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Reference Pricing Systems on the Pharmaceutical Market

Maximiliane Unsorg*

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Constantly rising expenditures for pharmaceuticals and uninformed consumers require government intervention in firms' pricing strategies. To this end, reference pricing systems are frequently employed as regulatory mechanisms. This paper considers a duopoly market with vertically differentiated firms: a brand-name firm and a firm producing a generic version or a branded copy (depending on competition type). It can be proven that the introduction of a reference price leads to lower equilibrium prices for both firms and that it can induce fiercer competition between brand-name and generic/branded copy firms. Additionally, it can be shown that reference pricing promotes generic usage under sequential price competition. When implementing a reference pricing system, an increased market coverage and, hence, an improved provision of medical supply can be achieved due to the lower prices and the stimulated demand for drugs. Even under a higher supply the consumers' expenditures decrease under reference pricing. Finally, the model proves the superiority of reference prices over price caps and therefore indicates that reference pricing systems should be preferred.

Keywords: reference pricing · pharmaceutical market · copayment · price cap · price competition · consumer expenditure

JEL Classification: I11, I18, L51

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1. Introduction and Literature Review

Worldwide, the market for pharmaceuticals is subject to certain regulations. Rising expenditures of state health insurance companies, increasing fees for patients and high drug prices have led to a multitude of regulatory instruments. The pharmaceutical market is highly innovative and always subject to change: a variety of new drugs is introduced continually to the market, bringing therapeutic advantages for the patients. However, after patent expiry the market is crowded with generic versions - lower priced copies of the original break-through innovation. One problem that arises is that patients often do not know about these cheaper alternatives or believe that they are of lower quality (uninformed consumers). Therefore, patients often tend to purchase high-priced brand-name drugs instead of their generic versions.

In order to handle the increase in expenditures and to overcome the high price difference between drugs, reference pricing systems are implemented in several countries (i.a., Germany, France, Spain). This reference pricing system is installed additionally to the existing copayment systems. Patients insured via a state insurance company have to bear a (percentage) part of the drug price ("copayment") in addition to their insurance premium (fixed premium) while the rest is paid for by their insurance. Via the reference price, an additional restriction is imposed on the brand-name drugs, making them more expensive. The reference price has been analyzed in theoretical and empirical work. The first relevant contribution concerning the competition between brand-name drugs and generic versions was contributed by Grabowski and Vernon (1992). They derived that while brand-name prices steadily increase, the prices of generic versions will remain low due to the competition among them. Scherer (1993) found that after generic entry when the original product's patent expired the brand-name producers maintained their high-price-strategy ("generic competition paradox"). This finding was confirmed by Frank and Salkever (1997). Pavcnik (2002) found that reference pricing leads to lower prices for both firms, while the decrease was even stronger for the brand-name firm. A relevant result is that reference pricing intensifies competition (Brekke et al. 2009, 2011, Pavcnik 2002). Recently, Antoñanzas et al. (2017) analyzed the effect of reference pricing under exogenous and endogenous reference pricing systems on the price setting.

Building on the existing literature, this paper tries to identify the link between reference pricing, generic market shares and consumer expenditure. It will be shown that while competition intensity is increased and prices drop, the reference price is also able to promote generic usage under certain circumstances. Further, the effect of reference pricing on the total quantities in the market can be identified and by analyzing the consumer expenditures it can be shown, that a reference pricing system can reduce expenditures despite the increase in consumption.

Despite following the idea of Merino-Castelló (2003) in the basic market set-up, this paper differs from her analysis in several ways. Firstly, simultaneous and sequential price competition will be analyzed alongside, emphasize the differences and clarify the economic relevance of both competition types. Secondly, the effects of the copayment rate and of the weight of the reference price on the market outcomes will be assessed and it can be shown how the generic market share can be varied accordingly. Thirdly, the effect of reference pricing on total quantities on the market and consumers' expenditures will be analyzed. Besides, the idea of an exogenously given price cap from Brekke et al. (2011) is adapted to this set-up in order to prove the superiority of reference pricing. This paper is organized as follows: After the introduction, part two contains the model with the analysis

of the market before and after the introduction of the reference price and also under a price cap. Further, it includes the market coverage and the consumers' expenditures. Part 4 concludes.

2. Model

A duopolistic model with a (leading) brand-name firm (1) producing an original drug and a (following) firm (2) producing either a generic version or a branded copy depending on the competition type is considered.¹ A constant copayment rate, $k \in [0, 1]$, which the consumers face when purchasing a drug is assumed. Thus, the patients bear a proportional part of the drug costs while the rest is paid for by their state insurance. The brand-name drug 1 and the drug version of firm 2 differ in their (perceived²) quality θ_i , $i = 1, 2$. The quality-ranking is given by $0 < \theta_2 < \theta_1 \leq 1$. The lower bound of θ_2 ensures the market entrance of firm 2 and makes the derivation of its price reaction functions possible without any restriction. This lower bound can be interpreted as a minimum quality requirement necessary to enter the market, like some bioequivalence criteria which must also be met by the generic drug or the branded copy respectively. Apparently, no upper bound of quality exists, but the simplifying assumption of $\theta_1 \leq 1$ can be made without loss of generality.

The consumers, characterized by heterogeneous preferences, are divided into two groups. The first group prefers the brand-name product. These consumers are price insensitive and face a huge utility loss when purchasing the generic version. The first consumer type is willing to pay a higher price for the high (perceived) quality. The second consumer type is not committed to purchasing a specific drug but he is very price sensitive. These consumers face no utility loss and therefore will decide to purchase the alternative drug due to its lower price. The consumers are equally distributed according to their drug valuation $\tau \in [0, 1]$.

Both firms charge positive prices p_i , $i = 1, 2$. The utility from purchasing one unit of the drug is given by the direct utility from drug consumption (as the product of the consumers' valuation and the quality) minus the consumer's copayment. The market is assumed to be not fully covered.³ The utility is defined as

$$U(\tau, \theta_i) = \begin{cases} \tau\theta_i - kp_i & \text{if consumer buys one unit} \\ 0 & \text{otherwise.} \end{cases}$$

2.1. Pre-Regulative Situation

The unregulated market serves as a benchmark. In this case, the copayment the consumers have to bear is equal for both drug types, i.e. $k p_i$, $i = 1, 2$. For the indifferent consumers, it has to hold respectively that the utility from purchasing drug i has to be higher than the

¹The analysis applies only to drugs which are available on prescription and therefore covered by the state insurance. Over-the-counter products are not included.

