The Design of External Reference Pricing Schemes and the Choice of Reference Countries and Pricing Rules

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Abstract

External reference pricing imposes a price cap for drugs based on prices in other countries. This paper studies the design of external reference pricing schemes, i.e., the choice of reference countries and pricing rules, in a three-country-framework. Given that the manufacturer sells to all three countries, the minimum-price rule yields the lowest drug price. If the referencing country is sufficiently large, the manufacturer may not export to reference countries under the minimum-price rule. Then the average-price rule may safeguard exports to reference countries and generate a lower drug price in the referencing country. As external reference pricing may increase drug prices in reference countries, it creates the incentive for the reference countries also to adopt external reference pricing. Thus external reference pricing results in regulatory convergence with a uniform price among all countries, i.e., price convergence.

JEL classification: I11, I18, F12

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1 Introduction

A widely used instrument in pharmaceutical price regulation is external reference pricing, which imposes a price cap for drugs based on their prices in other countries (Espin & Rovira, 2007). This is, external reference pricing follows the idea that prices in different countries may be compared. It is an easily applicable regulatory instrument, which requires no (additional)

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information, e.g., on the therapeutic value of a drug. Almost all European countries apply external reference pricing[1], with schemes varying in the number of reference countries and pricing rules. For instance, Portugal refers to prices in 3 other countries, while Italy uses 24 reference countries (Schneider & Vogler, 2019)[2]. In Austria, Belgium, the Netherlands, and Portugal, the reference price is calculated as the average price in the reference countries, while Denmark and Spain use the minimum price (Schneider & Vogler, 2019).

This paper explores the design of external reference pricing schemes in a three-country-framework. This framework allows for analyzing different sets of reference countries and pricing rules. Also, it makes it possible to study the effect of the manufacturer's export decision on the choice of external reference pricing schemes and the impact of reference pricing on third countries, especially their incentive also to introduce external reference pricing. This paper analyzes the choice of external reference pricing schemes in one country as well as its effect on the manufacturer's export decision, the impact of external reference pricing on drug prices in reference countries and thus the incentives for the other countries to also adopt an external reference pricing scheme.

Garcia Mariñoso, Jelovac & Olivella (2011) and Ackermann (2010) analyze the incentives for countries to adopt external reference pricing in a two-country framework. A country prefers external reference pricing against individual price negotiations with a firm under high copayments (Garcia Mariñoso, Jelovac & Olivella, 2011) or low bargaining power of its regulatory agency (Ackermann, 2010).

By making pricing decisions for different countries interdependent, external reference pricing may result in a (downward) price convergence (Toumi et al., 2013). Stargardt & Schreyögg (2006) study the impact of a price change in Germany on pharmaceutical prices in other countries under external reference pricing. They show that a €1-price reduction in Germany reduces prices from €0.15 in Austria to €0.36 in Italy. These price spillovers may induce firms to delay or even limit supply to low-price countries to (temporarily) retain high prices in other countries (Richter, 2008). Danzon, Wang & Wang (2005), who analyze launches of new drugs in 25 countries between 1994 and 1998, find that parallel exporting countries with relatively low drug prices have fewer launches and longer launch delays. Moreover, Danzon & Epstein (2008),

[1] Also, non-European countries such as Australia, Canada, Japan, South Korea, Mexico, New-Zealand, and Turkey apply external reference pricing (Toumi et al., 2013, Schneider & Vogler, 2019).

[2] Historically, reference countries have been chosen according to economic comparability and/or geographic proximity, but over the last years, a trend towards larger country baskets has evolved (Toumi et al., 2013).

Verniers, Stremersch & Croux (2011), Costa-Font, McGuire & Varol (2014) suggest that stricter regulation and/or interdependence between countries lead to greater launch delays. Houy & Jelovac (2015) study timing decisions of pharmaceutical firms when launching a drug under external reference pricing. They find no incentive to delay the launch when the countries only refer to the prices of a subset of all countries in a transitive way and any period. Persson & Jönsson (2016) argue that applying external reference pricing is attractive but costly, as it induces manufacturers to limit or delay launches and reduces opportunities for price discrimination among countries. Maini & Pammolli (2017), who analyze the impact of external reference pricing on launch delays, document the presence of launch delays across Europe, especially in Eastern Europe. They show that removing external reference pricing would reduce delays in Eastern Europe by up to 14 months. Houy & Jelovac (2019) study the effect of drug approval procedures on launch decisions of pharmaceutical firms under external reference pricing, showing that a centralized drug approval procedure limits the number of countries in which a firm launches a drug.

Against this background, the contribution of this paper is three-fold: First, this paper studies the design of external reference pricing schemes, especially the choice of reference countries and pricing rules, which has not been studied so far. Second, this paper contributes to the literature on the effect of external reference pricing on launch delays by studying the choice of external reference pricing scheme under an endogenous export decision of the manufacturer. The decision of a manufacturer not to sell to some countries may limit the effective set of reference countries and pricing rules. Third, this paper analyzes the incentives for reference countries also to adopt external reference pricing schemes. Since reference pricing makes drug prices interdependent, it may also make reference pricing regimes interdependent: One country applying external reference pricing may incentivize other countries to follow.

The paper shows that, given that the manufacturer sells to all three countries, the minimum-price rule yields the lowest drug price. If the referencing country is sufficiently large, the manufacturer may not export to reference countries under the minimum-price rule. Then the average-price rule may safeguard exports to reference countries and generate a lower drug price in the referencing country. This is, under external reference pricing not only direct launch delays may occur when a manufacturer does not export to a country with low prices due to strict regulation to avoid the spillover of low prices to high-price countries. But also the choice of a pricing rule may also provoke indirect launch delays, when a manufacturer does not export to a reference country under the minimum-price rule in a referencing country, because the minimum-price rule results in stronger spillovers of prices and higher price concessions. The choice of referencing countries for the average-price rule, which results in higher prices than the minimum-price rule, is not necessarily motivated by these countries being interested in avoiding launch delays in reference countries but may result from the possibility to use the information on prices in reference countries which would not be possible under a non-launch. In Europe, many countries apply the average-price rule, for instance, Austria, Ireland, the Netherlands, and Portugal. One potential explanation for this practice is that these countries – and the countries they reference to – are rather different in willingness to pay and thus prices, and indirect launch delays could be possible. However, there might also be other reasons for the application of the average-price rule, for instance, lobbying of pharmaceutical manufacturers, fear of (direct) launch delays under strict regulation or hedging against the effect of wrong prices being reported by some countries (Toumi et al. 2013). In addition, the results for one country applying external reference pricing in a three-country framework may only point towards one potential mechanism for launch delays in Europe where most countries apply external reference pricing and include each other as reference countries. Maini & Pammolli (2017) document substantial launch delays for many East European countries. This could be explained by small market size or low willingness to pay in these countries or by indirect launch delays if other countries use East European countries as reference countries. For instance, Spain refers to prices in Estonia, Latvia, Lithuania, Slovakia, and Slovenia (Schneider & Vogler, 2019).

Moreover, the paper shows that external reference pricing may create the incentive for the reference countries also to adopt external reference pricing. Thus, external reference pricing results in regulatory convergence and a uniform price among all countries, i.e., price convergence. The widespread use of external reference pricing in Europe seems to be in line with this incentive for other countries also to adopt external reference pricing. The empirical evidence for price convergence in the European Union, however, is mixed (Kyle, 2019). However, the manufacturer's decision not export to potential reference countries may counteract regulatory and thus price convergence.

Parallel trade, the cross border resale of goods without the authorization of the manufacturer (Maskus, 2000), can be considered a related instrument, as it generates price spillovers and may result in launch delays and price convergence (Kyle, 2007). While parallel trade can be seen as a form of competition and is mostly driven by the pricing strategies of pharmaceutical manufacturers, external reference pricing can be considered a form of regulation and is determined by regulatory choices of governments, e.g., the choice of reference countries and pricing rules.

The rest of the paper is organized as follows. The next section presents the model. Section 3 studies the regulatory scenarios. Section 4 analyzes the choice of regulatory schemes in one country; section 5 analyzes the choice of an external reference pricing schemes on the manufacturer's export decision. Section 6 and section 7 study the effect of external reference pricing on drug prices in reference countries and thus the incentives for other countries to also adopt an external reference pricing scheme. Section 8 concludes.

2 Model

Consider an innovative firm selling a drug in three countries, $j = A, B, C$. Assume that the firm is located in a fourth country. The firm produces at constant marginal cost, which is normalized to zero.

In all three countries, third-party payers cover drug costs partially. Consider that consumers pay a fraction γ_j, $\gamma_j \in (0,1)$, of the drug price out-of-pocket (coinsurance). Thus, the drug copayment and the effective price for consumers is $c_j = \gamma_j p_j$. Third-party payers reimburse a fraction $\left(1-\gamma_j\right) p_j$ of the drug price. Reimbursement and the role of third-party payers in financing the drug create an incentive for governments to decrease public cost.[3]

Each consumer demands either one or zero units of the drug. The utility derived from no drug consumption is zero. A consumer i in country j who buys one unit of the drug obtains a net utility of

$$U(\theta_{ij}, c_j) = \theta_{ij} - \gamma_j p_j, \tag{1}$$

where θ_{ij} is a preference parameter, γ_j is the coinsurance rate, and p_j is the drug price in country j.

Consumers differ in the preference parameter θ, which may be interpreted as willingness to pay. Heterogeneity among consumers may stem from differences in income or in the severity of the condition, prescription practices or insurance coverage (see, e.g. Brekke, Holmas & Straume, 2011). Assume that the parameter θ is uniformly distributed over the interval $[0, \mu_j]$ in country j, where μ_A, $\mu_B \geq \mu_C = 1$. The parameter μ_j can be interpreted as the maximum

[3] Also, welfare maximization or increasing consumer surplus may motivate regulating drug prices.

willingness to pay for a given price.[4] The total mass of consumers in all countries is one. Let $\beta_j = \frac{\gamma_j}{\mu_j}$ coinsurance rate relative to the maximum willingness to pay for simplification. A higher β_j indicates, therefore, a higher coinsurance rate and/or a lower maximum willingness to pay.

The marginal consumer in country j who is indifferent between buying the drug or not has a gross valuation $\widehat{\theta}_j = \gamma_j p_j$. Hence, demand in country j is given as $q_j = \left(1 - \beta_j p_j\right)$.

In this set-up, there are two sources of differences between countries (captured by differences in β_j): First, countries differ in maximum willingness to pay for a given price. Second, countries differ in price elasticity of demand (due to differences in coinsurance rates). Differences in μ_j and/or γ_j generate differences in drug prices, providing the incentive for governments to implement price caps based on the price in another country (external reference pricing).

Consider the following timing: In stage 1, the government in country A chooses the external reference pricing scheme to minimize the drug price. In stage 2, the firm sets prices.

3 Regulatory Scenarios

3.1 Coinsurance

Consider first the case of coinsurance (and no external reference pricing) where the manufacturer may price discriminate, i.e., set the price in all countries without being constrained. An asterisk denotes variables under coinsurance.

The manufacturer sets country-specific prices p_j^* to maximize its profit

$$\pi = \sum_{j \in A,B,C} \left(1 - \beta_j p_j^*\right) p_j^*. \tag{2}$$

The equilibrium price p_j in country j is

$$p_j^* = \frac{1}{2\beta_j}. \tag{3}$$

The price p_j in country j decreases in β_j, it increases in willingness to pay μ_j and decreases in the coinsurance rate γ_j. Thus, price differences between countries are driven by differences in willingness to pay μ_j and coinsurance rates γ_j.

[4] Following the interpretation of θ as income, a country with a high μ_j could be labeled as high-income country, and a country with a low μ_j could be labeled as low-income country.

The manufacturer's profit from selling in country j is

$$\pi_j^* = \frac{1}{4\beta_j}. \tag{4}$$

3.2 External Reference Pricing

Consider now the case where the government in country A adopts external reference pricing. The following external reference pricing schemes are studied:

- One reference country (B), denoted as $1B$. This scheme imposes a price cap $P_A^{1B} = p_B$.
- One reference country (C), denoted as $1C$. This scheme imposes a price cap $P_A^{1C} = p_C$.
- Two reference countries, denoted as $2minj$. This scheme imposes a price cap $P_A^{2min} = min\{p_B, p_C\}$.
- Two reference countries, denoted as $2avg$. This scheme imposes a price cap $P_A^{2avg} = \frac{1}{2}p_B + \frac{1}{2}p_C$.

3.2.1 One Reference Country

Consider first that the government in country A sets a price cap based on the price in one country. Two cases are possible; the price cap may be based on the drug price in country B (scheme $1B$) or the drug price in country C (scheme $1C$). The choice between the two reference countries is considered exogenous at this point.

Under scheme $1B$, the manufacturer sets prices to maximize

$$\begin{aligned} \pi^{1B} &= \left(1 - \beta_A p_A^{1B}\right) p_A^{1B} + \left(1 - \beta_B p_B^{1B}\right) p_B^{1B} + \left(1 - \beta_C p_C^{1B}\right) p_C^{1B} \\ &\quad \text{s.t. } p_A^{1B} \leq P_A^{1B} = p_B^{1B}. \end{aligned} \tag{5}$$

Equilibrium prices are

$$p_A^{1B} = p_B^{1B} = \frac{1}{\beta_A + \beta_B}, \; p_C^{1B} = \frac{1}{2\beta_C}. \tag{6}$$

The manufacturer's profit is

$$\pi^{1B} = \frac{\beta_B}{(\beta_A + \beta_B)^2} + \frac{\beta_A}{(\beta_A + \beta_B)^2} + \frac{1}{4\beta_C}. \tag{7}$$

The imposed price cap P_A^{1B} is binding, i.e., $p_A^{1B} \leq p_A^*$ if $\beta_A \leq \widehat{\beta}_{A1B} = \beta_B$. The scheme $1B$ decreases the drug price in country A if β_A is sufficiently low, i.e., the maximum willingness is sufficiently high and/or the coinsurance rate is sufficiently low.[5]

Under scheme $1C$, the manufacturer sets prices to maximize

$$\begin{aligned} \pi^{1C} &= \left(1-\beta_A p_A^{1C}\right) p_A^{1C} + \left(1-\beta_B p_B^{1C}\right) p_B^{1C} + \left(1-\beta_C p_C^{1C}\right) p_C^{1C} \\ & \text{s.t. } p_A^{1C} = P_A^{1C} \leq p_C^{1C}. \end{aligned} \tag{8}$$

Equilibrium prices are

$$p_A^{1C} = p_C^{1C} = \frac{1}{\beta_A + \beta_C},\ p_B^{1C} = \frac{1}{2\beta_B}. \tag{9}$$

The manufacturer's profit is

$$\pi^{1C} = \frac{\beta_C}{(\beta_A+\beta_C)^2} + \frac{1}{4\beta_B} + \frac{\beta_A}{(\beta_A+\beta_C)^2}. \tag{10}$$

The imposed price cap P_A^{1C} is binding, i.e., $p_A^{1C} \leq p_A^*$ if $\beta_A \geq \widehat{\beta}_{A1C} = \beta_C$.[6]

3.2.2 Two Reference Countries, Minimum Price

Consider now that the government in country A sets a price cap based on the lower of the prices in countries B and C. For instance, Denmark and Spain use the minimum-price rule (Toumi et al., 2013).

