions take place mostly during the first month, which means that firms adjust quickly after the announcement of the new reference price.

5 Conclusion

This paper studies the effects of reference pricing on competitive outcomes in the market for prescription drugs. In contrast to many existing contributions we do not focus on the introduction of reference pricing, but rather on the effects of reference pricing in an environment where reference prices have been applied for a long time. The markets for German prescription drugs is an ideal market for such an analysis as a reference price system has been in place since 25 years, and reference prices have been frequently adjusted.

In a simple model with loyal and price-sensitive consumers we have shown that reductions in the reference price lead to lower prices charged by pharmaceutical firms and to lower expenses for the health insurers. However, we have also shown that reference pricing can have the unintended effect of raising consumers' co-payments. Thus, a part of cost saving by the health insurance system does not come from lower prices, but by shifting costs to consumers. This negative effect on consumers is particularly large if the reference price is very low.

In the empirical analysis with German data for the years 2007 to 2010 we explore the effects of reference pricing on producer prices and consumer co-payments. We find that prices decrease only mildly if the reference price is reduced. A 1%-reduction of the reference price only leads to price reduction of around 0.3 - 0.38%. We also find evidence that consumers' co-payments increase due to a reduction of the reference. The size of this effects and which type of product is affected depends to a large extent whether or not co-payment exemption levels (CELs) are in place. Without CELs we find a large effect on co-payments of branded drugs; a 1%-reduction in the reference price increases the co-payment by roughly 0.6%. The effect on generic products is much smaller, but still positive. The picture reverses, however, if CELs are considered. Here, we find that a reduction of the reference price makes it much more likely that a positive co-payment is applied following a reduction of the reference price.

We can draw several policy conclusions from our analysis. First, as already confirmed in the existing literature, reference pricing helps to reduce health care expenditures by reducing prices. However, the size of this effect is only mild. Second, however, policy makers should be aware that reference pricing can lead to larger out-of-pocket payments for consumers. This larger cost-sharing my lead to lower expenditures for the public payers and to a more price-elastic and thus more efficient behavior by the insureds. On the other hand, sufficiently high cost-sharing amounts can lead individuals to avoid medical care which is actually necessary to their health, substitute drug use by more costly doctor visits and/or impose a substantial financial burden. For Germany, the latter issue is solved by income-related out-of-pocket-limits as (Gruber, 2006) suggests when summarizing the results of the RAND Health Insurance Experiment.

Third, we also provide evidence on the interaction of different regulatory schemes which policy makers should be aware of. Reference prices can, in particular, lead to higher co-payments if coupled with elements of tiered co-payment schemes. From the analysis of drugs with co-payment exemption levels we have seen that also co-payments for generic drugs can increase.

The results of our paper suggest that consumers may be hurt if reference prices are successively reduced as co-payments for both generic and brand products tend to increase. However, a limitation of our data is that while we can assess the effects on prices and on co-payments, we cannot evaluate changes in consumer behavior as we do not observe the sold quantities of the different drugs and how sales change due to adjustments in the reference price. A complete analysis needs to take this into account.

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A Appendix

A.1 Theoretical part

Proof of Lemma 1

Our approach follows Varian (1980). The key lies in the fact that a consumer's co-payment when consuming drug i is strictly increasing in the price charged by the respective firm. Hence, by similar arguments as in Varian (1980), there exists no equilibrium in pure strategies, but a unique mixed-strategy equilibrium. In this equilibrium, firms randomize over a support $(\underline{p}, \bar{p})$ with no mass points.

Equilibrium profits can be derived by evaluating profits at the upper boundary of the price support where a firm sells only to its loyal consumers. We start by deriving this upper bound $(\bar{p})$. The maximal price is such that the co-payment equals the consumer's willingness to pay, v. Provided that $\bar{p} > p_r$, this is $\gamma\bar{p} + (\bar{p} - p_r) = v$. Solving for $\bar{p}$ gives

$$\bar{p} = \frac{v + p_r}{1 + \gamma}. \tag{A1}$$

Hence, equilibrium profits are

$$E(\Pi(\bar{p})) = \frac{1 - \mu}{2}\bar{p} = \frac{(1 - \mu)(v + p_r)}{2(1 + \gamma)}. \tag{A2}$$