²The quality difference between the drugs does not explicitly have to be a "real" difference, it may also be a perceived one. The patients might be uninformed and therefore perceive the generic version/the branded copy as being of lesser quality. Nevertheless, both drug types have to pass several medical studies.

³There still exist consumers for whom it is preferable not to buy any drug at all. The considered drugs are used as a treatment for minor diseases and not for severe illnesses, e.g. drugs treating migraine where patients might decide to tolerate the pain because they do not value the medication sufficiently.

one from purchasing drug j , $i, j = 1, 2$, $i \neq j$. Furthermore, the utility from purchasing a drug must be non-negative.

Preferring 1:

$$\begin{aligned} U(\tau, \theta_1) &\geq U(\tau, \theta_2) \\ \tau^* &\geq \frac{k(p_1 - p_2)}{\theta_1 - \theta_2} \end{aligned}$$

Preferring 2:

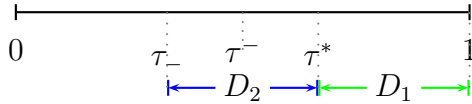
$$\begin{aligned} U(\tau, \theta_1) &\geq 0 \\ \tau^- &\geq \frac{k}{\theta_1} p_1 \end{aligned}$$

$$\begin{aligned} U(\tau, \theta_2) &> U(\tau, \theta_1) \\ \tau^* &< \frac{k(p_1 - p_2)}{\theta_1 - \theta_2} \end{aligned}$$

$$\begin{aligned} U(\tau, \theta_2) &\geq 0 \\ \tau_- &\geq \frac{k}{\theta_2} p_2 \end{aligned}$$

Accordingly, one obtains the location of the consumer indifferent between the brand-name firm and the generic firm at $\tau^* \geq \frac{k(p_1 - p_2)}{\theta_1 - \theta_2}$ and the location of the consumer indifferent between the generic firm and no purchase at $\tau_- \geq \frac{k}{\theta_2} p_2$.⁴ When the price is equal, the consumer indifferent between buying 1 and buying 2 will always decide to buy 1 (due to the (perceived quality difference), therefore, $U(\tau, \theta_2) > U(\tau, \theta_1)$ is defined with a strict inequality sign. The location of this indifferent consumer is given by τ^* , while the consumer indifferent between buying G and not buying any drug is given by τ_- . The demand system follows as depicted in Figure 1.

Figure 1: Demand System



It is worthwhile to take a look at the effects of the copayment rate on the indifferent consumers. The indifferent consumers τ^* and τ_- positively depend on the copayment rate k , i.e., $\frac{\partial \tau^*}{\partial k} > 0$ and $\frac{\partial \tau_-}{\partial k} > 0$. Hence, an increase in the copayment rate induces a shift to the right of both indifferent consumers. Consequently, a lower fraction of the market is covered and both firms have less consumers to serve. The demand functions the firms face are dependent on the indifferent consumer and read:

$$D_1 = 1 - \tau^* = 1 - \frac{k(p_1 - p_2)}{\theta_1 - \theta_2} \quad (1)$$

$$D_2 = \tau^* - \tau_- = \frac{k(p_1 - p_2)}{\theta_1 - \theta_2} - \frac{k p_2}{\theta_2} \quad (2)$$

Taking the derivatives of both demand functions with respect to each firm's own price yields for the price sensitivities:

$$\frac{\partial D_1}{\partial p_1} = \frac{-k}{\theta_1 - \theta_2} < 0 \quad (3)$$

$$\frac{\partial D_2}{\partial p_2} = \frac{-k}{\theta_1 - \theta_2} - \frac{k}{\theta_2} < 0 \quad (4)$$

Comparing equations (3) and (4) shows that the demand for the brand-name drug is less price sensitive than the demand for the drug of firm 2, i.e. $\frac{\partial D_1}{\partial p_1} > \frac{\partial D_2}{\partial p_2}$. This meets the assumption regarding the consumers' preferences.

The firms' profits are given by the sum of the direct revenues obtained from the consumers

⁴It is assumed that $\tau^* > \tau^- > \tau_-$, the proof can be given by substituting the prices calculated in the following and is robust for each competition type.

and the revenues obtained from the third party payers (e.g. state health insurance). For simplicity, the production costs are assumed to be zero.⁵ Then the firm profit is

$$\pi_i = \underbrace{kp_i D_i}_{\text{direct revenues from consumers}} + \underbrace{(1-k)p_i D_i}_{\text{revenues from third party}} = p_i D_i, i = 1, 2.$$

At first, the simultaneous price setting game will be considered.⁶ The brand-name firm comes up with a new drug but firm 2 is able to “invent around” the existing patent and can enter the market instantaneously. Firm 2’s drug is no generic version in the original definition but will be classified as a branded copy (“me-too drug”), i.e. it produces a therapeutically equivalent drug. While it treats the same disease, it has a different active substance than the brand-name drug, hence, it is chemically different and therefore, does not violate the patent. Maximizing the profit functions over the respective price yields the price reaction functions of both firms:

$$R_1^B(P_2^B) \equiv p_1^B = \frac{(\theta_1 - \theta_2) + kp_2^B}{2k} \quad (5)$$

$$R_2^B(P_1^B) \equiv p_2^B = \frac{\theta_2}{2\theta_1} p_1^B \quad (6)$$

Via substituting equation (6) into (5), one obtains the equilibrium prices as

$$p_1^B = \frac{2\theta_1(\theta_1 - \theta_2)}{k(4\theta_1 - \theta_2)} \quad \text{and} \quad p_2^B = \frac{\theta_2(\theta_1 - \theta_2)}{k(4\theta_1 - \theta_2)}.$$

The effect of a change in the copayment rate on the prices is described by $\frac{\partial p_i^B}{\partial k} < 0, i = 1, 2$. An increase in the copayment rate would induce both firms to lower their prices in order to maintain their consumers.