The manufacturer sets prices to maximize

$$\begin{aligned} \pi^{2minj} &= \left(1-\beta_A p_A^{2minj}\right) p_A^{2minj} + \left(1-\beta_B p_B^{2minj}\right) p_B^{2minj} + \left(1-\beta_C p_C^{2minj}\right) p_C^{2minj} \\ & \text{s.t. } p_A^{2minj} \leq P_A^{2min} = min\{p_B^{2minj}, p_C^{2minj}\}. \end{aligned} \tag{11}$$

Based on differences in willingness to pay and coinsurance rates, three cases can be distinguished for the equilibrium price vector p_A^{2minj}, p_B^{2minj}, p_C^{2minj} with $p_A^{2minj} = P_A^{2min} = min\{p_B^{2minj}, p_C^{2minj}\}$. In two cases, the manufacturer is constrained in setting the price for country A and a second country but may set the price without constraints in the third country:

[5] Equilibrium existence requires that the manufacturer has no incentive to deviate from the proposed prices. A deviation to $\widetilde{p_A^{1B}}$, $\widetilde{p_B^{1B}}$ with $\widetilde{p_A^{1B}} < \widetilde{p_B^{1B}}$ is not profitable, i.e., $\pi^{1B} - \pi\left(\widetilde{p_A^{1B}}, \widetilde{p_B^{1B}}\right) > 0$, see Appendix A.1.

[6] Similarly, as under 1B, there is no incentive for the manufacturer to deviate to a strategy $\widetilde{p_A^{1C}}$, $\widetilde{p_B^{1C}}$ with $\widetilde{p_A^{1C}} < \widetilde{p_B^{1C}}$ to avoid the price P_A^{1C}, see Appendix A.1.

In case $2minB$, the price cap in A is based on the price in country B, which is lower than the (unconstrained) price in country C. In case $2minC$, the price cap in A is based on the price in country C, which is lower than the (unconstrained) price in country B. In case $2minBC$, the manufacturer is constrained in price-setting in all three countries and sets a uniform price.

In case $2minB$, equilibrium prices are

$$p_A^{2minB} = p_B^{2minB} = \frac{1}{\beta_A + \beta_B}, \; p_C^{2minB} = \frac{1}{2\beta_C}. \tag{12}$$

The manufacturer's profit is

$$\pi^{2minB} = \frac{\beta_B}{(\beta_A + \beta_B)^2} + \frac{\beta_A}{(\beta_A + \beta_B)^2} + \frac{1}{4\beta_C}.$$

The imposed price cap P_A^{2minB} is binding, i.e., $p_A^{2minB} \leq p_A^*$ if $\beta_A \leq \widehat{\beta}_{A2minB} = \beta_B$. Note that the case $2minB$ yields the same price equilibrium as $1B$, as in both cases the manufacturer is constrained in setting prices in country A and country B but not in country C. Throughout the paper, the cases $1B$ and $2minB$ are labeled accordingly to indicate the choice of reference countries and pricing rule.[7]

In case $2minC$, equilibrium prices are

$$p_A^{2minC} = p_C^{2minC} = \frac{1}{\beta_A + \beta_C}, \; p_B^{2minC} = \frac{1}{2\beta_B}. \tag{13}$$

The manufacturer's profit is

$$\pi^{2minC} = \frac{\beta_C}{(\beta_A + \beta_C)^2} + \frac{1}{4\beta_B} + \frac{\beta_A}{(\beta_A + \beta_C)^2}. \tag{14}$$

The imposed price cap P_A^{2minC} is binding, i.e., $p_A^{2minC} \leq p_A^*$ if $\beta_A \leq \widehat{\beta}_{A2minC} = \beta_C$. Similarly, the case $2minC$ yields the same price equilibrium as $1C$, as in both cases the manufacturer is constrained in setting prices in country A and country C but not in country B.

In case $2minBC$, the uniform equilibrium price is

$$p_A^{2minBC} = p_B^{2minBC} = p_C^{2minBC} = \frac{3}{2(\beta_A + \beta_B + \beta_C)}. \tag{15}$$

[7] Note that it is useful to distinguish between $1B$ and $2minB$ as the choice of $2minj$ may also result in cases $2minC$ or $2minBC$. Also, the choice of $2minj$ may have different implications than the choice of $1B$ if more than one country adopts external reference pricing, see section 5.

The manufacturer's profit is

$$\pi^{2minBC} = \frac{6\left(\beta_B + \beta_C\right) - 3\beta_A}{4\left(\beta_A + \beta_B + \beta_C\right)^2} + \frac{6\left(\beta_A + \beta_C\right) - 3\beta_B}{4\left(\beta_A + \beta_B + \beta_C\right)^2} + \frac{6\left(\beta_A + \beta_B\right) - 3\beta_C}{4\left(\beta_A + \beta_B + \beta_C\right)^2}. \tag{16}$$

The imposed price cap P_A^{2minBC} is binding, i.e., $p_A^{2minBC} \leq p_A^*$ if $\beta_A \leq \widehat{\beta}_{A2minBC} = \frac{\beta_B + \beta_C}{2}$.

Under this rule, differences in β_j, i.e., willingness to pay and coinsurance rates, determine whether the price cap is based on the price in one country, allowing the manufacturer to set the price in the third country without constraints, as under coinsurance and no external reference pricing ($2minB$ or $2minC$) or whether this rule constrains price-setting in all three countries and the manufacturer sets a uniform price ($2minBC$). Whether case $2minB$ or $2minC$ or case $2minBC$ occurs depends on the deviations from the profit-maximizing price under coinsurance (and no external reference pricing) in country A and the reference country (the country with the lower of both prices) under this rule. When setting prices under the minimum-price rule, the manufacturer balances the loss in profit from a lower price in country A against the loss in profit from a higher price in the reference country. As the change in profit due to a deviation $+\lambda$ or $-\lambda$ from the price under coinsurance and no external reference pricing increases exponentially in λ[8], it is not optimal to adjust the price in only one country and not to change the price in the other country. Instead, the manufacturer minimizes losses in profits across countries by reducing the price in country A and increasing it in the reference country. The manufacturer's strategy to minimize losses from deviations from the price under coinsurance and no external reference pricing by adjusting prices in both the referencing country and the reference country imposes a constraint on price-setting in both countries. Thus, the adoption of the minimum-price rule in country A does not only change the drug price in country A but also in at least one of the other countries.

As the change in profit from price changes depends on β_j, the maximum willingness to pay and the coinsurance rate in the respective country, and the manufacturer balances losses in profit across all markets, price changes in all countries affected depend on β_j in all countries.

If countries B and C are rather different in β_j, so are the profit-maximizing prices under coinsurance and no external reference pricing. Then the price cap in A is based on the lower of both prices (price in the country with the higher β_j), and the manufacturer may set the price without constraints in the third country (the country with the lower β_j). This is, the

[8]The change in profit due to a price change $\Delta p = p^* - (p^* - \lambda)$ is $\Delta\pi = \pi_j(p^*) - \pi_j(p^* - \lambda) = -\beta_j \lambda^2$.

equilibrium outcome is $2minB$ or $2minC$, depending on which country is smaller and yields a lower price. For $\beta_B \geq \widehat{\beta_{B}}_{p_B=p_C}$, the price cap is based on the price in country B, and the price in country C is the same as under coinsurance. For $\beta_B \leq \widehat{\beta_{B}}_{p_B=p_C}$, the price cap is based on the price in country C, and the price in country B is the same as under coinsurance.

If countries B and C are rather similar in β_j, two cases can be distinguished: 1. If β_A is rather high relative to β_B and β_C, i.e., all three countries are rather similar, the deviations from the profit-maximizing price under coinsurance (and no external reference pricing) in the reference country are small and do not affect the price in the third country. Then the manufacturer may set the price without constraints in one country (the country with the lower β_j), and the price cap in A is based on the lower of the prices in countries B and C (the country with the higher β_j). This is, the equilibrium outcome is $2minB$ or $2minC$. 2. If β_A is rather low relative to β_B and β_C, the deviations from the profit-maximizing price under coinsurance (and no external reference pricing) in country A and the reference country are rather large. In this case, the manufacturer decreases the price in country A and increases the price in the reference country to a rather great extent (as indicated by the difference between β_A on the one hand and β_B and β_C on the other hand). This also affects the price in the third country, as the rather large increase in the price in the reference country changes the price ranking between the two potential reference countries. A failure to adjust the price in the third country would create an inconsistent price ranking, with country A setting a price cap based on the price in one country, while the price in the third country is lower. This violation of the minimum-price rule could induce the government in A to set a price cap based on the lower price in the third country, either triggering multiple adjustment decisions of the manufacturer's price-setting and the government in A choosing the reference country based on the lowest price or resulting in the manufacturer not adjusting his pricing decision at the cost of not setting profit-maximizing prices. So if β_A is rather low relative to β_B and β_C, the minimum rule constrains the manufacturer in all three countries. The equilibrium outcome is $2minBC$.

Depending on differences in β_j, three cases are possible under the minimum-price rule: For $\beta_B \geq \widehat{\beta_{B}}_{p_B=p_C}$ and $\beta_A \geq \widehat{\beta_{A}}_{p_B^{2minB}=p_C^{2minB}}$, the equilibrium outcome is $2minB$. For $\beta_B \leq \widehat{\beta_{B}}_{p_B=p_C}$ and $\beta_A \geq \widehat{\beta_{A}}_{p_B^{2minC}=p_C^{2minC}}$, the equilibrium outcome is $2minC$. For $\beta_B \geq \widehat{\beta_{B}}_{p_B=p_C}$ and $\beta_A \leq \widehat{\beta_{A}}_{p_B^{2minB}=p_C^{2minB}}$ or $\beta_B \leq \widehat{\beta_{B}}_{p_B=p_C}$ and $\beta_A \leq \widehat{\beta_{A}}_{p_B^{2minC}=p_C^{2minC}}$, the equilibrium outcome is $2minBC$.[9]

[9] Equilibrium existence requires that the manufacturer has no incentive to deviate from the proposed prices.

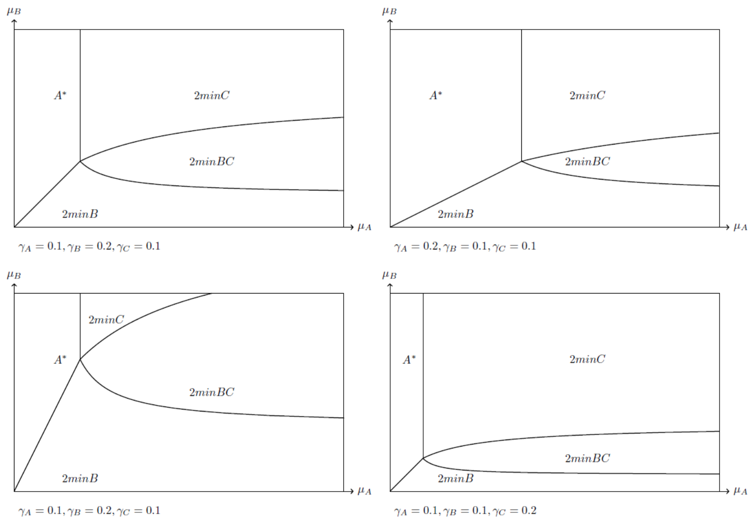

Figure 1: Equilibrium outcomes under the minimum price-rule.

These three cases are shown in Figure 1, which differentiates between the effect of maximum willingness to pay μ_j (on the axes) and the coinsurance rate γ_j (exogenous variation among the panels). In all four panels, the equilibrium outcomes under the minimum-price rule are depicted as a function of maximum willingness to pay in countries A and B. Panel 1 illustrates the case of identical coinsurance rates in all three countries, while panels 2-4 focus on the effect of an increase in the coinsurance rate in one country on equilibrium outcomes. Four areas can be distinguished: A^*: For a relatively small maximum willingness to pay in country A, the price cap under the minimum-price rule is not binding, and coinsurance is applied. For sufficiently large maximum willingness to pay in A, the price cap under the minimum-price rule is binding. This is the case for the areas $2minB$, $2minC$, and $2minBC$. As the maximum willingness to pay in C is normalized to one, variations in the maximum willingness to pay in B can also be interpreted as variations in relative variations in maximum willingness to pay. $2minB$: For small to intermediate maximum willingness to pay in B (relative to C), the drug price in B is lower than in C, and the equilibrium outcome is $2minB$. $2minC$: For sufficiently large maximum willingness to pay in B, the drug price in C is lower than in B, and the equilibrium outcome is $2minC$. $2minBC$: For an intermediate maximum willingness to pay in B (similar to the maximum willingness to pay in C), the equilibrium outcome is $2minBC$ with a uniform price.

Panel 2 (top right) illustrates the case of an increase in the coinsurance rate in country A.

Under the outcome $2minB$, a deviation to $\widetilde{p_A^{2minB}}$, $\widetilde{p_B^{2minB}}$ with $\widetilde{p_A^{2minB}} < \widetilde{p_B^{2minB}}$ would allow it to avoid the price cap. However, this is not profitable, i.e., $\pi^{2minB} - \pi\left(\widetilde{p_A^{2minB}}, \widetilde{p_B^{2minB}}\right) > 0$, see Appendix A.1. Similar for $2minC$, a deviation to $\widetilde{p_A^{2minC}}$, $\widetilde{p_B^{2minC}}$ with $\widetilde{p_A^{2minC}} < \widetilde{p_B^{2minC}}$ to avoid the price cap in country A is not profitable. Under $2minBC$, a deviation to $\widetilde{p_A^{2minBC}}$, $\widetilde{p_B^{2minBC}}$, $\widetilde{p_C^{2minBC}}$ with $\widetilde{p_A^{2minB}} < \widetilde{p_B^{2minB}} = \widetilde{p_C^{2minBC}}$.

Compared to the first panel, the area A^* is larger. Under the minimum-price rule, the price cap is binding if $\beta_A = \frac{\gamma_A}{\mu_A}$ is sufficiently low. For a higher coinsurance γ_A, a larger maximum willingness to pay μ_A is needed for the price cap under the minimum-price rule to be binding. The equilibrium price under coinsurance decreases in the coinsurance rate, so if consumers have to pay a larger fraction of the price out-of-pocket, the higher price elasticity may be seen as a substitute to direct price regulation. Also, the area $2minBC$ shifted to the right compared to panel 1. Similarly, $2minBC$ is the equilibrium outcome if $\beta_A = \frac{\gamma_A}{\mu_A}$ is sufficiently low, thus for a higher coinsurance γ_A, a larger maximum willingness to pay μ_A is required.

Panel 3 (bottom left) depicts an increase in the coinsurance rate in country B. Under the minimum-price rule, the choice between the reference countries B and C depends on the relation of $\beta_B = \frac{\gamma_B}{\mu_B}$ to $\beta_C = \gamma_C$. If β_B is sufficiently high, i.e., the maximum willingness to pay μ_B is sufficiently low, or the coinsurance rate γ_B is sufficiently high, the price in B is lower than in C, and the price cap in A is based on the price in B ($2minB$). The increase in the coinsurance rate and the corresponding price decrease make country B a more attractive reference country. The areas $2minBC$ and $2minC$ are shifted upwards. This is, the equilibrium outcomes $2minBC$ and $2minC$ are favorable only for a larger maximum willingness to pay in B.

Panel 4 (bottom right) illustrates the case of an increase in the coinsurance rate in country C, which is symmetric to the case of an increase in the coinsurance rate in country B. If β_C is sufficiently high, i.e. the coinsurance rate γ_C is sufficiently high, the price in C is lower than in B, make country C a more attractive reference country. The areas $2minB$ and $2minBC$ are shifted downwards.

3.2.3 Two Reference Countries, Average Price

Consider now that the regulatory agency in country A sets a price cap based on the average price in countries B and C (scheme $2avg$).

For example, in Austria, Belgium, the Netherlands, and Portugal, the average-price rule is applied (Toumi et al., 2013).