Next, let us determine the lower bound of the support. As firms can always sell to their loyal consumers, no firm would want to sell below a lower bound $\underline{p}$ which is determined by

$$\frac{(1 - \mu)(v + p_r)}{2(1 + \gamma)} = \underline{p}\left[\frac{1 - \mu}{2} + \mu\right]. \tag{A3}$$

Solving gives

$$\underline{p} = \frac{(1 - \mu)(v + p_r)}{(1 + \gamma)(1 + \mu)}. \tag{A4}$$

At prices $p \in (\underline{p}, \bar{p})$ a firm's expected profits are

$$E(\Pi_i) = p\left(\frac{1-\mu}{2} + \mu(1 - F(p))\right). \tag{A5}$$

Equating (A2) and (A5) we have

$$F(p) = \frac{1}{2}\left(\frac{1+\mu}{\mu} - \frac{1-\mu}{p\mu}\frac{v+p_r}{1+\gamma}\right). \tag{A6}$$

Note that under Assumption 1, $p_r \in (\underline{p}, \bar{p})$.

Proof of Proposition 2

Total co-payments are given by Eq. (11). Differentiation with respect to p_r yields

$$-\frac{\partial COP}{\partial p_r} = -\frac{1-\mu}{4\mu(1+\gamma)^2 p_r^2}[p_r^2[4\mu\gamma + (1+3\mu)\gamma^2] - v^2(1-\mu)]. \tag{A7}$$

Define $\bar{p}_r = \sqrt{\frac{v^2(1-\mu)}{4\mu\gamma+(1+3\mu)\gamma^2}}$, then $-\frac{\partial COP}{\partial p_r} < 0$ for $p_r > \bar{p}_r$ and $-\frac{\partial COP}{\partial p_r} > 0$ for $p_r < \bar{p}_r$.

Proof of Proposition 3

Total expenditures by the health insurance are given by Eq. (12). Differentiation with respect to p_r gives

$$-\frac{\partial EXP}{\partial p_r} = -\frac{1-\mu}{4\mu(1+\gamma)^2 p_r^2}[p_r^2(3\mu(1-\gamma^2) + (\mu - \gamma^2)) + v^2(1-\mu)]. \tag{A8}$$

Note that the derivative is negative at the lower and upper boundary of p_r as defined in Assumption 1:

$$-\frac{\partial EXP}{\partial p_r}\Big|_{p_r = \frac{(1-\mu)v}{\gamma(1+\mu)+2\mu}} < 0, \tag{A9}$$

and

$$-\frac{\partial EXP}{\partial p_r}\Big|_{p_r = \frac{v}{\gamma}} < 0. \tag{A10}$$

Moreover,

$$-\frac{\partial^2 EXP}{\partial p_r^2} > 0, \tag{A11}$$

which implies that $-\frac{\partial EXP}{\partial p_r} < 0$ for all $p_r \in \left(\frac{(1-\mu)v}{\gamma(1+\mu)+2\mu}, \frac{v}{\gamma}\right)$.

Proof of Lemma 2

Similar to the symmetric case, we now determine the lower and upper bound of the price interval out of which the firms choose prices in the mixed strategy equilibrium.

The upper bound of the price support is derived as in the symmetric case of Section 2 so that $\bar{p}^a = \frac{v+p_r}{1+\gamma}$. Since Firm 1 is indifferent between the different strategies in equilibrium, for any chosen equilibrium price, equilibrium profits equal the profits which result form charging the maximal price and only serving the loyal consumers:

$$E(\Pi_1^a) = (1-\mu)\bar{p}^a = \frac{(1-\mu)(v+p_r)}{1+\gamma}. \tag{A12}$$

The lower bound of the support is determined by Firm 1's incentives to attract price sensitive consumers. Firm 1 would not want to set a price lower than $\underline{p}^a$ implicitly defined as $\frac{(1-\mu)(v+p_r)}{1+\gamma} = \underline{p}^a[(1-\mu)+\mu]$, which gives

$$\underline{p}^a = \frac{(1-\mu)(v+p_r)}{1+\gamma}. \tag{A13}$$

Firm 2's profits can be determined by evaluating profits at $\underline{p}^a$ where Firm 2 sells to price sensitive consumers with probability one:

$$\Pi_2^a = \mu\underline{p}^a = \frac{\mu(1-\mu)(v+p_r)}{1+\gamma}. \tag{A14}$$

At prices $p \in (\underline{p}^a, \bar{p}^a)$ Firm 1's expected profits are

$$E(\Pi_1^a) = p[(1-\mu)+\mu(1-F_2(p))]. \tag{A15}$$

Equating (A12) and (A15), we have

$$F_2^a = \frac{1}{\mu} - \frac{(1-\mu)(v+p_r)}{(1+\gamma)\mu p}. \tag{A16}$$

At prices $p \in (\underline{p}^a, \bar{p}^a)$ Firm 2's expected profits are

$$E(\Pi_2^a) = p\mu(1-F_1(p)). \tag{A17}$$

Equating (A14) and (A17), we get

$$F_1^a = 1 - \frac{(1-\mu)(v+p_r)}{(1+\gamma)p}. \tag{A18}$$

Finally, note that under Assumption 2, $p_r \in (\underline{p}^a, \bar{p}^a)$.

Proof of Proposition 4

Differentiating (16) and (17) with respect to p_r immediately gives that $-\frac{\partial E(\Pi_1^a)}{\partial p_r} < 0$ and $-\frac{\partial E(\Pi_2^a)}{\partial p_r} < 0$.

Note that $-\frac{\partial F_1^a}{\partial p_r} > 0$ and $-\frac{\partial F_2^a}{\partial p_r} > 0$. This implies that average prices by both firms decrease with a decrease in the reference price.

A.2 Empirical part

Table 4: ALWAYS - CEL

	log(price)	log(price)	log(co-pay)	log(co-pay)
log(reference price) x generic	0.702***	0.676***	-0.108**	-0.585***
	(0.0141)	(0.0438)	(0.0369)	(0.117)
log(reference price)^2 x generic		0.00386		0.0655***
		(0.00636)		(0.0175)
log(reference price) x brand	0.494***	-0.0564	-0.829***	-2.125***
	(0.0201)	(0.0590)	(0.0465)	(0.146)
log(reference price)^2 x brand		0.0743***		0.174***
		(0.00731)		(0.0201)
log(firms per group)	-0.0137***	-0.0127**	-0.0261**	-0.0227**
	(0.00363)	(0.00387)	(0.00840)	(0.00880)
Constant	1.582***	2.106***	3.879***	5.453***
	(0.0565)	(0.0817)	(0.133)	(0.184)
Observations	86766	86766	86766	86766
R^2	0.657	0.667	0.154	0.173

Standard errors in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 5: Both samples with lags

	NEVER CEL		ALWAYS CEL	
	log(price)	log(co-pay)	log(price)	log(co-pay)
log(reference price) x generic	0.256***	-0.133***	0.268***	-0.167***
	(0.0133)	(0.0226)	(0.00532)	(0.0464)
L.log(reference price) x generic	0.0229***	0.0304**	0.0113***	0.00133
	(0.00522)	(0.0111)	(0.00309)	(0.00920)
L2.log(reference price) x generic	0.0113**	0.00709	0.00913***	-0.0125*
	(0.00367)	(0.00524)	(0.00216)	(0.00595)
L3.log(reference price) x generic	-0.00339	0.0163	0.0270***	-0.00679
	(0.00765)	(0.00900)	(0.00431)	(0.0129)
log(reference price) x brand	0.392***	-0.636***	0.394***	-0.894***
	(0.0330)	(0.0685)	(0.0126)	(0.0480)
L.log(reference price) x brand	-0.0336**	-0.0402*	0.0199*	0.148***
	(0.0105)	(0.0163)	(0.00964)	(0.0344)
L2.log(reference price) x brand	0.00924	0.00803	-0.0253***	-0.0693***
	(0.0110)	(0.0239)	(0.00541)	(0.0159)
L3.log(reference price) x brand	-0.0792**	0.0661	-0.0451***	-0.0576*
	(0.0280)	(0.0539)	(0.00793)	(0.0279)
log(firms per group)	-0.00355	0.00875	-0.0383***	-0.0210**
	(0.00391)	(0.00612)	(0.00398)	(0.00792)
Constant	1.886***	2.172***	2.320***	3.944***
	(0.0419)	(0.0652)	(0.0302)	(0.149)
Observations	32636	32636	138908	69278
R^2	0.366	0.191	0.434	0.195

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$