Dividing the price equations yields the relative price ratio of the brand-name drug: $\frac{p_1^B}{p_2^B} = \frac{2\theta_1}{\theta_2}$. The price charged by firm 1 is higher than that of firm 2 (due to $\theta_1 > \theta_2$). The relative price ratio can be interpreted as a measure of the degree of price competition: a high relative price ratio indicates weak price competition. The relative price ratio crucially depends on the qualities of the two products: the less differentiated they are (in terms of quality), the higher the pressure of price competition. The quantities resulting under simultaneous price competition are

$$q_1^B = \frac{2\theta_1}{4\theta_1 - \theta_2} \quad (7) \quad \text{and} \quad q_2^B = \frac{\theta_1}{4\theta_1 - \theta_2}. \quad (8)$$

With equations (7) and (8), the market share of the branded copy reads

$$\gamma^B = \frac{q_2^B}{q_1^B + q_2^B} = \frac{1}{3}.$$

Only one third of the market is served by the cheaper alternative of firm 2. It remains to calculate the profits

⁵This assumption can be made since production costs are quite similar for both firms. Further, the costs for the quality development are assumed to be sunk and are neglected here (Merino Castelló, 2003). The firms decide upon the quality before entering the market.

⁶The results for simultaneous price competition are additionally indexed by an upper “B” for “Bertrand-Competition”.

$$\pi_1^B = \frac{4\theta_1^2(\theta_1 - \theta_2)}{k(4\theta_1 - \theta_2)^2} \quad \text{and} \quad \pi_2^B = \frac{\theta_1\theta_2(\theta_1 - \theta_2)}{k(4\theta_1 - \theta_2)^2}.$$

The results of the simultaneous competition are given in Table 1.

Table 1: Simultaneous Price Competition

	Firm 1		Firm 2
prices	p_1^B	$>$	p_2^B
quantities	q_1^B	$>$	q_2^B
profits	π_1^B	$>$	π_2^B

Accordingly, sequential price competition is analyzed.⁷ The brand-name firm 1 is defined as the leader who is able to achieve a period of extensive patent protection. The drug produced by firm 2 is indeed a generic version of the brand-name drug in this competition type. The considered drug is therapeutically and chemically equivalent to the brand-name product. It contains the same active substance and therefore firm 2 can enter the market after the patent expiry only. Accordingly, the structure in this sequential game is as follows: firm 1 anticipates the reaction of firm 2 to its price setting strategy. Substituting the reaction function (6) into the profit function of firm 1 yields its optimization problem with the reduced form profit function

$$\max_{p_1} \pi_1^S(p_1^S) = p_1^S \left[1 - \frac{k(p_1^S - \frac{\theta_2}{2\theta_1}p_1^S)}{\theta_1 - \theta_2} \right].$$

The prices under sequential price competition are

$$p_1^S = \frac{\theta_1(\theta_1 - \theta_2)}{k(2\theta_1 - \theta_2)} \quad \text{and} \quad p_2^S = \frac{\theta_2(\theta_1 - \theta_2)}{2k(2\theta_1 - \theta_2)}.$$

The effect of the copayment rate on the prices under sequential price competition is similar to the one under simultaneous price competition, a higher copayment induces firms to reduce their prices ($\frac{\partial p_i^S}{\partial k} < 0$, $i = 1; 2$). The intensity of price competition coincides with the one under simultaneous competition, i.e. $\frac{p_1^S}{p_2^S} = \frac{2\theta_1}{\theta_2}$. Solving for the quantities yields

$$q_1^S = \frac{1}{2} \quad \text{and} \quad q_2^S = \frac{\theta_1}{2(2\theta_1 - \theta_2)}.$$

For the generic market share, one obtains

$$\gamma^S = \frac{\theta_1}{3\theta_1 - \theta_2}.$$

The profits under sequential price competition are

$$\pi_1^S = \frac{\theta_1(\theta_1 - \theta_2)}{2k(2\theta_1 - \theta_2)} \quad \text{and} \quad \pi_2^S = \frac{\theta_1\theta_2(\theta_1 - \theta_2)}{4k(2\theta_1 - \theta_2)^2}.$$

⁷The results in this subsection are additionally indexed by an upper “S” for “Stackelberg” competition.

The results of the sequential competition are provided in Table 2.

Table 2: Sequential Price Competition

	Firm 1		Firm 2
prices	p_1^S	$>$	p_2^S
quantities	q_1^S	$>$	q_2^S
profits	π_1^S	$>$	π_2^S

Table 3 summarizes the results of a comparison of the two types of competition.

Table 3: Simultaneous vs. Sequential Price Competition

	simultaneous		sequential
prices	p_1^B	$<$	p_1^S
	p_2^B	$<$	p_2^S
rel. price ratio	p_1^B/p_2^B	$=$	p_1^S/p_2^S
quantities	q_1^B	$>$	q_1^S
	q_2^B	$<$	q_2^S
generic MS	γ^B	$<$	γ^S
profits	π_1^B	$<$	π_1^S
	π_2^B	$<$	π_2^S

For both firms, it is profitable to enter the market sequentially because not only firm 1 is able to set a higher price, but also firm 2 has an incentive to raise its price in comparison to the simultaneous entrance. The leadership gives the brand-name firm the possibility to set a high price without losing consumers (“first mover advantage”). When entering the market, firm 2 gains from this high-price strategy of firm 1 and is likewise able to set a higher price (“second mover advantage”). Since the follower obtains advantages from sequential movement, he is more willing to accept the leadership of the other firm. The advantage of firm 2 to operate under sequential price competition is reflected in the higher generic market share.

2.2. Price Cap

Before examining a reference pricing system, it proves useful to shortly analyze regulation via a price cap.⁸ Assume an exogenously given and binding price cap for the brand-name drug 1, $p_1 = \bar{p}_1$.⁹ Substituting this price cap \bar{p}_1 into the reaction function of firm 2 (6) yields the generic price $p_2^{PC} = \frac{\theta_2}{2\theta_1} \bar{p}_1$.

⁸The results in this subsection are additionally indexed by an upper “PC” for “price cap”.

⁹The price cap is set beforehand, therefore, it is neither possible to assume price “leadership” of 1, nor simultaneous price competition because the price cap is known to 2.