The manufacturer sets prices to maximize

$$\begin{aligned}\pi^{2avg} &= \left(1-\beta_A p_A^{2avg}\right) p_A^{2avg} + \left(1-\beta_B p_B^{2avg}\right) p_B^{2avg} + \left(1-\beta_C p_C^{2avg}\right) p_C^{2avg} \\ &\text{s.t. } p_A^{2avg} \leq P_A^{2avg} = \frac{1}{2} p_B^{2avg} + \frac{1}{2} p_C^{2avg} \qquad (17)\end{aligned}$$

Equilibrium prices are

$$\begin{aligned} p_A^{2avg} &= \frac{3(\beta_B+\beta_C)}{2(\beta_A\beta_B+\beta_A\beta_C+4\beta_B\beta_C)} \\ p_B^{2avg} &= \frac{3\beta_C}{(\beta_A\beta_B+\beta_A\beta_C+4\beta_B\beta_C)}, \\ p_C^{2avg} &= \frac{3\beta_B}{(\beta_A\beta_B+\beta_A\beta_C+4\beta_B\beta_C)}. \end{aligned} \tag{18}$$

The manufacturer's profit is

$$\begin{aligned} \pi^{2avg} &= \frac{3(\beta_B+\beta_C)(8\beta_B\beta_C-\beta_A\beta_B-\beta_A\beta_C)}{4(\beta_A\beta_B+\beta_A\beta_C+4\beta_B\beta_C)^2} + \frac{3\beta_C(\beta_A\beta_B+\beta_A\beta_C+\beta_B\beta_C)}{(\beta_A\beta_B+\beta_A\beta_C+4\beta_B\beta_C)^2} \\ &+ \frac{3\beta_B(\beta_A\beta_B+\beta_A\beta_C+\beta_B\beta_C)}{(\beta_A\beta_B+\beta_A\beta_C+4\beta_B\beta_C)^2}. \end{aligned} \tag{19}$$

The imposed price cap P_A^{2avg} is binding, i.e., $p_A^{2avg} \leq p_A^*$ if $\beta_A \leq \widehat{\beta}_{A2avg} = \frac{2\beta_B\beta_C}{\beta_B+\beta_C}$.[10]

4 Choice of Regulatory Scheme

Consider now the choice of the external reference pricing scheme by the government in country A with the aim to minimize the drug price.

Welfare in country A is given as consumer surplus (CS_A) less third-party payer expenditure (E_A) [11]:

$$\begin{aligned} W_A &= \underbrace{\int_{\gamma_A p_A}^{\mu_A} \left(\frac{1}{\mu_A}\theta - \beta_A p_A\right) d\theta}_{CS_A} - \underbrace{(1-\beta_A p_A)\,p_A\,(1-\gamma_A)}_{E_A} \\ &= \frac{\mu_A}{2} + \beta_A p_A^2\left(1-\frac{1}{2}\gamma_A\right) - p_A\,(1-\gamma_A+\beta_A\mu_A)\,. \end{aligned} \tag{20}$$

Welfare decreases in the drug price[12]. Minimizing the drug price is thus equivalent to maximizing welfare.

[10] Equilibrium existence requires that the manufacturer has no incentive to deviate from the proposed prices. Under the average price-rule, a deviation to $\widetilde{p_A^{2avg}}$, $\widetilde{p_B^{2avg}}$, $\widetilde{p_C^{2avg}}$ with $\widetilde{p_B^{2avg}} < \frac{1}{2}\widetilde{p_B^{2avg}} + \frac{1}{2}\widetilde{p_C^{2avg}}$ would allow it to avoid the price cap. However, this is not profitable, i.e., $\pi^{2avg} - \pi\left(\widetilde{p_A^{2avg}}, \widetilde{p_B^{2avg}}, \widetilde{p_C^{2avg}}\right) > 0$, see Appendix A.1.

[11] Throughout this paper, profit generated in country j is not included in the definition of welfare of country j. Results do not change, however, if local profits were considered in country j (e.g. due to jobs or tax revenue), as welfare defined as local profits plus consumer surplus less third-party payer expenditure also decreases in the drug price.

[12] **Welfare decreases in the drug price:** $\frac{\partial W_A}{\partial p_A} = -(1-\beta_A p_A(2-\gamma_A)) < 0$, **as long as** $p_A < p_A^*$.

Prices increases decrease welfare, as consumer surplus decreases to a larger extent in the drug price than third-party payer expenditure does: Consumer surplus decreases, as an increase in the drug price increases copayments ($\gamma_A p_A$) and reduces demand. The higher drug price increases reimbursement per consumer ($(1-\gamma_A)\, p_A$), increasing third-party payer expenditure, whereas the reduction in demand decreases third-party payer expenditure. The effect of a higher reimbursement dominates the effect of lower demand, and third-party payer expenditure increases in the drug price.[13]

External reference pricing lowers the drug price compared to coinsurance if β_A is sufficiently low, i.e., the maximum willingness to pay is sufficiently high and/or the coinsurance rate is sufficiently low, and the price cap imposed by external reference pricing is binding.

Choosing only one reference country, i.e., scheme $1B$ or $1C$, is not optimal as the government in country A foregoes using the information on a lower price and accordingly the possibility of choosing a lower price cap. Schemes $1B$ and $1C$ yield the same drug price as schemes $2minB$ and $2minC$ but for the parameter set where the minimum rule generates a uniform price across all three countries, schemes $1B$ and $1C$ would yield a higher drug price than the minimum-price rule. The schemes $1B$ and $1C$ do not contain information on the rather low price in the third country and the possibility to use this country as a reference country. Thus, the minimum-price rule allows the regulator to exert a stronger restriction on the manufacturer's price-setting and to enforce a uniform price.

Consider in the following that the government in country A chooses two reference countries. If countries B and C are sufficiently different in β_j, the minimum-price rule generates a lower price than the average-price rule. The minimum-price rule does not use the information on the higher price in the third country, whereas the average-price rule necessarily uses the information on prices in both countries. Moreover, the link between prices in country A and the country with the lower price is stronger under the minimum-price rule: Whereas under the average-price rule price changes in the reference countries are transmitted to country A only by 50% each, the minimum-price rule enforces a direct one-to-one link between prices in the reference country and the referencing country A. Also, if all three countries are rather similar, the minimum-price rule yields a lower price as the manufacturer makes higher price concessions in the reference

[13] The higher the coinsurance rate, i.e., the higher the fraction the consumer pays of the drug price, the higher the increase in copayments for a given increase of the drug price and the stronger the reduction in demand. At the same time, a higher coinsurance rate dampens the effect of a higher reimbursement for the third-party payer. This is, under a higher coinsurance rate, a price increase decreases consumer surplus to a larger extent than it increases third-party payer expenditure.

country and country A to be able to set the price without being constrained in the third country. The average-price rule, on the contrary, imposes restrictions on the manufacturer's price-setting in all three countries[14]. If β_A is rather low relative to β_B and β_C, both the minimum-price rule and the average-price rule impose restrictions on the manufacturer's price-setting in all three countries. In this case, the minimum-price rule yields a lower price as it enforces a direct one-to-one link between prices in all countries.

Proposition 1 summarizes the choice of regulatory schemes in country A:

Proposition 1 *The government in country A chooses two reference countries and the minimum-price rule to minimize the drug price.*

5 Endogenous Export Decision

Consider now that the manufacturer may react to the choice for an external reference pricing scheme in country A by adjusting its export decision. In particular, it may refrain from exporting to one of the countries, if a low price may spill over to a high-price country. Consider in the following that country A applies the minimum-price rule, as it generates the lowest drug price. Export decisions under all external reference pricing schemes can be found in Appendix A.3.

If the government in country A applies the minimum-price rule, and $2minB$ is the equilibrium outcome, equilibrium are $p_A^{2minB} = p_B^{2minB} = \frac{1}{\beta_A+\beta_B}$, $p_C^{2minB} = \frac{1}{2\beta_C}$. If the manufacturer does not export to B, the price cap in country A is based on the price in country C instead. Thus, the manufacturer can avoid lower prices under the scheme $2minB$ at the cost of foregoing profits from not selling in country B and not being able to set the price in country C without constraints. However, the resulting price cap based on the price in country C is less restrictive, deviations from the profit-maximizing price under coinsurance in country A are thus smaller.

The manufacturer does not export to country B if the profit from selling only in country A and C under the scheme $1C$ is higher than the profit from selling in all three countries under the scheme $2minB$, i.e., $\pi_A^{1C} + \pi_C^{1C} - \pi^{2minB} \geq 0$, which is the case if $\beta_A \leq \widetilde{\beta}_{A2minB,1C}$ and $\beta_B \geq \widetilde{\beta}_{B2minB,1C}$.

Similarly, if $2minC$ is the equilibrium outcome under the minimum-price rule, the manufacturer may decide not to export to C (with the price cap being based on the price in country B

[14] The minimum-price rule allows the manufacturer to set the same price as under coinsurance and no external reference pricing in the third country, as under this rule, only the lowest price spills over to the referencing country. Under the average-price rule, prices in all countries spill over to the referencing country, imposing a constraint on price-setting in all three countries.

instead) to avoid low prices. The manufacturer does not export to country C if the profit from selling only in country A and B under the scheme $1B$ is higher than the profit from selling in all three countries under the scheme $2minC$, i.e., $\pi_A^{1B} + \pi_B^{1B} - \pi^{2minC} \geq 0$, which is the case if $\beta_A \leq \widetilde{\beta}_{A2minC,1B}$ and $\beta_B \leq \widetilde{\beta}_{B2minC,1B}$.

If $2minBC$ is the equilibrium outcome under the minimum-price rule, the manufacturer does not export to country B if $\pi_A^{1C} + \pi_C^{1C} - \pi^{2minBC} \geq 0$, which is the case if $\beta_A \leq \widetilde{\beta}_{A2minBC,1C}$ and $\beta_B \geq \widetilde{\beta}_{B2minBC,1C}$. It does not export to country C if $\pi_A^{1B} + \pi_B^{1B} - \pi^{2minBC} \geq 0$, which is the case if $\beta_A \leq \widetilde{\beta}_{A2minBC,1B}$ and $\beta_B \leq \widetilde{\beta}_{B2minBC,1B}$, and it exports to neither country if $\pi_A^* - \pi^{2minBC} \geq 0$ if $\beta_A \leq \widetilde{\beta}_{A2minBC,A^*}$. The manufacturer decides not to export if the loss in profit in country A from reducing the price is higher than the loss in profit from not selling to one country and accepting a price constraint in the third country. As the loss in profit from deviations from the optimal price decreases in β_j, the manufacturer decides not to export if β_A is rather small. This implies that the minimum-price rule may not be feasible for all combinations of willingness to pay in all three countries.

If the government in country A applied the average-price rule instead, the manufacturer would not export to country B and accept a price cap based on the price in country C instead if $\pi_A^{1C} + \pi_C^{1C} - \pi^{2avg} \geq 0$ which is the case if $\beta_A \leq \widetilde{\beta}_{A2avg,1C}$ and $\beta_B \geq \widetilde{\beta}_{B2avg,1C}$. Similarly, it would not export to country C and accept a price cap based on the price in country B if $\pi_A^{1B} + \pi_B^{1B} - \pi^{2avg} \geq 0$ which is the case if $\beta_A \leq \widetilde{\beta}_{A2avg,1B}$ and $\beta_B \leq \widetilde{\frac{1}{\beta_B}}_{2avg,1B}$. As $\widetilde{\beta}_{A2avg,1C} < \widetilde{\beta}_{A2minB,1C}$ and $\widetilde{\beta}_{A2avg,1B} < \widetilde{\beta}_{A2minC,1B}$ as well as $p_A^{2avg} < p_A^{1C}$ and $p_A^{2avg} < p_A^{1B}$, the government in A could achieve a lower price by the average- price rule than by the minimum-price rule if it takes the export decision of the manufacturer into account.

Figure 2 depicts equilibrium outcomes under the minimum-price rule for different willingness to pay in A and B and identical coinsurance rates in all three countries when the export decision is endogenous. If the willingness to pay in country A is sufficiently large and the willingness to pay in B is sufficiently small, the firm may refrain from exporting to B. As a result, the minimum-price rule turns into the rule $1C$. Similarly, if the willingness to pay in countries A and B are large, the firm refrains from supplying country C under the minimum-price rule, so that the resulting reference price rule is $1B$ instead. In both cases, $1B$ and $1C$ result in a higher price than the equilibrium outcomes $2minB$ and $2minC$ would have. The average-price rule may buffer the risk stemming from country B not being supplied under the rule $2minB$ and endogenous export decisions. If applying the rule $2minB$ results in the risk of country B

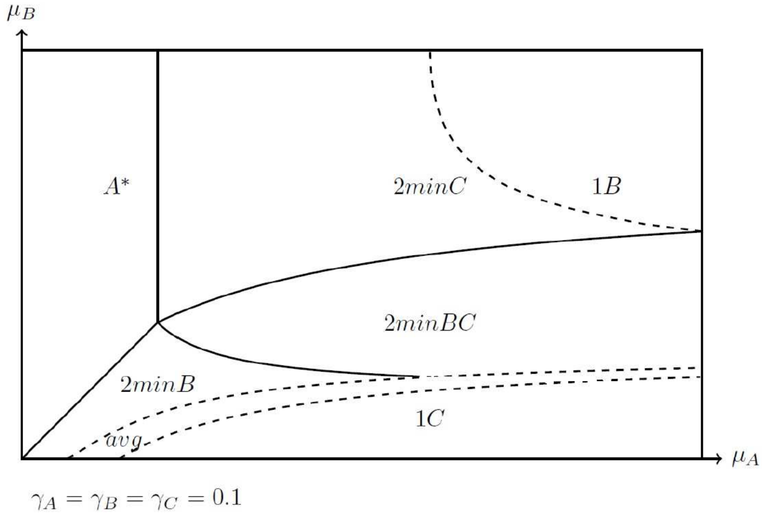

Figure 2: Minimum price-rule, average price-rule, and endogenous export decision.

of not being supplied (as in Figure 2), country A may switch to the average-price rule if the willingness to pay in A is sufficiently small. The price under the average-price rule is lower than under the resulting outcome $1C$. At the same time, the adoption of the average-price rule safeguards exports to country B, respectively, country C.

Proposition 2 summarizes the effect of an endogenous export decision on the choice of the external reference pricing scheme:

Proposition 2 *If country A adopts the minimum-price rule, the manufacturer does not export to country B (C) if $\beta_A \leq \widetilde{\beta}_{A2minB,1C}$ ($\beta_A \leq \widetilde{\beta}_{A2minC,1B}$). For $\widetilde{\beta}_{A2minB,1C} \geq \beta_A \geq \widetilde{\beta}_{A2avg,1C}$ ($\widetilde{\beta}_{A2minC,1B} \geq \beta_A \geq \widetilde{\beta}_{A2avg,1B}$), the average-price rule yields a lower drug price in country A than the minimum-price rule.*

6 Effect on Drug Prices in Reference Countries

This section studies the effect of external reference pricing in country A on drug prices and welfare in countries B and C.

Welfare in country B and C is given as

$$\begin{aligned} W_B &= CS_B - E_B = \frac{\mu_B}{2} + \beta_B p_B^2 \left(1 - \frac{1}{2}\gamma_B\right) - p_B\left(1 - \gamma_B + \beta_B \mu_B\right) \\ W_C &= CS_C - E_C = \frac{1}{2} + \beta_C p_C^2 \left(1 - \frac{1}{2}\gamma_C\right) - p_C\left(1 - \gamma_C + \beta_C\right). \end{aligned} \tag{21}$$

As welfare decreases in the price, higher prices decrease welfare.