A first shortcoming of this kind of regulation becomes visible in the price ratio which does not change in comparison to the benchmark case, i.e. $\frac{\bar{p}_1}{p_2^{PC}} = \frac{2\theta_1}{\theta_2}$. Hence, the price cap cannot induce fiercer competition. Given the two prices \bar{p}_1 and $p_2(\bar{p}_1)$, the quantities can be derived by using the demand functions (1) and (2) from the simultaneous price competition

$$q_1^{PC}(\bar{p}_1) = \frac{2\theta_1(\theta_1 - \theta_2) - k\bar{p}_1(2\theta_1 - \theta_2)}{2\theta_1(\theta_1 - \theta_2)} \quad (9)$$

$$q_2^{PC}(\bar{p}_1) = \frac{k\bar{p}_1}{2(\theta_1 - \theta_2)}. \quad (10)$$

It is sufficient to solve for the generic market share, which is

$$\gamma_{PC} = \frac{q_2^{PC}}{q_1^{PC} + q_2^{PC}} = \frac{k\theta_1\bar{p}_1}{(\theta_1 - \theta_2)(2\theta_1 - k\bar{p}_1)}.$$

Obviously, a second shortcoming is shown in the generic market share which is increasing in the price cap

$$\frac{\partial \gamma_{PC}}{\partial \bar{p}_1} = \frac{2k\theta_1^2}{(\theta_1 - \theta_2)(2\theta_1 - k\bar{p}_1)^2} > 0.$$

Consequently, decreasing the price cap leads to a lower generic market share. A regulator would implement the lowest possible price cap to induce low prices, but this does not induce an increased generic usage. A change in the price cap of a regulated product leads to a change in the same direction for the non-regulated product since prices are strategic complements.

2.3. Reference Pricing

Assume an endogenous reference price¹⁰ as a linear combination of the two drugs' prices, weighted by $\alpha \in [k, 1]$:¹¹

$$p_R = \alpha p_2^R + (1 - \alpha)p_1^R$$

Consequently, a higher weight induces a more restrictive reference price. The lowest reference price is the price of drug 2 ($p_R = p_2$) where $\alpha = 1$. It is not possible to set a reference price lower than the generic price, since it is not intended to restrict the generic firm as well. Under the reference pricing, the consumers face different copayments for the drugs

$$c_i^R = \begin{cases} kp_1^R + (p_1^R - p_R) & \text{for } i = 1 \\ kp_2^R & \text{for } i = 2. \end{cases}$$

When a consumer decides to buy the brand-name drug, he additionally has to pay the difference between the brand-name drug's price and the reference price. With the introduction of the reference price, the locations of the indifferent consumers change.¹²

¹⁰The results in this section are additionally indexed by an upper "R" for the reference price.

¹¹This restriction is necessary to ensure that the reference price is always higher than the generic price which leads to a higher copayment for 1.

¹²The calculation of the indifferent consumers follows the same method as before. The demand system reveals the same pattern as before: $\tau_R^* > \tau_R^- > \tau_{R-}$. The proof can be given analogously to the benchmark case by substituting the prices.

The consumer indifferent between the brand-name drug and its alternative is located at $\tau_R^* \geq \frac{(k+\alpha)(p_1^R - p_2^R)}{\theta_1 - \theta_2}$ and the consumer indifferent between the alternative drug and no purchase is located at $\tau_{R-} \geq \frac{kp_2^R}{\theta_2}$. An increase in the copayment rate shifts the location of both indifferent consumers to the right, i.e., $\frac{\partial \tau_R^*}{\partial k} > 0$ and $\frac{\partial \tau_{R-}}{\partial k} > 0$. Therefore, a lower fraction of the market is covered.

While an increase in the weight (lower reference price) has no effect on the consumer indifferent between buying 2 and not buying any drug at all, i.e. $\frac{\partial \tau_{R-}}{\partial \alpha} = 0$, a higher weight on the 2nd drug's price leads to a rightward shift of the consumer indifferent between buying 1 and buying 2, i.e. $\frac{\partial \tau_R^*}{\partial \alpha} > 0$. Consequently, a more restrictive reference price (initiated by a higher weight) induces a shift of the consumers who initially would buy the brand-name version to the generic drug. Hence, the demand functions read

$$\begin{aligned} D_1^R &= 1 - \tau_R^* = 1 - \frac{(k + \alpha)(p_1^R - p_2^R)}{\theta_1 - \theta_2} \\ D_2^R &= \tau_R^* - \tau_{R-} = \frac{(k + \alpha)(p_1^R - p_2^R)}{\theta_1 - \theta_2} - \frac{kp_2^R}{\theta_2}. \end{aligned}$$

Calculating the price sensitivities yields:

$$\frac{\partial D_1^R}{\partial p_1^R} = \frac{-(k + \alpha)}{\theta_1 - \theta_2} < 0 \quad (11)$$

$$\frac{\partial D_2^R}{\partial p_2^R} = \frac{-(k + \alpha)}{\theta_1 - \theta_2} - \frac{k}{\theta_2} < 0 \quad (12)$$

Equations (11) and (12) show that the price sensitivity of 1 is still lower than that of 2, i.e. $\frac{\partial D_1^R}{\partial p_1^R} < \frac{\partial D_2^R}{\partial p_2^R}$. When comparing equation (3) to (11) for the price sensitivity of 1 and equation (4) to (12) for the price sensitivity of 2, the effect of the reference pricing system becomes clear. The introduction of a reference price leads to a more price sensitive demand for both firms than before, i.e. $\frac{\partial D_1}{\partial p_1} > \frac{\partial D_1^R}{\partial p_1^R}$ and $\frac{\partial D_2}{\partial p_2} > \frac{\partial D_2^R}{\partial p_2^R}$. Finally, the optimization problems of both firms are:

$$\begin{aligned} \max_{p_1} \pi_1^R &= p_1^R \left[1 - \frac{(k + \alpha)(p_1^R - p_2^R)}{\theta_1 - \theta_2} \right] \\ \max_{p_2} \pi_2^R &= p_2^R \left[\frac{(k + \alpha)(p_1^R - p_2^R)}{\theta_1 - \theta_2} - \frac{kp_2^R}{\theta_2} \right] \end{aligned}$$

Again, simultaneous price competition is considered first. The derivation is similar to the case without reference pricing. The reaction functions of 1 and 2 read

$$R_1^{RB}(p_2^{RB}) \equiv p_1^{RB} = \frac{\theta_1 - \theta_2}{2(k + \alpha)} + \frac{1}{2}p_2^{RB} \quad (13)$$

$$R_2^{RB}(p_1^{RB}) \equiv p_2^{RB} = \frac{(k + \alpha)\theta_2}{2(k\theta_1 + \alpha\theta_2)}p_1^{RB}. \quad (14)$$

Plugging (14) into (13) yields the prices

$$\begin{aligned} p_1^{RB} &= \frac{2(\theta_1 - \theta_2)(k\theta_1 + \alpha\theta_2)}{(k + \alpha)(4(k\theta_1 + \alpha\theta_2) - (k + \alpha)\theta_2)} \\ p_2^{RB} &= \frac{\theta_2(\theta_1 - \theta_2)}{4(k\theta_1 + \alpha\theta_2) - (k + \alpha)\theta_2}, \end{aligned}$$

as well as the relative price ratio

$$\frac{p_1^{RB}}{p_2^{RB}} = \frac{2(k\theta_1 + \alpha\theta_2)}{(k + \alpha)\theta_2}.$$