Consider that country A implements the minimum-price rule to minimize the drug price. In the case $2minB$, the drug price in country B is higher than under coinsurance and no external reference pricing in A, while the drug price in country C is not affected, i.e., $p_B^{2minB} > p_B^*$, $p_C^{2minB} = p_C^*$. Similarly, under $2minC$, the drug price in country C is higher than under coinsurance and no external reference pricing in A, while the drug price in country B is not affected, i.e., $p_C^{2minC} > p_C^*$, $p_B^{2minC} = p_B^*$. Also, under $2minBC$, drug prices in countries B and C are higher than under coinsurance if β_A is sufficiently low ($p_B^{2minBC} - p_B^* > 0$ if $\beta_A \leq \widehat{\beta}_{Ap_B^{2minC}=p_C^{2minC}}$, $p_C^{2minBC} - p_C^* > 0$ if $\beta_A \geq \widehat{\beta}_{Ap_B^{2minB}=p_C^{2minB}}$).

Also, if country A applies the average-price rule, e.g., because of an endogenous export decision, drug prices in countries B and C are higher than under coinsurance ($p_B^{2avg} - p_B^* > 0$, $p_C^{2avg} - p_C^* > 0$).

Proposition 3 summarizes the effect of the choice of the regulatory scheme in country A on drug prices in countries B and C:

Proposition 3 *If country A adopts the minimum-price rule or the average-price rule, drug prices in countries B and C are higher than under no external reference pricing in country A.*

7 Mutual Referencing

Consider now that also countries B and C may adopt external reference pricing schemes. In countries B and C, the increase in drug prices under external reference pricing in country A may create the incentive to apply also an external reference pricing scheme.

7.1 Choice of Second Country

Consider first the choice of a second country to adopt an external reference pricing scheme given that external reference pricing is applied in country A. Without loss of generality, consider the choice of country B in what follows. For all combinations of choices of countries A and B, the manufacturer's profit and equilibrium prices can be found in Appendix A.5. Superscripts denote choices in countries A and B, respectively.

7.1.1 One Reference Country

Consider first that country A chooses the scheme $1B$. If country B does not adopt external reference pricing, equilibrium prices are $p_A^{1B} = p_B^{1B} = \frac{1}{\beta_A+\beta_B}$, $p_C^{1B} = \frac{1}{2\beta_C}$.

If country B chooses the scheme $1A$, the choice of B does not affect equilibrium prices. If country B chooses the scheme $2minj$, the manufacturer does not change equilibrium prices if $\beta_A \geq \widehat{\beta}_{Ap_B^{2minB}=p_C^{2minB}}$ and the manufacturer sets a uniform price if $\beta_A \leq \widehat{\beta}_{Ap_B^{2minB}=p_C^{2minB}}$. If country B chooses the scheme $1C$ or the scheme $2avg$, the manufacturer sets a uniform price $p = \frac{3}{2(\beta_A+\beta_B+\beta_C)}$. Compared to the price p_B^{1B}, uniform pricing increases the drug price in country B ($p - p_B^{1B,(.)} \geq 0$ if $\beta_A \geq \widehat{\beta}_{Ap_B^{2minB}=p_C^{2minB}}$). This is, the best response for country B is not to choose an external reference pricing scheme or choose $1A$ or $2minj$ if $\beta_A \geq \widehat{\beta}_{Ap_B^{2minB}=p_C^{2minB}}$ (which also does not affect the price equilibrium).

Consider now that country A chooses the scheme $1C$. If country B does not adopt external reference pricing, equilibrium prices are $p_A^{1C} = p_C^{1C} = \frac{1}{\beta_A+\beta_C}$, $p_B^{1C} = \frac{1}{2\beta_B}$.

Irrespective of which scheme country B chooses, the manufacturer sets a uniform price p. In country B, uniform pricing yields a lower drug price than the price p_B^{1C}, which results in country B does not adopt external reference pricing ($p - p_B^{*} \leq 0$ if $\beta_A \geq \widehat{\beta}_{Ap_B^{2minC}=p_C^{2minC}}$). This is, the best response for country B is to choose any external reference pricing scheme to induce uniform pricing.

7.1.2 Two Reference Countries, Minimum Price

If country A chooses the scheme $2minj$ and country B does not adopt external reference pricing, equilibrium prices are $p_A^{2minB} = p_B^{2minB} = \frac{1}{\beta_A+\beta_B}$, $p_C^{2minB} = \frac{1}{2\beta_C}$ if $\beta_B \geq \widehat{\beta}_{Bp_B=p_C}$ and $\beta_A \geq \widehat{\beta}_{Ap_B^{2minB}=p_C^{2minB}}$, $p_A^{2minC} = p_C^{2minC} = \frac{1}{\beta_A+\beta_C}$, $p_B^{2minC} = \frac{1}{2\beta_B}$ if $\beta_B \leq \widehat{\beta}_{Bp_B=p_C}$ and $\beta_A \geq \widehat{\beta}_{Ap_B^{2minC}=p_C^{2minC}}$, and $p_A^{2minBC} = p_B^{2minBC} = p_C^{2minBC} = \frac{3}{2(\beta_A+\beta_B+\beta_C)}$ if $\beta_B \geq \widehat{\beta}_{Bp_B=p_C}$ and $\beta_A \leq \widehat{\beta}_{Ap_B^{2minB}=p_C^{2minB}}$ or $\beta_B \leq \widehat{\beta}_{Bp_B=p_C}$ and $\beta_A \leq \widehat{\beta}_{Ap_B^{2minC}=p_C^{2minC}}$.

If country B chooses $1A$ or $2minj$, the manufacturer does not change the price if $\beta_A \geq \widehat{\beta}_{Ap_B^{2minB}=p_C^{2minB}}$ and the manufacturer sets a uniform price if $\beta_A \leq \widehat{\beta}_{Ap_B^{2minB}=p_C^{2minB}}$. If country B chooses $1C$ or $2avg$, the manufacturer sets a uniform price. As in country B the price under the scheme $2minB$ is lower than the uniform price, whereas the price under the scheme $2minC$ is higher than the uniform price, the best response for country B is not to choose an external reference pricing scheme or to choose $1B$ or $2minj$ (which does not affect drug prices) if $\beta_A \geq \widehat{\beta}_{Ap_B^{2minB}=p_C^{2minB}}$ and to choose $1C$ or $2avg$ to induce a uniform price if $\beta_A \leq \widehat{\beta}_{Ap_B^{2minB}=p_C^{2minB}}$. If $\beta_B \geq \widehat{\beta}_{Bp_B=p_C}$ and $\beta_A \leq \widehat{\beta}_{Ap_B^{2minB}=p_C^{2minB}}$ or $\beta_B \leq \widehat{\beta}_{Bp_B=p_C}$ and $\beta_A \leq \widehat{\beta}_{Ap_B^{2minC}=p_C^{2minC}}$, the manufacturer sets a uniform price anyway, irrespective of the choice by country B for an external reference pricing scheme.

7.1.3 Two Reference Countries, Average Price

If country A chooses the scheme $2avg$ and country B does not adopt external reference pricing, equilibrium prices are $p_A^{2avg} = \frac{3(\beta_B+\beta_C)}{2(\beta_A\beta_B+\beta_A\beta_C+4\beta_B\beta_C)}$, $p_B^{2avg} = \frac{3\beta_C}{(\beta_A\beta_B+\beta_A\beta_C+4\beta_B\beta_C)}$, $p_C^{2avg} = \frac{3\beta_B}{(\beta_A\beta_B+\beta_A\beta_C+4\beta_B\beta_C)}$.

Irrespective of which scheme country B chooses, the manufacturer sets a uniform price. In country B, the uniform price is lower than the price under $2avg$ if β_B is sufficiently low ($p - p_B^{2avg} \leq 0$ if $\beta_B \leq \widehat{\beta}_{Bp_B=p_C}$). This is, the best response for country B is not to choose an external reference pricing scheme if $\beta_B \geq \widehat{\beta}_{Bp_B=p_C}$ and to choose any external reference pricing scheme to induce uniform pricing if $\beta_B \leq \widehat{\beta}_{Bp_B=p_C}$.

7.1.4 Best Response of Country A

In country A, the uniform price is higher than the price under $2minB$ or $2minC$ ($p - p_A^{2minB} \geq 0$ if $\beta_A \geq \widehat{\beta}_{Ap_B^{2minB}=p_C^{2minB}}$, $p_A - p_A^{2minC} \geq 0$ if $\beta_A \geq \widehat{\beta}_{Ap_B^{2minC}=p_C^{2minC}}$) but the uniform price is lower than the price under $2avg$ ($p - p_A^{2avg} \leq 0$). The best response of country A given the choice of country B is to choose $1B$ or $2minB$ if $\beta_A \geq \widehat{\beta}_{Ap_B^{2minB}=p_C^{2minB}}$ and to choose any external reference pricing scheme in all other cases.

Both country A and country B prefer the pricing scheme $1B$ or $2minB$ over a uniform price if $\beta_A \leq \widehat{\beta}_{Ap_B^{2minB}=p_C^{2minB}}$, as in this case using the higher price in country C would yield higher prices in countries A and B. The combinations of choices that yield pricing scheme $1B$ or $2minB$ are equilibrium outcomes.[15] Note that in these cases, the choice of country B does not affect prices. Thus, the outcome would be the same if country B would choose not to adopt any external reference pricing scheme.

Country A prefers the pricing scheme $1C$ or $2minC$ over a uniform price, but B prefers a uniform price over the price under the pricing scheme $1C$ or $2minC$. This implies that the pricing scheme $1C$ or $2minC$ is not an equilibrium outcome.

Country A prefers uniform pricing over the pricing scheme $2avg$, and country B does so also if $\beta_B \leq \widehat{\beta}_{Bp_B=p_C}$. This implies that the pricing scheme $2avg$ is also not an equilibrium outcome.

[15] The following combinations of choices by country A and B yield the pricing scheme $1B$ or $2minB$: A chooses $1B$, B chooses $1A$; A chooses $1B$, B chooses $2minj$ if $\beta_A \geq \widehat{\beta}_{Ap_B^{2minB}=p_C^{2minB}}$; A chooses $2minj$, B chooses $1A$ if $\beta_A \geq \widehat{\beta}_{Ap_B^{2minB}=p_C^{2minB}}$; A chooses $2minj$, B chooses $2minj$ if $\beta_A \geq \widehat{\beta}_{Ap_B^{2minB}=p_C^{2minB}}$.

7.2 Choice of Third Country

Consider now the choice of the third country to adopt an external reference pricing scheme given that external reference pricing is applied in the other two countries.

From section 6.1, the choice of external reference pricing by two countries yields either the pricing scheme $1B$ or $2minB$ or uniform pricing. In the former case, country C has the incentive also to adopt an external reference pricing scheme to induce uniform pricing (this case is equivalent to the choice of country B for any external reference pricing scheme given that country A chooses the scheme $1C$). In the latter case, the choice of country C for or against an external reference pricing scheme has no effect on equilibrium prices.

There is no incentive for the country with the lower price (country B if the implemented scheme is $1B$ or $2minB$) to adopt an external reference pricing scheme.[16] But there is an incentive for the third country (country C if the implemented scheme is $1B$ or $2minB$) or the country with the higher price (country B (C) if the implemented scheme is $1C$ or $2minC$ ($1B$ or $2minB$)) also to adopt an external reference pricing scheme. In these cases, the outcome is a uniform price, implying price convergence across all countries.

Proposition 4 summarizes the incentive for the other countries also to adopt an external reference pricing scheme under any external reference pricing scheme in country A:

Proposition 4 *There is no incentive for the country with the lower price to adopt an external reference pricing scheme, but there is an incentive for the third country or country with the higher drug price also to adopt external reference pricing. If all countries adopt an external reference pricing scheme, the manufacturer sets a uniform drug price for all three countries.*

If country A applies any external reference scheme, the incentive for the third country or country with the higher drug price also to adopt external reference pricing results in a uniform price in all three countries.

Compared to the scenario with coinsurance, a uniform price increases welfare in country A if β_A is sufficiently low, i.e., $\Delta W_A = W_A^* - W_A^p \geq 0$ if $\beta_A \leq \widehat{\beta}_{A\Delta W_A}$. In this case, the uniform price is lower than the price under coinsurance and no external reference pricing, increasing consumer surplus and decreasing third-party payer expenditure. In country B, the uniform price increases welfare if β_A is sufficiently high or β_B is sufficiently low, i.e., $\Delta W_B = W_B^p - W_B^* \geq 0$

[16] The choices of country B for an external reference pricing scheme that are best responses do not affect equilibrium prices.

if $\beta_A \geq \widehat{\beta_{A\Delta W_B}} \vee \beta_B \leq \widehat{\beta_{B\Delta W_B}}$. In both cases, the uniform price is lower than the price under coinsurance. A high β_A decreases the uniform price, a low β_B increases the price under coinsurance by more than the uniform price. Similarly, in country C, the uniform price increases welfare if β_A is sufficiently high or β_C is sufficiently low, i.e., $\Delta W_C = W_C^p - W_C^* > 0$ if $\beta_A \geq \widehat{\beta_{A\Delta W_C}} \vee \beta_C \leq \widehat{\beta_{C\Delta W_C}}$. A high β_A decreases the uniform price, a low β_C increases the price under coinsurance by more than the uniform price. For all three countries, these effects offset each other and global welfare increases, i.e., $W^p - W^* > 0$.

Proposition 5 summarizes the welfare effect of uniform pricing.

Proposition 5 *If other countries also apply external reference pricing and a uniform price is the outcome, global welfare increases.*

Under uniform pricing, the manufacturer may also decide not export to one of the countries. If the manufacturer does not to export to country B, prices in country A and country C are the same (scheme $1C$). The manufacturer can avoid a lower uniform price at the cost of foregoing profits from not selling in country B. The manufacturer does not export to country B if the profit from selling only in country A and C under the scheme $1C$ is higher than the profit from selling at a uniform price in all three countries, i.e., $\pi_A^{1C} + \pi_C^{1C} - \pi \geq 0$ if $\beta_A \leq \widetilde{\beta_{Ap,1C}} \wedge \beta_B \geq \widetilde{\beta_{Bp,1C}}$, see Appendix A.5. If the manufacturer decided not to export to country C as well, this would be equivalent to the corresponding case in Appendix A.3.1.

Similarly, if the manufacturer does not export to country C, prices in country A and country B are the same (scheme $1B$). The manufacturer does not export to country C if the profit from selling only in country A and B under the scheme $1B$ is higher than the profit from selling at a uniform price in all three countries, i.e., $\pi_A^{1B} + \pi_B^{1B} - \pi \geq 0$ if $\beta_A \leq \widetilde{\beta_{Ap,1B}} \wedge \beta_B \leq \widetilde{\beta_{Bp,1B}}$.

This is, the manufacturer's decision not export to potential reference countries may works against regulatory and thus price convergence. If countries take the threat of a non-launch of the drug into account when deciding whether or not to adopt external reference pricing, they may refrain from strict regulation or the application of external reference pricing.

8 Conclusion

This paper has studied the design of external reference pricing schemes, in particular, the choice of reference countries and pricing rules, in a three-country-framework.

Given that the manufacturer sells to all three countries, the minimum-price rule yields the lowest drug price. If the referencing country is sufficiently large, the manufacturer may not export to reference countries under the minimum-price rule. Then the average-price rule may safeguard exports to reference countries and generate a lower drug price in the referencing country. The choice of the referencing country for the average-price rule, which results in higher prices than the minimum-price rule, does not necessarily stem from the motivation to avoid launch delays in reference countries but results from the possibility to use the information on prices in reference countries which would not be possible under a non-launch. In Europe, many countries apply the average-price rule, for instance, Austria, Ireland, the Netherlands, and Portugal, which could be explained by the possibility of launch delays. However, there might be also other reasons for the application of the average-price rule outside the model, for instance, lobbying of pharmaceutical manufacturers.

In the referencing countries, external reference pricing lowers drug prices and increases welfare. At the same time, it increases drug prices in the reference countries, creating the incentive for other countries also to adopt external reference pricing. Thus, external reference pricing results in regulatory convergence and a uniform price among all countries, i.e., price convergence. The widespread use of external reference pricing in Europe seems to be in line with this incentive for using external reference pricing. However, the manufacturer's decision not export to potential reference countries may counteract regulatory and thus price convergence. Also, the manufacturer may prevent the use of external reference pricing and price comparisons by strategic modifications of products such as different dosage forms for different countries (Kyle, 2011).

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Appendix

A.1 Regulatory Scenarios

External Reference Pricing Scheme 1B

Binding price cap P_A^{1B}: The price cap P_A^{1B} is binding if β_A is sufficiently low $(p_A^{1B} - p_A^* = -\frac{\beta_B - \beta_A}{2\beta_A(\beta_A+\beta_B)} \leq 0$ if $\beta_A \leq \widehat{\beta_{A1B}} = \beta_B)$.

Equilibrium existence: Consider the pricing strategy $\widetilde{p_A^{1B}} = \widetilde{p_B^{1B}} - \varepsilon$, which allows the manufacturer to avoid the price cap P_A^{1B}. The manufacturer's profit is maximized for $\widetilde{p_B^{1B}} = \frac{1+\varepsilon\beta_A}{\beta_A+\beta_B}$, $\widetilde{p_A^{1B}} = \widetilde{p_B^{1B}} - \varepsilon = \frac{1-\varepsilon\beta_B}{\beta_A+\beta_B}$. The profit for this pricing strategy is

$\pi\left(\widetilde{p_A^{1B}}, \widetilde{p_B^{1B}}, \widetilde{p_C^{1B}}\right) = \frac{\beta_B(1-\varepsilon\beta_B)(\varepsilon\beta_A+1)}{(\beta_A+\beta_B)^2} + \frac{\beta_A(1-\varepsilon\beta_B)(\varepsilon\beta_A+1)}{(\beta_A+\beta_B)^2} + \frac{1}{4\beta_C}$, with

$\pi^{1B}\left(p_A^{1B}, p_B^{1B}, p_C^{1B}\right) - \pi\left(\widetilde{p_A^{1B}}, \widetilde{p_B^{1B}}, \widetilde{p_C^{1B}}\right) = \frac{\varepsilon(\beta_B - \beta_A + \varepsilon\beta_A\beta_B)}{\beta_A+\beta_B} > 0$, if $\beta_A < \widehat{\beta_{A\widetilde{1B}}} = \frac{\beta_B}{1-\varepsilon\beta_B}$, with $\widehat{\beta_{A\widetilde{1B}}} > \widehat{\beta_{A1B}}$. Thus, this deviation is not profitable.

External Reference Pricing Scheme 1C

Binding price cap P_A^{1C}: The price cap P_A^{1C} is binding if β_A is sufficiently low $(p_A^{1C} - p_A^* = -\frac{\beta_C - \beta_A}{2\beta_A(\beta_A+\beta_C)} \leq 0$ if $\beta_A \leq \widehat{\beta_{A1C}} = \beta_C)$.

Equilibrium existence: Consider the pricing strategy $\widetilde{p_A^{1C}} = \widetilde{p_C^{1C}} - \varepsilon$, which allows the manufacturer to avoid the price cap P_A^{1C}. The manufacturer's profit is maximized for $\widetilde{p_C^{1B}} = \frac{1+\varepsilon\beta_A}{\beta_A+\beta_C}$, $\widetilde{p_A^{2minB}} = \widetilde{p_B^{2minB}} - \varepsilon = \frac{1-\varepsilon\beta_C}{\beta_A+\beta_C}$. The profit for this pricing strategy is $\pi\left(\widetilde{p_A^{1C}}, p_B, \widetilde{p_C^{1C}}\right) = \frac{\beta_C(1-\varepsilon\beta_C)(\varepsilon\beta_A+1)}{(\beta_A+\beta_C)^2} + \frac{1}{4\beta_B} + \frac{\beta_A(1-\varepsilon\beta_C)(\varepsilon\beta_A+1)}{(\beta_A+\beta_C)^2}$, with

$\pi^{2minB}\left(p_A^{2minB}, p_B^{2minB}, p_C^{2minB}\right) - \pi\left(\widetilde{p_A^{2minB}}, \widetilde{p_B^{2minB}}, \widetilde{p_C^{2minB}}\right) = \frac{\varepsilon(\beta_C - \beta_A + \varepsilon\beta_A\beta_C)}{\beta_A+\beta_C} > 0$, if $\beta_A < \widehat{\beta_{A\widetilde{1C}}} = \frac{\beta_C}{1-\varepsilon\beta_C}$, with $\widehat{\beta_{A\widetilde{1C}}} > \widehat{\beta_{A1C}}$. Thus, this deviation is not profitable.

External Reference Pricing Scheme 2min

Binding price cap P_A^{2minB}: The price cap P_A^{2minB} is binding if β_A is sufficiently low $(p_A^{2minB} - p_A^* = -\frac{\beta_B - \beta_A}{2\beta_A(\beta_A+\beta_B)} \leq 0$ if $\beta_A \leq \widehat{\beta_{A2minB}} = \beta_B)$.

Binding price cap P_A^{2minC}: The price cap P_A^{2minC} is binding if β_A is sufficiently low $(p_A^{2minC} - p_A^* = -\frac{\beta_C - \beta_A}{2\beta_A(\beta_A+\beta_C)} \leq 0$ if $\beta_A \leq \widehat{\beta_{A2minC}} = \beta_C)$.

Binding price cap P_A^{2minBC}: The price cap P_A^{2minBC} is binding if β_A is sufficiently low $(p_A^{2minBC} - p_A^* = -\frac{\beta_B + \beta_C - 2\beta_A}{2\beta_A(\beta_A+\beta_B+\beta_C)} \leq 0$ if $\beta_A \leq \widehat{\beta_{A2minBC}} = \frac{\beta_B+\beta_C}{2})$.

If β_B is sufficiently high, the threshold for P_A^{2minBC} to be binding is lower than the threshold for P_A^{2minB} to be binding $(\widehat{\beta_{A2minBC}} - \widehat{\beta_{A2minB}} = -\frac{1}{2}(\beta_B - \beta_C) < 0$ if $\beta_B > \widehat{\beta_{B_{p_B=p_C}}} = \beta_C$.)

If β_B is sufficiently low, the threshold for P_A^{2minBC} to be binding is lower than the threshold for P_A^{2minB} to be binding $(\widehat{\beta_{A2minBC}} - \widehat{\beta_{A2minC}} = -\frac{1}{2}(\beta_C - \beta_B) < 0$ if $\beta_B < \widehat{\beta_{B_{p_B=p_C}}} = \beta_C$.)

Consistent scheme $2minB$: Under the scheme $2minB$, the price cap in A, i.e. the price in B, p_B^{2minB} is lower than the price in C if β_A is sufficiently high $(p_B^{2minB} - p_C^{2minB} = -\frac{\beta_A+\beta_B-2\beta_C}{2\beta_C(\beta_A+\beta_B)} \leq 0$, if $\beta_A \geq \widehat{\beta_{A_{p_B^{2minB}=p_C^{2minB}}}} = 2\beta_C - \beta_B$, with $\widehat{\beta_{A_{p_B^{2minB}=p_C^{2minB}}}} - \widehat{\beta_{A2minB}} = -2(\beta_B - \beta_C) < 0$, if $\beta_B > \widehat{\beta_{B_{p_B=p_C}}})$.

Consistent scheme $2minC$: Under the scheme $2minC$, the price cap in A, i.e. the price in C p_C^{2minC} is lower than the price in B if β_A is sufficiently high $(p_C^{2minC} - p_B^{2minC} = -\frac{\beta_A+\beta_C-2\beta_B}{2\beta_B(\beta_A+\beta_C)} \leq 0$, if $\beta_A \geq \widehat{\beta_{A_{p_B^{2minC}=p_C^{2minC}}}} =$

$2\beta_B - \beta_C$, with $\widehat{\beta}_{A p_B^{2minC} = p_C^{2minC}} - \widehat{\beta}_{A2minC} = -2(\beta_C - \beta_B) < 0$, if $\beta_B < \widehat{\beta}_{B p_B = p_C}$).

Equilibrium existence $2minB$: Consider the pricing strategy $\widetilde{p_A^{2minB}} = \widetilde{p_B^{2minB}} - \varepsilon$, which allows the manufacturer to avoid the price cap P_A^{2minB}. The manufacturer's profit is maximized for $\widetilde{p_B^{2minB}} = \frac{1+\varepsilon\beta_A}{\beta_A+\beta_B}$,
$\widetilde{p_A^{2minB}} = \widetilde{p_B^{2minB}} - \varepsilon = \frac{1-\varepsilon\beta_B}{\beta_A+\beta_B}$. The profit for this pricing strategy is
$\pi\left(\widetilde{p_A^{2minB}}, \widetilde{p_B^{2minB}}, p_C\right) = \frac{\beta_B(1-\varepsilon\beta_B)(\varepsilon\beta_A+1)}{(\beta_A+\beta_B)^2} + \frac{\beta_A(1-\varepsilon\beta_B)(\varepsilon\beta_A+1)}{(\beta_A+\beta_B)^2} + \frac{1}{4\beta_C}$, with
$\pi^{2minB}\left(p_A^{2minB}, p_B^{2minB}, p_C^{2minB}\right) - \pi\left(\widetilde{p_A^{2minB}}, \widetilde{p_B^{2minB}}, \widetilde{p_C^{2minB}}\right) = \frac{\varepsilon(\beta_B-\beta_A+\varepsilon\beta_A\beta_B)}{\beta_A+\beta_B} > 0$, if $\beta_A < \widehat{\beta}_{A\widetilde{2minB}} = \frac{\beta_B}{1-\varepsilon\beta_B}$, with $\widehat{\beta}_{A\widetilde{2minB}} > \widehat{\beta}_{A2minB}$. Thus, this deviation is not profitable.

Equilibrium existence $2minC$: Consider the pricing strategy $\widetilde{p_A^{2minC}} = \widetilde{p_C^{2minC}} - \varepsilon$, which allows the manufacturer to avoid the price cap P_A^{2minC}. The manufacturer's profit is maximized for $\widetilde{p_C^{2minC}} = \frac{1+\varepsilon\beta_A}{\beta_A+\beta_C}$,
$\widetilde{p_A^{2minC}} = \widetilde{p_B^{2minC}} - \varepsilon = \frac{1-\varepsilon\beta_C}{\beta_A+\beta_C}$. The profit for this pricing strategy is
$\pi\left(\widetilde{p_A^{2minC}}, p_B, \widetilde{p_C^{2minC}}\right) = \frac{\beta_C(1-\varepsilon\beta_C)(\varepsilon\beta_A+1)}{(\beta_A+\beta_C)^2} + \frac{1}{4\beta_B} + \frac{\beta_A(1-\varepsilon\beta_C)(\varepsilon\beta_A+1)}{(\beta_A+\beta_C)^2}$, with
$\pi^{2minC}\left(p_A^{2minC}, p_B^{2minC}, p_C^{2minC}\right) - \pi\left(\widetilde{p_A^{2minC}}, \widetilde{p_B^{2minC}}, \widetilde{p_C^{2minC}}\right) = \frac{\varepsilon(\beta_C-\beta_A+\varepsilon\beta_A\beta_C)}{\beta_A+\beta_C} > 0$,
if $\beta_A < \widehat{\beta}_{A\widetilde{2minC}} = \frac{\beta_C}{1-\varepsilon\beta_C}$, with $\widehat{\beta}_{A\widetilde{2minC}} > \widehat{\beta}_{A1C}$. Thus, this deviation is not profitable.

Equilibrium existence $2minBC$: Consider the pricing strategy $\widetilde{p_A^{2minBC}} = \widetilde{p_{BC}^{2minBC}} - \varepsilon$, which allows the manufacturer to avoid the price cap P_A^{2minBC}. The manufacturer's profit is maximized for $\widetilde{p_{BC}^{2minBC}} = \frac{3+2\varepsilon\beta_A}{2(\beta_A+\beta_B+\beta_C)}$.
The profit for this pricing strategy is
$\pi\left(\widetilde{p_A^{2minBC}}, \widetilde{p_{BC}^{2minBC}}\right) = \frac{(2\varepsilon(\beta_B+\beta_C)-3)(\beta_A-2\beta_B-2\beta_C-2\varepsilon(\beta_A\beta_B+\beta_A\beta_C))}{4(\beta_A+\beta_B+\beta_C)^2} + \frac{(2\beta_A-\beta_B+2\beta_C-2\varepsilon\beta_A\beta_B)(2\varepsilon\beta_A+3)}{4(\beta_A+\beta_B+\beta_C)^2}$
$+\frac{(2\beta_A+2\beta_B-\beta_C-2\varepsilon\beta_A\beta_C)(2\varepsilon\beta_A+3)}{4(\beta_A+\beta_B+\beta_C)^2}$, with
$\pi^{2minBC} - \pi\left(\widetilde{p_A^{2minBC}}, \widetilde{p_{BC}^{2minBC}}\right) = \frac{\varepsilon(\beta_B-2\beta_A+\beta_C+\varepsilon(\beta_A\beta_B+\beta_A\beta_C))}{\beta_A+\beta_B+\beta_C} > 0$, if $\beta_A < \widehat{\beta}_{A\widetilde{2minBC}} = \frac{\beta_B+\beta_C}{2-\varepsilon\beta_B-\varepsilon\beta_C}$, with $\widehat{\beta}_{A\widetilde{2minBC}} > \widehat{\beta}_{A2minBC}$. Thus, this deviation is not profitable.

External Reference Pricing Scheme 2avg

Binding price cap P_A^{2avg}: The price cap P_A^{2avg} is binding if β_A is sufficiently low
($p_A^{2avg} - p_A^* = -\frac{2\beta_B\beta_C-\beta_A\beta_B-\beta_A\beta_C}{\beta_A(\beta_A\beta_B+\beta_A\beta_C+4\beta_B\beta_C)} \leq 0$ if $\beta_A \leq \widehat{\beta}_{A2avg} = \frac{2\beta_B\beta_C}{\beta_B+\beta_C}$).