The effect of the reference price can be measured by the effect of the weight of the reference price on the prices of both firms:

$$\begin{aligned}\frac{\partial p_1^{RB}}{\partial \alpha} &= \frac{2(\theta_1 - \theta_2)(2k^2\theta_1\theta_2 - 6\alpha k\theta_1\theta_2 - 3\alpha^2\theta_2^2 - k^2\theta_2^2 - 4k^2\theta_1^2)}{(\alpha + k)^2(4(k\theta_1 + \alpha\theta_2) - (\alpha + k)\theta_2)^2} < 0 \\ \frac{\partial p_2^{RB}}{\partial \alpha} &= -\frac{3\theta_2^2(\theta_1 - \theta_2)}{(4(k\theta_1 + \alpha\theta_2) - (\alpha + k)\theta_2)^2} < 0\end{aligned}$$

Since both derivations are negative, a more restrictive reference price (induced by a higher weight on the 2nd drug's price) leads to lower prices of both firms. The brand-name firm is directly affected, since the pressure of the reference price and the additional copayment induces the firm to lower its price. Further, firm 2 realizes an indirect effect. Since prices are strategic complements, it reacts with a price decrease, too. The effects of the copayment on the prices under reference pricing are

$$\begin{aligned}\frac{\partial p_1^{RB}}{\partial k} &= \frac{2(\theta_1 - \theta_2)\xi}{(\alpha + k)^2(4(k\theta_1 + \alpha\theta_2) - (\alpha + k)\theta_2)^2} < 0 \\ \frac{\partial p_2^{RB}}{\partial k} &= -\frac{\theta_2(\theta_1 - \theta_2)(4\theta_1 - \theta_2)}{(4(k\theta_1 + \alpha\theta_2) - (\alpha + k)\theta_2)^2} < 0\end{aligned}$$

where $\xi = (k^2\theta_1\theta_2 + 2\alpha k\theta_2^2 - 4k^2\theta_1^2 - \alpha^2\theta_1\theta_2 - 8\alpha k\theta_1\theta_2 - 2\alpha^2\theta_2^2)$. The direction of this effect is unchanged.

To state whether the reference price is successful in introducing fiercer competition, it is necessary to determine the effect of the weight on the relative price ratio:

$$\frac{\partial \frac{p_1^{RB}}{p_2^{RB}}}{\partial \alpha} = \frac{2k\theta_2^2 - 2k\theta_1\theta_2}{(\alpha + k)^2\theta_2^2} < 0$$

If the reference price is lower (higher weight on the 2nd drug's price), the relative price ratio decreases. The negative derivation proves that reference pricing induces fiercer price competition. Deriving the relative price ratio with respect to the copayment rate yields

$$\frac{\partial \frac{p_1^{RB}}{p_2^{RB}}}{\partial k} = \frac{2\alpha\theta_1\theta_2 - 2\alpha\theta_2^2}{(\alpha + k)^2\theta_2^2} > 0.$$

A higher copayment for the patients leads to weaker price competition between the two firms. Given the prices, the equilibrium quantities can be derived by using the demand functions

$$q_1^{RB} = \frac{2(k\theta_1 + \alpha\theta_2)}{4(k\theta_1 + \alpha\theta_2) - (k + \alpha)\theta_2} \quad (15)$$

$$q_2^{RB} = \frac{k\theta_1 + \alpha\theta_2}{4(k\theta_1 + \alpha\theta_2) - (k + \alpha)\theta_2}. \quad (16)$$

The market share of the branded copy is still $\gamma_R^B = \frac{1}{3}$. Under simultaneous price competition, its market share is independent of the reference price's weight. Hence, when firms

simultaneously compete in prices, the reference price is not able to affect the market share of firm 2. Finally, the profits of both firms are calculated as

$$\pi_1^{RB} = \frac{4(\theta_1 - \theta_2)(k\theta_1 + \alpha\theta_2)^2}{(k + \alpha)(4(k\theta_1 + \alpha\theta_2) - (k + \alpha)\theta_2)^2}$$

$$\pi_2^{RB} = \frac{\theta_2(\theta_1 - \theta_2)(k\theta_1 + \alpha\theta_2)}{(4(k\theta_1 + \alpha\theta_2) - (k + \alpha)\theta_2)^2}.$$

The results of simultaneous price competition under reference pricing are summarized in Table 4.

Table 4: Simultaneous Price Competition

	Firm 1		Firm 2
prices	p_1^{RB}	$>$	p_2^{RB}
quantities	q_1^{RB}	$>$	q_2^{RB}
profits	π_1^{RB}	$>$	π_2^{RB}

If firms engage in sequential price competition under reference pricing, the optimization problem of the generic firm remains unchanged and therefore the reaction function is analogous to the simultaneous case by equation (14). Substituting the reaction function of firm 2 into the profit function of firm 1 yields its maximization problem:

$$\max_{p_1^{RS}} \pi_1^{RS} = p_1^{RS} \left[1 - \frac{(k + \alpha)(2k\theta_1 + (\alpha - k)\theta_2)}{2(\theta_1 - \theta_2)(k\theta_1 + \alpha\theta_2)} p_1^{RS} \right]$$

The prices are

$$p_1^{RS} = \frac{(\theta_1 - \theta_2)(k\theta_1 + \alpha\theta_2)}{(k + \alpha)(2k\theta_1 + (\alpha - k)\theta_2)} \quad \text{and} \quad p_2^{RS} = \frac{\theta_2(\theta_1 - \theta_2)}{2(2k\theta_1 + (\alpha - k)\theta_2)}$$

and the relative price ratio is

$$\frac{p_1^{RS}}{p_2^{RS}} = \frac{2(k\theta_1 + \alpha\theta_2)}{(k + \alpha)\theta_2}.$$

The weight of the reference price has a negative impact on both prices:

$$\frac{\partial p_1^{RS}}{\partial \alpha} = \frac{(\theta_1 - \theta_2)(2k^2\theta_1\theta_2 - 2k^2\theta_1^2 - 2\alpha k\theta_1\theta_2 - \alpha^2\theta_2^2 - k^2\theta_2^2)}{(k + \alpha)^2(2k\theta_1 + (\alpha - k)\theta_2)^2} < 0$$

$$\frac{\partial p_2^{RS}}{\partial \alpha} = -\frac{\theta_2^2(\theta_1 - \theta_2)}{2(2k\theta_1 + (\alpha - k)\theta_2)^2} < 0$$