Equilibrium existence $2avg$: Consider the pricing strategy $\widetilde{p_A^{2avg}} = \frac{1}{2}\widetilde{p_B^{2avg}} + \frac{1}{2}\widetilde{p_C^{2avg}} - \varepsilon$, which allows the manufacturer to avoid the price cap P_A^{2minBC}. The manufacturer's profit is maximized for
$\widetilde{p_B^{2avg}} = \frac{3\beta_C+2\varepsilon\beta_A\beta_C}{\beta_A\beta_B+\beta_A\beta_C+4\beta_B\beta_C}$, $\widetilde{p_C^{2avg}} = \frac{3\beta_B+2\varepsilon\beta_A\beta_B}{\beta_A\beta_B+\beta_A\beta_C+4\beta_B\beta_C}$. The profit for this pricing strategy is $\pi\left(\widetilde{p_B^{2avg}}, \widetilde{p_C^{2avg}}\right) =$
$\frac{(3\beta_B+3\beta_C-8\varepsilon\beta_B\beta_C)(8\beta_B\beta_C-\beta_A\beta_B-\beta_A\beta_C+8\varepsilon\beta_A\beta_B\beta_C)}{4(\beta_A\beta_B+\beta_A\beta_C+4\beta_B\beta_C)^2} + \frac{\beta_C(2\varepsilon\beta_A+3)(\beta_A\beta_B+\beta_A\beta_C+\beta_B\beta_C-2\varepsilon\beta_A\beta_B\beta_C)}{(\beta_A\beta_B+\beta_A\beta_C+4\beta_B\beta_C)^2}$
$+\frac{\beta_B(2\varepsilon\beta_A+3)(\beta_A\beta_B+\beta_A\beta_C+\beta_B\beta_C-2\varepsilon\beta_A\beta_B\beta_C)}{(\beta_A\beta_B+\beta_A\beta_C+4\beta_B\beta_C)^2}$, with $\pi^{2avg} - \pi\left(\widetilde{p_B^{2avg}}, \widetilde{p_C^{2avg}}\right)$
$= 2\frac{\varepsilon(2\beta_B\beta_C-\beta_A\beta_B-\beta_A\beta_C+2\varepsilon\beta_A\beta_B\beta_C)}{\beta_A\beta_B+\beta_A\beta_C+4\beta_B\beta_C} > 0$, if $\beta_A < \widehat{\beta}_{A\widetilde{2avg}} = \frac{2\beta_B\beta_C}{(\beta_B+\beta_C-2\varepsilon\beta_B\beta_C)}$ with $\widehat{\beta}_{A\widetilde{2avg}} > \widehat{\beta}_{A2avg}$. Thus, this deviation is not profitable.

8.1 A.2 Choice of Regulatory Scheme

Minimum price rule vs. average price rule, $2minB$: The price is lower under the scheme $2minB$ than under the scheme $2avg$ if β_A is sufficiently high ($p_A^{2avg} - p_A^{2minB} = \frac{3\beta_B^2+\beta_A\beta_B+\beta_A\beta_C-5\beta_B\beta_C}{2(\beta_A+\beta_B)(\beta_A\beta_B+\beta_A\beta_C+4\beta_B\beta_C)} \geq 0$ if $\beta_A \geq \widehat{\beta}_{A p_A^{2avg} = p_A^{2minB}} = \frac{\beta_B(5\beta_C-3\beta_B)}{\beta_B+\beta_C}$, $\widehat{\beta}_{A p_A^{2avg} = p_A^{2minB}} - \widehat{\beta}_{A p_B^{2minB} = p_C^{2minB}} = \frac{\beta_B\left(3\beta_B^2-11\beta_B\beta_C+10\beta_C^2\right)}{2(\beta_B-\beta_C)^2} \leq 0$ if $\beta_B > \underline{\underline{\beta_B}} = 2\beta_C \vee \beta_B > \underline{\beta_B} = \frac{5\beta_C}{3}$).

Minimum price rule vs. average price rule, $2minC$: The price is lower under the scheme $2minC$ than under the scheme $2avg$ if β_A is sufficiently high ($p_A^{2avg} - p_A^{2minC} = \frac{3\beta_C^2+\beta_A\beta_B+\beta_A\beta_C-5\beta_B\beta_C}{2(\beta_A+\beta_C)(\beta_A\beta_B+\beta_A\beta_C+4\beta_B\beta_C)} \geq 0$ if $\beta_A \geq$

$\widehat{\beta}_{Ap_A^{2avg}=p_A^{2minC}} = \frac{\beta_C(5\beta_B-3\beta_C)}{\beta_B+\beta_C}$, $\widehat{\beta}_{Ap_A^{2avg}=p_A^{2minC}} - \widehat{\beta}_{Ap_B^{2minC}=p_C^{2minC}} = \frac{\beta_C\left(10\beta_B^2-11\beta_B\beta_C+3\beta_C^2\right)}{2(\beta_B-\beta_C)^2} \leq 0$ if $\beta_B > \overline{\beta_B} = \frac{3\beta_C}{5} \vee \beta_B > \overline{\overline{\beta_B}} = \frac{\beta_C}{2}$).

Minimum price rule vs. average price rule, $2minBC$: The price is lower under the scheme $2minBC$ than under the scheme $2avg$ ($p_A^{2avg} - p^{2minBC} = -\frac{3(\beta_B-\beta_C)^2}{2(\beta_A+\beta_B+\beta_C)(\beta_A\beta_B+\beta_A\beta_C+4\beta_B\beta_C)} < 0$).

A.3 Endogenous Export Decision

One Reference Country

$1B$ vs. no exports to B and coinsurance in A and C: Under the scheme $1B$, the profit from selling only in countries A and C (under coinsurance) is higher than the profit from selling in all three countries (under the scheme $1B$) if β_A is sufficiently low ($\pi_A^* + \pi_C^* - \pi^{1B} = \frac{(\beta_A-3\beta_B)}{4\beta_B(\beta_A+\beta_B)} \geq 0$, if $\beta_A \leq \widetilde{\beta_{A1B,A^*C^*}} = \frac{\beta_B}{3}$).

$1B$ vs. no exports to B and $1C$: Under the scheme $1B$, the profit from selling only in countries A and C (under the scheme $1C$) is higher than the profit from selling in all three countries (under the scheme $1B$) if β_A is sufficiently low and β_B is sufficiently high ($\pi_A^{1C} + \pi_C^{1C} - \pi^{1B} = \frac{3\beta_B\beta_C-\beta_A^2-\beta_A\beta_C-\beta_B\beta_A-4\beta_C^2}{4\beta_C(\beta_A+\beta_B)(\beta_A+\beta_C)} \geq 0$ if $\beta_A \leq \widetilde{\beta}_{A1B,1C} = \frac{2\beta_C(3\beta_B-4\beta_C)}{\beta_B+\beta_C+\sqrt{(\beta_B-\beta_C)(\beta_B+15\beta_C)}} \wedge \beta_B \geq \widetilde{\beta}_{B1B,1C} = \frac{4\beta_C}{3}$.

$1B$ vs. no exports to B and C: Under the scheme $1B$, the profit from selling only in country A (under coinsurance) is higher than the profit from selling in all three countries (under the scheme $1B$) if β_A is sufficiently low ($\pi_A^* - \pi^{1B} = \frac{\beta_B\beta_C-\beta_A\beta_B-3\beta_A\beta_C-\beta_A^2}{4\beta_A\beta_C(\beta_A+\beta_B)} \geq 0$ if $\beta_A \leq \widetilde{\beta}_{A1B,A^*} = \frac{2\beta_B\beta_C}{\beta_B+3\beta_C+\sqrt{(\beta_B+\beta_C)(\beta_B+9\beta_C)}}$).

$1C$ vs. no exports to C and coinsurance in A and B: Under the scheme $1C$, the profit from selling only in countries A and B (under coinsurance) is higher than the profit from selling in all three countries (under the scheme $1C$) if β_A is sufficiently low ($\pi_A^* + \pi_B^* - \pi^{1C} = \frac{(\beta_C-3\beta_A)}{4\beta_A(\beta_A+\beta_C)} \geq 0$ if $\beta_A \leq \widetilde{\beta}_{A1C,A^*B^*} = \frac{\beta_C}{3}$).

$1C$ vs. no exports to C and $1B$: Under the scheme $1C$, the profit from selling only in countries A and C (under the scheme $1B$) is higher than the profit from selling in all three countries (under the scheme $1C$) if β_A is sufficiently low and β_B is sufficiently low ($\pi_A^{1B} + \pi_B^{1B} - \pi^{1C} = \frac{3\beta_C\beta_B-\beta_A^2-\beta_A\beta_B-\beta_C\beta_A-4\beta_B^2}{4\beta_B(\beta_A+\beta_B)(\beta_A+\beta_C)} \geq 0$ if $\beta_A \leq \widetilde{\beta}_{A1C,1B} = \frac{2\beta_B(3\beta_C-4\beta_B)}{\beta_B+\beta_C+\sqrt{(\beta_C-\beta_B)(15\beta_B+\beta_C)}} \wedge \beta_B \leq \widetilde{\beta}_{B1C,1B} = \frac{3\beta_C}{4}$).

$1C$ vs. no exports to B and C: Under the scheme $1C$, the profit from selling only in country A (under coinsurance) is higher than the profit from selling in all three countries (under the scheme $1C$) if β_A is sufficiently low ($\pi_A^* - \pi^{1C} = \frac{\beta_B\beta_C-3\beta_A\beta_B-\beta_A\beta_C-\beta_A^2}{4\beta_A\beta_B(\beta_A+\beta_C)} \geq 0$ if $\beta_A \leq \widetilde{\beta}_{A1C,A^*} = \frac{2\beta_B\beta_C}{3\beta_B+\beta_C+\sqrt{(\beta_B+\beta_C)(9\beta_B+\beta_C)}}$).

Two Reference Countries, Minimum Rule

$2minB$ vs. no exports to B and $1C$: Under the scheme $2minB$, the profit from selling only in countries A and C (under the scheme $1C$) is higher than the profit from selling in all three countries (under the scheme $2minB$) if β_A is sufficiently low and β_B is sufficiently high ($\pi_A^{1C} + \pi_C^{1C} - \pi^{2minB} = \frac{3\beta_B\beta_C-\beta_A^2-\beta_A\beta_C-\beta_B\beta_A-4\beta_C^2}{4\beta_C(\beta_A+\beta_B)(\beta_A+\beta_C)} \geq 0$ if $\beta_A \leq \widetilde{\beta}_{A2minB,1C} = \frac{2\beta_C(3\beta_B-4\beta_C)}{\beta_B+\beta_C+\sqrt{(\beta_B-\beta_C)(\beta_B+15\beta_C)}} \wedge \beta_B \geq \widetilde{\beta}_{B2minB,1C} = \frac{4\beta_C}{3}$).

$2minB$ vs. no exports to B and C: Under the scheme $2minB$, the profit from selling only in country A (under coinsurance) is higher than the profit from selling in all three countries (under the scheme $2minB$) if β_A is sufficiently low ($\pi_A^* - \pi^{2minB} = \frac{\beta_B\beta_C-\beta_A\beta_B-3\beta_A\beta_C-\beta_A^2}{4\beta_A\beta_C(\beta_A+\beta_B)} \geq 0$ if $\beta_A \leq \widetilde{\beta}_{A2minB,A^*} = \frac{2\beta_B\beta_C}{\beta_B+3\beta_C+\sqrt{(\beta_B+\beta_C)(\beta_B+9\beta_C)}}$).

$2minC$ vs. no exports to C and $1B$: Under the scheme $2minC$, the profit from selling only in countries A and B (under the scheme $1B$) is higher than the profit from selling in all three countries (under the scheme $2minC$)

if β_A is sufficiently low and β_B is sufficiently low
($\pi_A^{1B} + \pi_B^{1B} - \pi^{2minC} = \frac{3\beta_C\beta_B - \beta_A^2 - \beta_A\beta_B - \beta_C\beta_A - 4\beta_B^2}{4\beta_B(\beta_A+\beta_B)(\beta_A+\beta_C)} \geq 0$ if $\beta_A \leq \widetilde{\beta}_{A2minC,1B} = \frac{2\beta_B(3\beta_C - 4\beta_B)}{\left(\beta_B+\beta_C+\sqrt{(\beta_C-\beta_B)(15\beta_B+\beta_C)}\right)}$
$\wedge \beta_B \leq \widetilde{\beta}_{B2minC,1B} = \frac{3\beta_C}{4}$).

$2minC$ vs. no exports to B and C: Under the scheme $2minC$, the profit from selling only in country A (under coinsurance) is higher than the profit from selling in all three countries (under the scheme $2minC$) if β_A is sufficiently low ($\pi_A^* - \pi^{2minC} = \frac{\beta_B\beta_C - 3\beta_A\beta_B - \beta_A\beta_C - \beta_A^2}{4\beta_A\beta_B(\beta_A+\beta_C)} \geq 0$ if $\beta_A \leq \widetilde{\beta}_{A2minC,A^*} = \frac{2\beta_B\beta_C}{3\beta_B+\beta_C+\sqrt{(\beta_B+\beta_C)(9\beta_B+\beta_C)}}$).

$2minBC$ vs. no exports to B and $1C$: Under the scheme $2minBC$, the profit from selling only in countries A and C (under the scheme $1C$) is higher than the profit from selling in all three countries (under the scheme $2minBC$) if β_A is sufficiently low and β_B is sufficiently high ($\pi_A^{1C} + \pi_C^{1C} - \pi^{2minBC} = \frac{4\beta_B - 5\beta_A - 5\beta_C}{4(\beta_A+\beta_C)(\beta_A+\beta_B+\beta_C)} \geq 0$ if $\beta_A \leq \widetilde{\beta}_{A2minBC,1C} = \frac{4\beta_B - 5\beta_C}{5}$ $\wedge \beta_B \geq \widetilde{\beta}_{B2minBC,1C} = \frac{5\beta_C}{4}$).

$2minBC$ vs. no exports to C and $1B$: Under the scheme $2minBC$, the profit from selling only in countries A and B (under the scheme $1B$) is higher than the profit from selling in all three countries (under the scheme $2minBC$) if β_A is sufficiently low and β_B is sufficiently low
($\pi_A^{1B} + \pi_B^{1B} - \pi^{2minBC} = \frac{4\beta_C - 5\beta_B - 5\beta_A}{4(\beta_A+\beta_B)(\beta_A+\beta_B+\beta_C)} \geq 0$ if $\beta_A \leq \widetilde{\beta}_{A2minBC,1B} = \frac{4\beta_C - 5\beta_B}{5} \wedge \beta_B \leq \widetilde{\beta}_{B2minBC,1B} = \frac{4\beta_C}{5}$).

$2minBC$ vs. no exports to B and C: Under the scheme $2minBC$, the profit from selling only in country A (under coinsurance) is higher than the profit from selling in all three countries (under the scheme $2minBC$) if β_A is sufficiently low ($\pi_A^* - \pi^{2minBC} = \frac{\beta_B + \beta_C - 8\beta_A}{4\beta_A(\beta_A+\beta_B+\beta_C)} \leq 0$ if $\beta_A \leq \widetilde{\beta}_{A2minBC,A^*} = \frac{\beta_B+\beta_C}{8}$).

Two Reference Countries, Average Rule

$2avg$ vs. no exports to B and coinsurance in A and C: Under the scheme $2avg$, the profit from selling only in countries A and C (under coinsurance) is higher than the profit from selling in all three countries (under the scheme $2avg$) if β_A is sufficiently low ($\pi_A^* + \pi_C^* - \pi^{2avg} = \frac{\left(\beta_A^2\beta_C + \beta_B\beta_A^2 - 4\beta_C(\beta_A\beta_B + 2\beta_A\beta_C - \beta_B\beta_C)\right)}{4\beta_A\beta_C(\beta_A\beta_B+\beta_A\beta_C+4\beta_B\beta_C)} \geq 0$, if $\beta_A \leq \widetilde{\beta}_{A2avg,A^*C^*} = \frac{2\beta_B\beta_C}{\sqrt{\beta_C(3\beta_B+4\beta_C)}+\beta_B+2\beta_C}$).

$2avg$ vs. no exports to C and coinsurance in A and B: Under the scheme $2avg$, the profit from selling only in countries A and B (under coinsurance) is higher than the profit from selling in all three countries (under the scheme $2avg$) if β_A is sufficiently low ($\pi_A^* + \pi_B^* - \pi^{2avg} = \frac{\beta_A^2\beta_B + \beta_C\beta_A^2 - 4\beta_B(2\beta_A\beta_B + \beta_A\beta_C - \beta_B\beta_C)}{4\beta_A\beta_B(\beta_A\beta_B+\beta_A\beta_C+4\beta_B\beta_C)} \geq 0$, if $\beta_A \leq \widetilde{\beta}_{A2avg,A^*B^*} = \frac{2\beta_B\beta_C}{\sqrt{\beta_B(4\beta_B+3\beta_C)}+2\beta_B+\beta_C}$).