So the lower the reference price (the higher the weight), the more the firms will decrease their prices. The direction of the influence of the copayment remains unchanged after the introduction of reference pricing:

$$\frac{\partial p_1^{RS}}{\partial k} = \frac{(\theta_1 - \theta_2)(k^2\theta_1\theta_2 - 2k^2\theta_1^2 - \alpha^2\theta_1\theta_2 + 2\alpha k\theta_2 - 4\alpha k\theta_1\theta_2)}{(k + \alpha)^2(2k\theta_1 + (\alpha - k)\theta_2)^2} < 0$$

$$\frac{\partial p_2^{RS}}{\partial k} = -\frac{\theta_2(\theta_1 - \theta_2)(2\theta_1 - \theta_2)}{2(2k\theta_2 + (\alpha - k)\theta_2)^2} < 0$$

The reference price induces fiercer price competition due to the negative influence of the weight on the relative price ratio:

$$\frac{\partial \frac{p_1^{RS}}{p_2^{RS}}}{\partial \alpha} = \frac{2k\theta_2^2 - 2k\theta_1\theta_2}{(k + \alpha)^2\theta_2^2} < 0$$

Under a higher weight, the price ratio decreases. Hence, the reference price also induces fiercer price competition under sequential movement. The influence of the copayment rate on the relative price ratio is positive:

$$\frac{\partial \frac{p_1^{RS}}{p_2^{RS}}}{\partial k} = \frac{2\alpha\theta_1\theta_2 - 2\alpha\theta_2^2}{(k + \alpha)^2\theta_2^2} > 0$$

The relative price ratio is increasing in the copayment rate. The quantities are

$$q_1^{RS} = \frac{1}{2} \quad (17) \quad \text{and} \quad q_2^{RS} = \frac{k\theta_1 + \alpha\theta_2}{2(2k\theta_1 + (\alpha - k)\theta_2)} \quad (18)$$

and the generic market share is

$$\gamma_R^S = \frac{k\theta_1 + \alpha\theta_2}{3k\theta_1 + 2\alpha\theta_2 - k\theta_2}.$$

In contrast to the simultaneous case, firm 2's market share depends on the reference price. Via

$$\frac{\partial \gamma_R^S}{\partial \alpha} = \frac{k\theta_1\theta_2 - k\theta_2^2}{(3k\theta_1 + 2\alpha\theta_2 - k\theta_2)^2} > 0$$

the generic market share increases under reference pricing. Therefore, the reference price can induce higher generic usage if firms compete in sequential price competition. Finally, it remains to calculate the profits obtained under sequential price competition:

$$\begin{aligned} \pi_1^{RS} &= \frac{(\theta_1 - \theta_2)(k\theta_1 + \alpha\theta_2)}{2(\alpha + k)(2k\theta_1 + (\alpha - k)\theta_2)} \\ \pi_2^{RS} &= \frac{\theta_2(\theta_1 - \theta_2)(k\theta_1 + \alpha\theta_2)}{4(2k\theta_1 + (\alpha - k)\theta_2)^2} \end{aligned}$$

Table 5 provides a summary of the results of the sequential price competition under reference pricing, while Table 6 contrasts the two competition types. Clearly, the sequential set-up is still favorable for the firms, since both are able to realize higher profits. While the relative price ratio does not change under the two scenarios, firm 2's market share increases in the sequential set-up.

Figure 2 depicts the reaction functions before and after the introduction of the reference price. The firms adjust their reaction functions under reference pricing and consequently, price reductions are realized. The grey/red lines depict the reaction functions before/after the introduction of the reference pricing system. The equilibria of simultaneous price competition lie in the intersection of the two respective reaction functions. The equilibria of the sequential price competition are denoted by the black and red circles on the respective reaction functions of firm 2.

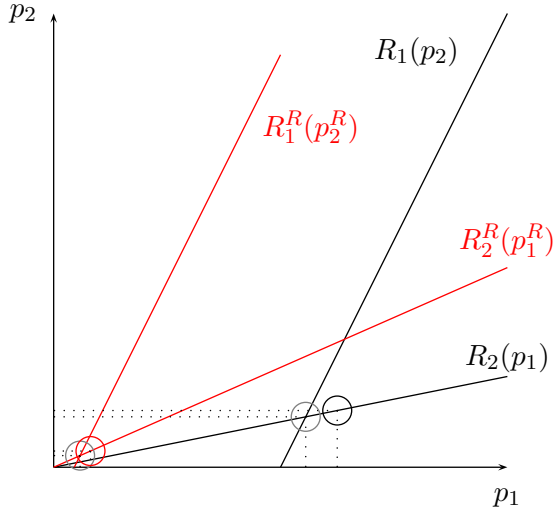
Table 5: Sequential Price Competition

	Firm 1		Firm 2
prices	p_1^{RS}	$>$	p_2^{RS}
quantities	q_1^{RS}	$>$	q_2^{RS}
profits	π_1^{RS}	$>$	π_2^{RS}

Table 6: Simultaneous vs. Sequential Price Competition

	simultaneous		sequential
prices	p_1^{RB}	$<$	p_1^{RS}
	p_2^{RB}	$<$	p_2^{RS}
rel. price ratio	p_1^{RB}/p_2^{RB}	$=$	p_1^{RS}/p_2^{RS}
quantities	q_1^{RB}	$>$	q_1^{RS}
	q_2^{RB}	$<$	q_2^{RS}
generic MS	γ^{RB}	$<$	γ^{RS}
profits	π_1^{RB}	$<$	π_1^{RS}
	π_2^{RB}	$<$	π_2^{RS}

Figure 2: Comparison of Reaction Functions



2.4. Total Quantities and Consumer Expenditure

Let us take a look at total quantities and compare them with respect to the market shares of the alternative drug to the brand-name product, since a higher market coverage improves the consumers' welfare. The total quantities in the market are defined as the sum of the quantities of both firms which are given for simultaneous price competition by equations (7) and (8) and for sequential price competition by equations (17) and (18).