$2avg$ vs. no exports to B and $1C$: Under the scheme $2avg$, the profit from selling only in countries A and C (under the scheme $1C$) is higher than the profit from selling in all three countries (under the scheme $2avg$) if β_A is sufficiently low and β_B is sufficiently high ($\pi_A^{1C} + \pi_C^{1C} - \pi^{2avg} = \frac{7\beta_B\beta_C - 5\beta_A\beta_B - 5\beta_A\beta_C - 9\beta_C^2}{4(\beta_A+\beta_C)(\beta_A\beta_B+\beta_A\beta_C+4\beta_B\beta_C)} \geq 0$ if $\beta_A \leq \widetilde{\beta}_{A2avg,1C} = \frac{\beta_C(7\beta_B - 9\beta_C)}{5(\beta_B+\beta_C)}$ $\wedge \beta_B \geq \widetilde{\beta}_{B2avg,1C} = \frac{9\beta_C}{7}$).

$2avg$ vs. no exports to C and $1B$: Under the scheme $2avg$, the profit from selling only in countries A and B (under the scheme $1B$) is higher than the profit from selling in all three countries (under the scheme $2avg$) if β_A is sufficiently low and β_B is sufficiently low ($\pi_A^{1B} + \pi_B^{1B} - \pi^{2avg} = \frac{7\beta_B\beta_C - 5\beta_A\beta_B - 5\beta_A\beta_C - 9\beta_B^2}{4(\beta_A+\beta_B)(\beta_A\beta_B+\beta_A\beta_C+4\beta_B\beta_C)} \geq 0$ if $\beta_A \leq \widetilde{\beta}_{A2avg,1B} = \frac{\beta_B(7\beta_C - 9\beta_B)}{5(\beta_C+\beta_B)}$ $\wedge \beta_B \leq \widetilde{\beta}_{B2avg,1B} = \frac{7\beta_C}{9}$).

$2avg$ vs. no exports to B and C: Under the scheme $2avg$, the profit from selling only in country A (under coinsurance) is higher than the profit from selling in all three countries (under the scheme $2avg$) if β_A is sufficiently low ($\pi_A^* - \pi^{2avg} = \frac{\beta_B\beta_C - 2\beta_A\beta_C - 2\beta_A\beta_B}{\beta_A(\beta_A\beta_B+\beta_A\beta_C+4\beta_B\beta_C)} \geq 0$ if $\beta_A \leq \widetilde{\beta}_{A2avg,A^*} = \frac{\beta_B\beta_C}{2(\beta_B+\beta_C)}$).

The threshold for not selling to country B under the scheme $2avg$ is lower than the threshold for not selling to country B under the scheme $2minB$ if β_B is sufficiently high
$(\widetilde{\beta}_{A2avg,1C} - \widetilde{\beta}_{A2minB,1C} = \frac{2\beta_C\left(21\beta_B^2-55\beta_B\beta_C+36\beta_C^2\right)}{\left(23\beta_B^2-31\beta_C^2-8\beta_B\beta_C-(7\beta_B-9\beta_C)\sqrt{(\beta_B-\beta_C)(\beta_B+15\beta_C)}\right)} \leq 0 \text{ if } \beta_B \geq \widetilde{\beta}_{B2minB,1C} = \frac{4\beta_C}{3})$.
The threshold for not selling to country C under the scheme $2avg$ is lower than the threshold for not selling to country C under the scheme $2minC$ if β_B is sufficiently low
$(\widetilde{\beta}_{A2avg,1B} - \widetilde{\beta}_{A2minC,1B} = \frac{2\beta_B\left(36\beta_B^2-55\beta_B\beta_C+21\beta_C^2\right)}{\left(23\beta_C^2-31\beta_B^2-8\beta_B\beta_C+(9\beta_B-7\beta_C)\sqrt{(\beta_C-\beta_B)(15\beta_B+\beta_C)}\right)} \leq 0 \text{ if } \beta_B \leq \widetilde{\beta}_{B2minC,1B} = \frac{3\beta_C}{4})$.
In country A, the price under the average rule is lower than under the scheme $1C$ if β_A is sufficiently low ($p_A^{2avg} - p_A^{1C} = -\frac{5\beta_B\beta_C-\beta_A\beta_B-\beta_A\beta_C-3\beta_C^2}{2(\beta_A+\beta_C)(\beta_A\beta_B+\beta_A\beta_C+4\beta_B\beta_C)} \leq 0$ if $\beta_A \leq \widehat{\beta}_{Ap_A^{2avg}=p_A^{2minC}} = \frac{\beta_C(5\beta_B-3\beta_C)}{\beta_B+\beta_C}$), with $\widehat{\beta}_{Ap_A^{2avg}=p_A^{2minC}} \geq 0$ if $\beta_B \geq \overline{\beta_B} = \frac{3\beta_C}{5}$).
In country A, the price under the average rule is lower than under the scheme $1B$ if β_A is sufficiently low ($p_A^{2avg} - p_A^{1B} = -\frac{5\beta_B\beta_C-\beta_A\beta_B-\beta_A\beta_C-3\beta_B^2}{2(\beta_A+\beta_B)(\beta_A\beta_B+\beta_A\beta_C+4\beta_B\beta_C)} \leq 0$ if $\beta_A \leq \widehat{\beta}_{Ap_A^{2avg}=p_A^{2minB}} = \frac{\beta_B(5\beta_C-3\beta_B)}{\beta_B+\beta_C}$), with $\widehat{\beta}_{Ap_A^{2avg}=p_A^{2minB}} \geq 0$ if $\beta_B \leq \underline{\beta_B} = \frac{5\beta_C}{3}$).
The threshold for not selling to country B under the scheme $2avg$ is lower than the threshold for the scheme $2avg$ decreasing the price in country A more than under the scheme $2minC$ if β_B is sufficiently high
$(\widetilde{\beta}_{A2avg,1C} - \widehat{\beta}_{Ap_A^{2avg}=p_A^{2minC}} = \frac{6(3\beta_B-\beta_C)(\beta_B+\beta_C)}{\beta_C(5\beta_B-3\beta_C)(7\beta_B-9\beta_C)} \leq 0 \text{ if } \beta_B \geq \frac{\beta_C}{3})$. The threshold for not selling to country C under the scheme $2avg$ is lower than the threshold for the scheme $2avg$ decreasing the price in country A more than under the scheme $2minB$ if β_B is sufficiently high or if β_B is sufficiently low
$(\widetilde{\beta}_{A2avg,1B} - \widehat{\beta}_{Ap_A^{2avg}=p_A^{2minB}} = \frac{6(3\beta_C-\beta_B)(\beta_B+\beta_C)}{\beta_B(5\beta_C-3\beta_B)(7\beta_C-9\beta_B)} \leq 0 \text{ if } \beta_B \geq \underline{\beta_B} \vee \beta_B \leq \frac{\beta_C}{3})$.

A.4 Welfare in Reference Countries

Under the scheme $2minB$, the price in B is higher than under coinsurance ($p_B^{2minB} - p_B^* = \frac{(\beta_B-\beta_A)}{2\beta_B(\beta_A+\beta_B)} > 0$).
Under the scheme $2minC$, the price in C is higher than under coinsurance ($p_C^{2minC} - p_C^* = \frac{(\beta_C-\beta_A)}{2\beta_C(\beta_A+\beta_C)} > 0$).
Under the scheme $2avg$, the price in B is higher than under coinsurance ($p_B^{2avg} - p_B^* = \frac{2\beta_B\beta_C-\beta_A\beta_B-\beta_A\beta_C}{2\beta_C(\beta_A\beta_B+\beta_A\beta_C+4\beta_B\beta_C)} > 0$).
Under the scheme $2avg$, the price in C is higher than under coinsurance ($p_C^{2avg} - p_C^* = \frac{2\beta_B\beta_C-\beta_A\beta_B-\beta_A\beta_C}{2\beta_C(\beta_A\beta_B+\beta_A\beta_C+4\beta_B\beta_C)} > 0$).
Under the scheme $2minBC$, the price in B is higher than under coinsurance if β_A is sufficiently low
($p_B^{2minBC} - p_B^* = \frac{2\beta_B-\beta_A-\beta_C}{2\beta_B(\beta_A+\beta_B+\beta_C)} > 0$ if $\beta_A \leq \widehat{\beta}_{Ap_B^{2minC}=p_C^{2minC}} = 2\beta_B - \beta_C$).
Under the scheme $2minBC$, the price in C is higher than under coinsurance if β_A is sufficiently low
($p_C^{2minBC} - p_C^* = \frac{2\beta_C-\beta_A-\beta_B}{2\beta_C(\beta_A+\beta_B+\beta_C)} > 0$ if $\beta_A \geq \widehat{\beta}_{Ap_B^{2minB}=p_C^{2minB}} = 2\beta_C - \beta_B$).

A.5 Mutual Referencing

8.1.1 One Reference Country

Country A chooses $1B$, country B chooses $1A$: The manufacturer maximizes
$\pi^{1B,1A} = p_A^{1B,1A}\left(1-\beta_A p_A^{1B,1A}\right) + p_B^{1B,1A}\left(1-\beta_B p_B^{1B,1A}\right) + p_C^{1B,1A}\left(1-\beta_C p_C^{1B,1A}\right)$ s.t. $p_A^{1B,1A} \leq P_A^{1B,1A} = p_B^{1B,1A} \wedge p_B^{1B,1A} \leq P_B^{1B,1A} = p_A^{1B,1A}$. Equilibrium prices are $p_A^{1B} = p_B^{1B} = \frac{1}{\beta_A+\beta_B}$, $p_C^{1B} = \frac{1}{2\beta_C}$.
Country A chooses $1B$, country B chooses $1C$: The manufacturer maximizes
$\pi^{1B,1C} = p_A^{1B,1C}\left(1-\beta_A p_A^{1B,1C}\right) + p_B^{1B,1C}\left(1-\beta_B p_B^{1B,1C}\right) + p_C^{1B,1C}\left(1-\beta_C p_C^{1B,1C}\right)$ s.t. $p_A^{1B,1C} \leq P_A^{1B,1C} =$

$p_B^{1B,1C} \wedge p_B^{1B,1C} \leq P_B^{1B,1C} = p_C^{1B,1C}$. The equilibrium uniform price is $p = \frac{3}{2(\beta_A+\beta_B+\beta_C)}$.

Country A chooses $1B$, country B chooses $2minj$: The manufacturer maximizes $\pi^{1B,2minj} = p_A^{1B,2minj}\left(1-\beta_A p_A^{1B,2minj}\right) + p_B^{1B,2minj}\left(1-\beta_B p_B^{1B,2minj}\right) + p_C^{1B,2minj}\left(1-\beta_C p_C^{1B,2minj}\right)$ s.t. $p_A^{1B,2minj} \leq P_A^{1B,2minj} = p_B^{1B,2minj} \wedge p_B^{1B,2minj} \leq P_B^{1B,2minj} = min\{p_A^{1B,2minj}, p_C^{1B,2minj}\}$. Equilibrium prices are $p_A^{1B,2minA} = p_B^{1B,2minA} = \frac{1}{\beta_A+\beta_B}$, $p_C^{1B,2minA} = \frac{1}{2\beta_C}$ if $\beta_A \geq \widehat{\beta}_{A_{p_B^{2minB}=p_C^{2minB}}}$ and the equilibrium uniform price is $p = \frac{3}{2(\beta_A+\beta_B+\beta_C)}$. if $\beta_A \leq \widehat{\beta}_{A_{p_B^{2minB}=p_C^{2minB}}}$.

Country A chooses $1B$, country B chooses $2avg$: The manufacturer maximizes $\pi^{1B,2avg} = p_A^{1B,2avg}\left(1-\beta_A p_A^{1B,2avg}\right) + p_B^{1B,2avg}\left(1-\beta_B p_B^{1B,2avg}\right) + p_C^{1B,2avg}\left(1-\beta_C p_C^{1B,2avg}\right)$ s.t. $p_A^{1B,2avg} \leq P_A^{1B,2avg} = p_B^{1B,2avg} \wedge p_B^{1B,2avg} \leq P_B^{1B,2avg} = \frac{1}{2}p_A^{1B,2avg} + \frac{1}{2}p_C^{1B,2avg}$. The equilibrium uniform price is $p = \frac{3}{2(\beta_A+\beta_B+\beta_C)}$.

Country A chooses $1C$, country B chooses $1A$: The manufacturer maximizes $\pi^{1C,1A} = p_A^{1C,1A}\left(1-\beta_A p_A^{1C,1A}\right) + p_B^{1C,1A}\left(1-\beta_B p_B^{1C,1A}\right) + p_C^{1C,1A}\left(1-\beta_C p_C^{1C,1A}\right)$ s.t. $p_A^{1C,1A} \leq P_A^{1C,1A} = p_C^{1C,1A} \wedge p_B^{1C,1A} \leq P_B^{1C,1A} = p_A^{1C,1A}$. The equilibrium uniform price is $p = \frac{3}{2(\beta_A+\beta_B+\beta_C)}$.

Country A chooses $1C$, country B chooses $1C$: The manufacturer maximizes $\pi^{1C,1C} = p_A^{1C,1C}\left(1-\beta_A p_A^{1C,1C}\right) + p_B^{1C,1C}\left(1-\beta_B p_B^{1C,1C}\right) + p_C^{1C,1C}\left(1-\beta_C p_C^{1C,1C}\right)$ s.t. $p_A^{1C,1C} \leq P_A^{1C,1C} = p_C^{1C,1C} \wedge p_B^{1C,1C} \leq P_B^{1C,1C} = p_C^{1C,1C}$. The equilibrium uniform price is $p = \frac{3}{2(\beta_A+\beta_B+\beta_C)}$.

Country A chooses $1C$, country B chooses $2minj$: The manufacturer maximizes $\pi^{1C,2minj} = p_A^{1C,2minj}\left(1-\beta_A p_A^{1C,2minj}\right) + p_B^{1C,2minj}\left(1-\beta_B p_B^{1C,2minj}\right) + p_C^{1C,2minj}\left(1-\beta_C p_C^{1C,2minj}\right)$ s.t. $p_A^{1C,2minj} \leq P_A^{1C,2minj} = p_B^{1C,2minj} \wedge p_B^{1C,2minj} \leq P_B^{1C,2minj} = min\{p_A^{1C,2minj}, p_C^{1C,2minj}\}$. The equilibrium uniform price is $p = \frac{3}{2(\beta_A+\beta_B+\beta_C)}$.

Country A chooses $1C$, country B chooses $2avg$: The manufacturer maximizes $\pi^{1C,2avg} = p_A^{1C,2avg}\left(1-\beta_A p_A^{1C,2avg}\right) + p_B^{1C,2avg}\left(1-\beta_B p_B^{1C,2avg}\right) + p_C^{1C,2avg}\left(1-\beta_C p_C^{1C,2avg}\right)$ s.t. $p_A^{1C,2avg} \leq P_A^{1C,2avg} = p_B^{1C,2avg} \wedge p_B^{1C,2avg} \leq P_B^{1C,2avg} = \frac{1}{2}p_A^{1C,2avg} + \frac{1}{2}p_C^{1C,2avg}$. The equilibrium uniform price is $p = \frac{3}{2(\beta_A+\beta_B+\beta_C)}$.

In country B, the drug price under $1B$ (or $2minB$) is lower than the uniform price ($p - p_B^{1B,(.)} = \frac{\beta_A+\beta_B-2\beta_C}{2(\beta_A+\beta_B)(\beta_A+\beta_B+\beta_C)} \geq 0$ if $\beta_A \geq \widehat{\beta}_{A_{p_B^{2minB}=p_C^{2minB}}} = 2\beta_C - \beta_B$).

In country B, the uniform price is lower than the price under coinsurance (under $1C$ or $2minC$) ($p - p_B^* = -\frac{\beta_A-2\beta_B+\beta_C}{2\beta_B(\beta_A+\beta_B+\beta_C)} \leq 0$ if $\beta_A \geq \widehat{\beta}_{A_{p_B^{2minC}=p_C^{2minC}}} = 2\beta_B - \beta_C$).

Two Reference Countries, Minimum Price

Country A chooses $2minj$, country B chooses $1A$: The manufacturer maximizes $\pi^{2minj,1A} = p_A^{2minj,1A}\left(1-\beta_A p_A^{2minj,1A}\right) + p_B^{2minj,1A}\left(1-\beta_B p_B^{2minj,1A}\right) + p_C^{2minj,1A}\left(1-\beta_C p_C^{2minj,1A}\right)$ s.t. $p_A^{2minj,1A} \leq P_A^{2minj,1A} = min\{p_B^{2minj,1A}, p_C^{2minj,1A}\} \wedge p_B^{2minj,1A} \leq P_B^{2minj,1A} = p_A^{2minj,1A}$. Equilibrium prices are $p_A^{2minB,1A} = p_B^{2minB,1A} = \frac{1}{\beta_A+\beta_B}$, $p_C^{2minB,1A} = \frac{1}{2\beta_C}$ if $\beta_A \geq \widehat{\beta}_{A_{p_B^{2minB}=p_C^{2minB}}}$ and the equilibrium uniform price is $p = \frac{3}{2(\beta_A+\beta_B+\beta_C)}$. if $\beta_A \leq \widehat{\beta}_{A_{p_B^{2minB}=p_C^{2minB}}}$.

Country A chooses $2minj$, country B chooses $1C$: The manufacturer maximizes $\pi^{2minj,1C} = p_A^{2minj,1C}\left(1-\beta_A p_A^{2minj,1C}\right) + p_B^{2minj,1C}\left(1-\beta_B p_B^{2minj,1C}\right) + p_C^{2minj,1C}\left(1-\beta_C p_C^{2minj,1C}\right)$ s.t. $p_A^{2minj,1C} \leq P_A^{2minj,1C} = min\{p_B^{2minj,1C}, p_C^{2minj,1C}\} \wedge p_B^{2minj,1C} \leq P_B^{2minj,1C} = p_C^{2minj,1C}$. Equilibrium prices are $p_A^{2minBC,1C} = p_B^{2minBC,1C} = p_C^{2minBC,1C} = \frac{3}{2(\beta_A+\beta_B+\beta_C)}$.

Country A chooses $2minj$, country B chooses $2minj$: The manufacturer maximizes
$\pi^{2minj,2minj} = p_A^{2minj,2minj}\left(1-\beta_A p_A^{2minj,2minj}\right)+p_B^{2minj,2minj}\left(1-\beta_B p_B^{2minj,2minj}\right)+p_C^{2minj,2minj}\left(1-\beta_C p_C^{2minj,2minj}\right)$
s.t. $p_A^{2minj,2minj} \leq P_A^{2minj,2minj} = min\{p_B^{2minj,2minj}, p_C^{2minj,2minj}\}$
$\wedge\ p_B^{2minj,2minj} \leq P_B^{2minj,2minj} = min\{p_A^{2minj,2minj}, p_C^{2minj,2minj}\}$. Equilibrium prices are $p_A^{2minB,2minA} = p_B^{2minB,2minA} = \frac{1}{\beta_A+\beta_B}$, $p_C^{2minB,2minA} = \frac{1}{2\beta_C}$ if $\beta_A \geq \widehat{\beta}_{A_{p_B^{2minB}=p_C^{2minB}}}$ and the equilibrium uniform price is $p = \frac{3}{2(\beta_A+\beta_B+\beta_C)}$. if $\beta_A \leq \widehat{\beta}_{A_{p_B^{2minB}=p_C^{2minB}}}$.
Country A chooses $2minj$, country B chooses $2avg$: The manufacturer maximizes
$\pi^{2minj,2avg} = p_A^{2minj,2avg}\left(1-\beta_A p_A^{2minj,2avg}\right)+p_B^{2minj,2avg}\left(1-\beta_B p_B^{2minj,2avg}\right)+p_C^{2minj,2avg}\left(1-\beta_C p_C^{2minj,2avg}\right)$
s.t. $p_A^{2minj,2avg} \leq P_A^{2minj,2avg} = min\{p_B^{2minj,2avg}, p_C^{2minj,2avg}\} \wedge\ p_B^{2minj,2avg} \leq P_B^{2minj,2avg} = \frac{1}{2}p_A^{2minj,2avg} + \frac{1}{2}p_C^{2minj,2avg}$. The equilibrium uniform price is $p = \frac{3}{2(\beta_A+\beta_B+\beta_C)}$.

Two Reference Countries, Average Price

Country A chooses $2avg$, country B chooses $1A$: The manufacturer maximizes
$\pi^{2avg,1A} = p_A^{2avg,1A}\left(1-\beta_A p_A^{2avg,1A}\right)+p_B^{2avg,1A}\left(1-\beta_B p_B^{2avg,1A}\right)+p_C^{2avg,1A}\left(1-\beta_C p_C^{2avg,1A}\right)$ s.t. $p_A^{2avg,1A} \leq P_A^{2avg,1A} = \frac{1}{2}p_B^{2avg,1A} + \frac{1}{2}p_C^{2avg,1A} \wedge\ p_B^{2avg,1A} \leq P_B^{2avg,1A} = p_A^{2avg,1A}$. The equilibrium uniform price is $p = \frac{3}{2(\beta_A+\beta_B+\beta_C)}$.
Country A chooses $2avg$, country B chooses $1C$: The manufacturer maximizes
$\pi^{2avg,1C} = p_A^{2avg,1C}\left(1-\beta_A p_A^{2avg,1C}\right)+p_B^{2avg,1C}\left(1-\beta_B p_B^{2avg,1C}\right)+p_C^{2avg,1C}\left(1-\beta_C p_C^{2avg,1C}\right)$ s.t. $p_A^{2avg,1C} \leq P_A^{2avg,1C} = \frac{1}{2}p_B^{2avg,1C} + \frac{1}{2}p_C^{2avg,1C} \wedge\ p_B^{2avg,1C} \leq P_B^{2avg,1C} = p_A^{2avg,1C}$. The equilibrium uniform price is $p = \frac{3}{2(\beta_A+\beta_B+\beta_C)}$.
Country A chooses $2avg$, country B chooses $2minj$: The manufacturer maximizes
$\pi^{2avg,2minj} = p_A^{2avg,2minj}\left(1-\beta_A p_A^{2avg,2minj}\right)+p_B^{2avg,2minj}\left(1-\beta_B p_B^{2avg,2minj}\right)+p_C^{2avg,2minj}\left(1-\beta_C p_C^{2avg,2minj}\right)$
s.t. $p_A^{2avg,2minj} \leq P_A^{2avg,2minj} = \frac{1}{2}p_B^{2avg,2minj}+\frac{1}{2}p_C^{2avg,2minj} \wedge p_B^{2avg,2minj} \leq P_B^{2avg,2minj} = min\{p_A^{2avg,2minj}, p_C^{2avg,2minj}\}$.
The equilibrium uniform price is $p = \frac{3}{2(\beta_A+\beta_B+\beta_C)}$.
Country A chooses $2avg$, country B chooses $2avg$: The manufacturer maximizes
$\pi^{2avg,2avg} = p_A^{2avg,2avg}\left(1-\beta_A p_A^{2avg,2avg}\right)+p_B^{2avg,2avg}\left(1-\beta_B p_B^{2avg,2avg}\right)+p_C^{2avg,2avg}\left(1-\beta_C p_C^{2avg,2avg}\right)$ s.t. $p_A^{2avg,2avg} \leq P_A^{2avg,2avg} = \frac{1}{2}p_B^{2avg,2avg} + \frac{1}{2}p_C^{2avg,2avg} \wedge\ p_B^{2avg,2avg} \leq P_B^{2avg,2avg} = \frac{1}{2}p_A^{2avg,2avg} + \frac{1}{2}p_C^{2avg,2avg}$. The equilibrium uniform price is $p = \frac{3}{2(\beta_A+\beta_B+\beta_C)}$.
In country B, the uniform price is lower than the price under $2avg$ if β_B is sufficiently low ($p - p_B^{2avg} = -\frac{3(\beta_A+2\beta_C)(\beta_C-\beta_B)}{2(\beta_A+\beta_B+\beta_C)(\beta_A\beta_B+\beta_A\beta_C+4\beta_B\beta_C)} \leq 0$ if $\beta_B \leq \widehat{\beta}_{B_{p_B=p_C}}$).

Best Response of Country A

In country A, the uniform price is higher than the price under $2minB$
($p - p_A^{2minB} = \frac{\beta_A+\beta_B-2\beta_C}{2(\beta_A+\beta_B)(\beta_A+\beta_B+\beta_C)} \geq 0$ if $\beta_A \geq \widehat{\beta}_{A_{p_B^{2minB}=p_C^{2minB}}} = 2\beta_C - \beta_B$).
In country A, the uniform price is higher than the price under $2minC$
($p - p_A^{2minC} = \frac{\beta_A-2\beta_B+\beta_C}{2(\beta_A+\beta_C)(\beta_A+\beta_B+\beta_C)} \geq 0$ if $\frac{1}{\beta_A} \leq \widehat{\frac{1}{\beta_A}}_{p_B^{2minC}=p_C^{2minC}} = 2\beta_B - \beta_C$).
In country A, the uniform price is lower than the price under $2avg$
($p - p_A^{2avg} = -\frac{3(\beta_B-\beta_C)^2}{2(\beta_A+\beta_B+\beta_C)(\beta_A\beta_B+\beta_A\beta_C+4\beta_B\beta_C)} \leq 0$).

Welfare

In country A, welfare under a uniform price is higher than under coinsurance if β_A is sufficiently low $(\Delta W_A = W_A^p - W_A^* = \frac{(\beta_B - 2\beta_A + \beta_C)(2\beta_B - 4\beta_A + 2\beta_C + 4\beta_A\mu_A(\beta_A+\beta_B+\beta_C) - 3\gamma_A(\beta_B+\beta_C))}{8\beta_A(\beta_A+\beta_B+\beta_C)^2} \geq 0$ if $\beta_A \leq \widehat{\beta_{A}}_{\Delta W_A} = \frac{\beta_C+\beta_B}{2}$).

In country B, welfare under a uniform price is higher than under coinsurance if β_A is sufficiently high or β_B is sufficiently low $(\Delta W_B = W_B^p - W_B^* = \frac{(\beta_A - 2\beta_B + \beta_C)(2\beta_A - 4\beta_B + 2\beta_C + 4\beta_B\mu_B(\beta_A+\beta_B+\beta_C) - 3\gamma_B(\beta_A+\beta_C))}{8\beta_B(\beta_A+\beta_B+\beta_C)^2} \geq 0$ if $\beta_A \geq \widehat{\beta_{A}}_{\Delta W_B} = 2\beta_B - \beta_C \vee \beta_B \leq \widehat{\beta_{B}}_{\Delta W_B} = \frac{\beta_C+\beta_A}{2}$).

In country C, welfare a uniform price is higher than under coinsurance if β_A is sufficiently high or β_C is sufficiently low $(\Delta W_C = W_C^p - W_C^* = \frac{(\beta_A + \beta_B - 2\beta_C)(2\beta_A + 2\beta_B - 4\beta_C + 4\beta_C(\beta_A+\beta_B+\beta_C) - 3\beta_C(\beta_A+\beta_B))}{8\beta_C(\beta_A+\beta_B+\beta_C)^2} > 0$ if $\beta_A \geq \widehat{\beta_{A}}_{\Delta W_C} = 2\beta_C - \beta_B \vee \ \beta_C \leq \widehat{\beta_{C}}_{\Delta W_C} = \frac{\beta_A+\beta_B}{2}$).

Global welfare under coinsurance is $W^* = \frac{3(\beta_A\beta_B\beta_C + \beta_A\beta_C\gamma_B + \beta_B\gamma_A\beta_C) - 2(\beta_A\beta_B + \beta_A\beta_C + \beta_B\beta_C)}{8\beta_A\beta_B\beta_C}$.

Global welfare under a uniform price is

$$W^p = \frac{2(2\beta_A + 2\beta_B - 4\beta_C - 9)(\beta_A+\beta_B+\beta_C) + 3(\gamma_A(\beta_A+4\beta_B+4\beta_C) + \gamma_B(4\beta_A+\beta_B+4\beta_C) + \beta_C(4\beta_A+4\beta_B+\beta_C))}{8(\beta_A+\beta_B+\beta_C)^2}$$
$$- \frac{4(\beta_A+\beta_B+\beta_C)(\mu_A(2\beta_A-\beta_B-\beta_C) - \mu_B(\beta_A-2\beta_B+\beta_C))}{8(\beta_A+\beta_B+\beta_C)^2}.$$

Global welfare under a uniform price is higher than global welfare under coinsurance $(W^p - W^* = \frac{\Omega_W}{8\beta_C(\beta_A+\beta_B+\beta_C)^2} > 0$, with $\Omega_W = -2\beta_B^2 - 26\beta_C^2 - 4\beta_A\beta_B - 10\beta_A\beta_C - 10\beta_B\beta_C - 2\beta_A^2 + 3\gamma_A\beta_C(\beta_A + 4\beta_B + 4\beta_C) + 3\beta_C\gamma_B(4\beta_A + \beta_B + 4\beta_C) + 3\beta_C(\beta_A + \beta_B + \beta_C)^2 - 4\mu_A\beta_C(\beta_A + \beta_B + \beta_C)(2\beta_A - \beta_B - \beta_C) + 4\beta_C\mu_B(\beta_A - 2\beta_B + \beta_C)(\beta_A + \beta_B + \beta_C)$).

8.1.2 Export Decision

The manufacturer's profit under uniform pricing is $\pi = \frac{9}{4(\beta_A+\beta_B+\beta_C)}$.

Uniform price vs. no exports to B and $1C$: Under uniform pricing, the profit from selling only in countries A and C (under the scheme $1C$) is higher than the profit from selling in all three countries (under a uniform price) if β_A is sufficiently low and β_B is sufficiently high $(\pi_A^{1C} + \pi_C^{1C} - \pi = \frac{4\beta_B - 5\beta_A - 5\beta_C}{4(\beta_A+\beta_C)(\beta_A+\beta_B+\beta_C)} \geq 0$ if $\beta_A \leq \widetilde{\beta_{A}}_{p,1C} = \frac{4\beta_B - 5\beta_C}{5} \wedge \beta_B \geq \widetilde{\beta_{B}}_{p,1C} = \frac{5(\beta_A+\beta_C)}{4}$).

Uniform price vs. no exports to C and $1B$: Under uniform pricing, the profit from selling only in countries A and B (under the scheme $1B$) is higher than the profit from selling in all three countries (under a uniform price) if β_A is sufficiently low and β_B is sufficiently low $(\pi_A^{1B} + \pi_B^{1B} - \pi = \frac{4\beta_C - 5\beta_B - 5\beta_A}{4(\beta_A+\beta_B)(\beta_A+\beta_B+\beta_C)} \geq 0$ if $\beta_A \leq \widetilde{\beta_{A}}_{p,1B} = \frac{4\beta_C - 5\beta_B}{5} \wedge \beta_B \leq \widetilde{\beta_{B}}_{p,1B} = \frac{4\beta_C - 5\beta_A}{5}$).