Before the introduction of a reference price the total quantities are:

$$\begin{aligned} Q^B &= q_1^B + q_2^B = \frac{3\theta_1}{4\theta_1 - \theta_2} \\ Q^S &= q_1^S + q_2^S = \frac{3\theta_1 - \theta_2}{2(2\theta_1 - \theta_2)} \end{aligned}$$

Under simultaneous price competition, more consumers in the market are served ($Q^B > Q^S$). However, the market share of branded copies under simultaneous price competition is lower ($\gamma^B < \gamma^S$).

Repeating this analysis with the equations (9) and (10) for the market restricted by a price cap yields for the total quantity: $Q^{PC} = q_1^{PC} + q_2^{PC} = 1 - \frac{k}{2\theta_1}\bar{p}_1$. It is decreasing in the price cap ($\frac{\partial Q^{PC}}{\partial \bar{p}_1} < 0$). The more restrictive (lower) the price cap, the more patients are served. Nevertheless, a price cap is inferior to reference pricing systems.

As a next step, total quantities are compared under reference pricing. By using equations (15) and (16) for the total quantity under simultaneous price competition and equations (17) and (18) for the sequential price setting the total quantities read

$$\begin{aligned} Q^{RB} &= q_1^{RB} + q_2^{RB} = \frac{3k\theta_1 + 3\alpha\theta_2}{4(k\theta_1 + \alpha\theta_2) - (k + \alpha)\theta_2} \\ Q^{RS} &= q_1^{RS} + q_2^{RS} = \frac{3k\theta_1 + 2\alpha\theta_2 - k\theta_2}{2(2k\theta_1 + (\alpha - k)\theta_2)}. \end{aligned}$$

Total quantities are higher under simultaneous price competition ($Q^{RB} > Q^{RS}$), while the generic market share is higher under sequential price competition ($\gamma_R^B < \gamma_R^S$). To assess the effect of reference pricing, comparing total quantities before and after the introduction of the regulation is necessary. The reference price increases the number of consumers served ($Q^B < Q^{RB}$ and $Q^S < Q^{RS}$). This increase is reflected in the effect of α on the total quantities. For both cases the total quantities increase in the weight of the reference price, i.e., $\frac{\partial Q^{RB}}{\partial \alpha} > 0$ and $\frac{\partial Q^{RS}}{\partial \alpha} > 0$. Concluding, the lower the reference price, the more consumers are served.

Lastly, it is interesting to shed some light on the effects of reference pricing on the consumers' expenditures. The expenditures of the consumers for the drugs are defined as the product of the copayment and the quantity consumed:

$$e_i = \underbrace{kp_i}_{\text{copayment}} q_i \quad \text{with} \quad i = 1, 2$$

Consequently, the consumer expenditures under the different competition types and reg-
ulative situations yield:

$$\begin{aligned}
e_1^B &= \frac{4\theta_1^2(\theta_1 - \theta_2)}{(4\theta_1 - \theta_2)^2} \\
e_2^B &= \frac{\theta_1\theta_2(\theta_1 - \theta_2)}{(4\theta_1 - \theta_2)^2} \\
e_1^{RB} &= \frac{4k(\theta_1 - \theta_2)(k\theta_1 + \alpha\theta_2)^2}{(k + \alpha)(4(k\theta_1 + \alpha\theta_2) - (k + \alpha)\theta_2)^2} \\
e_2^{RB} &= \frac{k\theta_2(\theta_1 - \theta_2)(k\theta_1 + \alpha\theta_2)}{(4(k\theta_1 + \alpha\theta_2) - (k + \alpha)\theta_2)^2} \\
e_1^S &= \frac{\theta_1(\theta_1 - \theta_2)}{2(2\theta_1 - \theta_2)} \\
e_2^S &= \frac{\theta_1\theta_2(\theta_1 - \theta_2)}{4(2\theta_1 - \theta_2)^2} \\
e_1^{RS} &= \frac{k(\theta_1 - \theta_2)(k\theta_1 + \alpha\theta_2)}{2(k + \alpha)(2k\theta_1 + (\alpha - k)\theta_2)} \\
e_2^{RS} &= \frac{k\theta_2(\theta_1 - \theta_2)(k\theta_1 + \alpha\theta_2)}{4(2k\theta_1 + (\alpha - k)\theta_2)^2}
\end{aligned}$$

The index B denotes the expenditures under simultaneous price competition without reg-
ulation, RB stands for reference pricing under simultaneous competition and when indexed
with S the firms compete sequentially.

Due to the variety of parameters it is not possible to compare the expenditures analytically,
hence, a numerical comparison of the expenditures with respect to different parameter val-
ues for the quality of drug 2 and changed also the weight of the reference price is carried
out. The computations were made with a copayment rate $k = 0.1$ and under the assump-
tion that the quality of drug 1 takes on the highest possible value $\theta_1 = 1$. A copayment
rate equal to 10 % resembles the German system. Furthermore, it is plausible to assume a
brand-name drug to provide excellent quality since standards for drug approvals are very
high. The parameter of the quality of drug 2 varies between the values 0.5 and 0.9 for
 θ_2 .¹³ To show the effect of a reference price the calculations are made with a very low
weight of the reference price ($\alpha = 0.1$) and a very restrictive reference price ($\alpha = 1$).

The results are given in table 8 in the appendix. The numerical simulation shows that
reference pricing leads to a reduction in the consumers' expenditures even under the least
restrictive reference price (with the weight $\alpha = 0.1$, see lines 11 vs. 12 and 23 vs. 24). The
expenditures for the brand-name drug are affected more than the expenditures for drug
2, this finding holds for both competition types (see lines 7 vs. 9, 8 vs. 10, 19 vs. 21 or 20
vs. 22). Furthermore, the decrease in expenditures is stronger for the simultaneous than
for the sequential price competition (see lines 11 vs. 23 or 12 vs. 24). When looking at the
overall expenditures it shows that the expenditures decrease further the more restrictive
the reference price is (compare lines 11 vs. 12 or 23 vs. 24). All these findings are robust
with respect to a varying quality of drug 2, the results hold for intermediate as well as for
high quality levels of the second drug.

¹³The decision to vary the quality parameter of drug two only between 0.5 and 0.9 is made due to
the minimum quality requirements a branded copy or a generic drug have to fulfill.

Table 7: Effects of Reference Pricing

	Simultaneous		Sequential	
	Pre-Regulative	RP-System	Pre-Regulative	RP-System
prices	p_1^B	$>$ p_1^{RB}	p_1^S	$>$ p_1^{RS}
	p_2^B	$>$ p_2^{RB}	p_2^S	$>$ p_2^{RS}
relative price ratio	p_1^B/p_2^B	$>$ p_1^{RB}/p_2^{RB}	p_1^S/p_2^S	$>$ p_1^{RS}/p_2^{RS}
quantities	q_1^B	$<$ q_1^{RB}	q_1^S	$=$ q_1^{RS}
	q_2^B	$<$ q_2^{RB}	q_2^S	$<$ q_2^{RS}
generic market share	γ^B	$=$ γ^{RB}	γ^S	$<$ γ^{RS}
market coverage	Q^B	$<$ Q^{RB}	Q^S	$<$ Q^{RS}
consumer expenditures*	e_1^B	$>$ e_1^{RB}	e_1^S	$>$ e_1^{RS}
(*numerical simulation)	e_2^B	$>$ e_2^{RB}	e_2^S	$>$ e_2^{RS}

3. Summary and Discussion

In general it can be concluded that sequential price competition is more advantageous to both firms than competing simultaneously. Further, it is demonstrated that even if a price cap lowers the prices, it is neither capable of introducing fiercer price competition, nor promoting generic usage. Comparing the outcomes of sequential and simultaneous price competition before and after the introduction of the reference price, the effects of reference pricing can be seen. Table 7 summarizes these results.

Under simultaneous price competition, the introduction of the reference price leads to lower equilibrium prices for both firms. Firm 1 has to decrease its price in order to keep the additional copayment the consumers have to pay when purchasing the brand-name drug as low as possible. Via the effect of prices being strategic complements, firm 2 lowers its price accordingly. The relative price ratio decreases under the reference pricing system. Hence, fiercer price competition between the two firms is introduced, even though they differ in their (perceived) quality. The equilibrium quantities increase under the reference pricing system, since more consumers decide to buy a drug due to lower prices. Nevertheless, the reference price is not able to induce a higher generic market share. The generic usage cannot be stimulated.

The equilibrium results under sequential price competition differ crucially in the generic supply. While the brand-name drug's quantities do not change under the reference pricing system, the quantities of the generic drug increase. Consequently, this leads to a higher generic market share. The reference price stimulates generic usage. The reference price ensures higher market coverage. Due to lower prices, more consumers decide to purchase drugs, especially the generic version. This effect is intensified under sequential competition. The expenditures of the consumers can be reduced when implementing a reference pricing system. The reduction in expenditures is independently from the competition type and is robust for differing weights of the reference price.

This paper demonstrated the advantage of a reference pricing system in introducing fiercer

price competition. Additionally, it showed that under sequential price competition the generic market share increased as a consequence of the reference price. Sequential price competition is the more common type of competition on the pharmaceutical market. After patent expiry brand-name drugs are more often followed by generic versions instead of being threatened by firms inventing around the patent and coming up with branded copies (“me-too drugs”). Therefore, the derived increase in generic market share under sequential competition justifies the use of a reference pricing system. Furthermore, the improved market coverage shows that a reference price ensures that more consumers have access to medical treatment. Additionally, it could be shown that consumers’ expenditures decrease crucially under regulation. It is in the interest of both firms and the consumers to keep the copayment low. However, it is evident that these interests are not aligned with those of state insurance companies. Therefore, a trade-off between these two parties should be considered in detail, but this is left for future research.

A. Appendix

Table 8: Consumer expenditure

	θ_2	0.5	0.6	0.7	0.8	0.9
1	e_1^B	0.1633	0.1384	0.1102	0.0781	0.0416
2	e_2^B	0.0204	0.0208	0.0193	0.0156	0.0094
3	$e_1^{RB} _{\alpha=1}$	0.0191	0.0156	0.0118	0.0080	0.0040
4	$e_1^{RB} _{\alpha=0.1}$	0.0900	0.0757	0.0595	0.0413	0.0215
5	$e_2^{RB} _{\alpha=1}$	0.0044	0.0037	0.0028	0.0019	0.0010
6	$e_2^{RB} _{\alpha=0.1}$	0.0150	0.0142	0.0122	0.0092	0.0051
7	$\Delta e_1^B _{\alpha=1}$	-88.30%	-88.73%	-89.29%	-89.76%	-90.38%
8	$\Delta e_1^B _{\alpha=0.1}$	-44.89%	-45.30%	-46.01%	-47.12%	-48.32%
9	$\Delta e_2^B _{\alpha=1}$	-78.43%	-82.21%	-85.49%	-87.82%	-89.36%
10	$\Delta e_2^B _{\alpha=0.1}$	-26.47%	-31.73%	-36.79%	-41.03%	-45.74%
11	$\Delta E^B _{\alpha=1}$	-87.21%	-87.88%	-88.73%	-89.43%	-90.20%
12	$\Delta E^B _{\alpha=0.1}$	-42.84%	-43.53%	-44.63%	-46.10%	-47.84%
13	e_1^S	0.1667	0.1429	0.1154	0.0833	0.0455
14	e_2^S	0.0278	0.0306	0.0311	0.0278	0.0186
15	$e_1^{RS} _{\alpha=1}$	0.0210	0.0172	0.0131	0.0089	0.0045
16	$e_1^{RS} _{\alpha=0.1}$	0.0938	0.0800	0.0637	0.0450	0.0237
17	$e_2^{RS} _{\alpha=1}$	0.0089	0.0077	0.0061	0.0043	0.0022
18	$e_2^{RS} _{\alpha=0.1}$	0.0234	0.0240	0.0223	0.0180	0.0107
19	$\Delta e_1^S _{\alpha=1}$	-87.40%	-87.96%	-88.65%	-89.32%	-90.11%
20	$\Delta e_1^S _{\alpha=0.1}$	-43.73%	-44.02%	-44.80%	-45.98%	-47.91%
21	$\Delta e_2^S _{\alpha=1}$	-67.99%	-74.84%	-80.39%	-84.53%	-88.17%
22	$\Delta e_2^S _{\alpha=0.1}$	-15.83%	-21.57%	-28.30%	-35.25%	-42.47%
23	$\Delta E^S _{\alpha=1}$	-84.63%	-85.65%	-86.89%	-88.12%	-89.55%
24	$\Delta E^S _{\alpha=0.1}$	-39.74%	-40.06%	-41.30%	-43.29%	-46.33%

The index B gives the expenditures under simultaneous price competition without regulation. The index RB stands for reference pricing under simultaneous competition. When indexed with S the firms compete sequentially. Δe denotes the change in expenditures from no regulation to the reference pricing for the respective firm and competition type, where ΔE gives the changes for the total expenditures over both drugs.

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