University of Kent

Department of Economics Discussion Papers

Health systems, inequality and incentives to innovate.

Rajat Acharyya and María D. C. García-Alonso

February 2009

KDPE 0902

Health systems, inequality and incentives to innovate*

Rajat Acharyya[†] and María D. C. García-Alonso[‡]

February 13, 2009

Abstract

Governments often subsidize poorer groups in society to ensure their access to new drugs. We analyze here the optimal income-based price subsidies in a strategic environment. We show that asymmetric health systems can arise even though countries are ex-ante symmetric when international price discrimination is possible. Universal access is less likely to arise without price discrimination but also health policy coordination becomes more important. This is due to the multiple equilibria which make the attainment of universal coverage within a given income range ambiguous. We also show that an increase in intra-country inequality does not always lead to less likely universal coverage when international price discrimination is possible.

JEL Classification: D4, L1, I1.
Keywords: Health systems; Pharmaceuticals; Innovation; Income Based Subsidies; price discrimination

*We would like to acknowledge financial support from the British Academy Grant number SG-50473 and the University of Kent Small Faculty Grants. We would also like to thank Mathan Satchi and Jagjit Chadha for helpful comments. The usual disclaimer applies.

†Department of Economics, Jadavpur University, Calcutta 700 032, India.

‡Corresponding author. Department of Economics, University of Kent, Kent CT2 7NP, U.K. Tel.: +44 (0)1227827488; fax: +44 (0)1227827850. E-mail address: m.c.garcia-alonso@kent.ac.uk.

1 Introduction

In June, 2006, the Council of the European Union stated as the overarching values in EU Health Systems universality, access to good quality care, equity and solidarity. The European Commission has committed to developing "a Community framework for safe, high quality and efficient health services, by reinforcing cooperation between Member States" (see http://europa.eu).

As European Union (EU) countries aim to cooperate in the design of their health systems a question immediately arises, is such cooperation more valuable in the context of more integrated markets? The aspect of health systems we choose to focus on in this paper refers to the provision of universal access to health care. Motivation for this analysis comes from two observations. First, exemptions are applied to medicines for children and pensioners in countries such as the UK, whereas Medicaid covers poorer sections of society in the US. Second, pressure is being put on the US authorities by the poorer members of society to allow for parallel imports from other countries to lower the internal price of medicines.

The objective of this paper is to analyze the interaction between governments choosing their provision of universal health coverage and its impact on drug innovation and prices. We also examine the impact that price arbitrage across countries may have over the incentives to implement such policies and the incentives that firms have to innovate.

Ganslandt and Maskus (2007) give a detailed description of the literature on price arbitrage and price discrimination in the context of pharmaceutical markets. As they point out, an under-researched branch of such literature is the design of price regulation and its effects on firm's decisions.[1] A price regulation tool used in the literature is price caps set on the firm's pharmaceutical sales domestically. A good example of this literature can be found in Jelovac and Bordoy (2005). They construct a model of optimal pricing of pharmaceuticals and parallel imports with exogenous quality. The price regulation consists of patients being reimbursed a proportion of the price they pay for medicines, which can be seen as a standard price subsidy. Alternatively, the reimbursement can be interpreted as the co-payment of patients to an insurance company. Still, in their paper, the reimbursement is identical for all consumers although allowed to differ across countries. A more developed insurance system policy can be found in Garber et al. (2006), where in the context of a closed economy the impact of insurance policies on the firm's incentives to innovate has been analyzed. But both in Garber et

[1] Ganslandt and Maskus (2007) use a dynamic general equilibrium model to analyze the impact of price controls on the firm's incentives to innovate.

al. (2006) and Jelovac and Bordoy (2005) there is no income heterogeneity across patients. The heterogeneity comes entirely from the valuation for the pharmaceutical innovation in terms of its efficacy being different for each patient.[2]

The purpose of this paper is to construct a simple model of (intra-country) income heterogeneity and study the implications of price subsidies on the market coverage and innovation level of a pharmaceutical MNC. Our analytical framework draws from Acharyya and García-Alonso (2006, 2008). Acharyya and García-Alonso (2006), with no intra-country but only inter-country income heterogeneity, show that with restrictions on how the global income was initially distributed across countries, a transfer of income from rich countries (the countries having per capita income level above the world average) to the poor countries would raise the innovation level and thus make such a transfer essentially self-interested rather than altruistic. The subsequent analysis studies the implications of parallel imports on innovation and price of the drug, and the national welfare levels, when intra-country income heterogeneity exists. However, we do touch upon the issue of choice of parallel imports as a trade strategy when countries can also subsidize their poor buyers to ensure market access for them. Our primary motivation is to examine optimal subsidy choices when there are no significant cross-country income heterogeneity differences.

The interesting but nontrivial result we derive here in a two-country framework are the following. First, we find that the MNC's ability to implement international price discrimination only affects the level of quality provision when the firm prefers to provide universal coverage in only one country. In such case, quality is higher when international price discrimination is feasible. In addition, this quality is proven to be higher than the quality provided when the firm prefers to provide universal coverage in both countries. Second, we find that whether governments decide to induce universal coverage will depend on the level of intra-country income inequality. We conclude that, when international price discrimination is not possible, more inequality leads to less likely provision of universal coverage. However, and interestingly, when price discrimination is allowed, an increase in inequality may actually lead to a higher chance of universal coverage by a country alone, in other words the provision of universal coverage may be different across the two countries. Indeed, we show that when

[2]A problem with this structure, as discussed in García-Alonso and García-Mariñoso (2008), is that the efficacy of medicines varies with each medicine so it is difficult to think of the design of general price regulation policies that would depend on the efficacy of different medicines across patient groups. Hence, income heterogeneity makes more sense when it comes to the design of general pricing policies.

international price discrimination is possible, asymmetric health systems (in their provision of universal coverage) may be supported by the Subgame Perfect Nash Equilibrium (SPNE) price subsidies even when countries are ex-ante completely symmetric. Finally, our results show that universal coverage arises under a wider range of income inequality levels and price subsidy pairs when international price discrimination is possible. When this is not the case, under some income ranges, universal coverage in both countries can be supported by SPNE subsidies together with partial provision everywhere, in such cases coordination on the Pareto optimum equilibrium becomes an issue for policy makers.

The rest of the paper is organized as follows, Section 2 presents the basic structure of the model, Section 3 finds the equilibrium producer prices, quality and subsidy levels. Finally, Section 4 concludes the paper. Long proofs are relegated to a technical Appendix.

2 The model

We consider a symmetric two-country world. In each country i, $i = 1, 2$, there are two types of individuals, rich and poor with incomes y_R and y_T respectively. Let n_R and n_T be the number of rich and poor consumers in each country.

There is a single pharmaceutical multinational company (MNC) that plans to develop a new drug of quality s by investing the amount C in research and development (R&D). This R&D investment is increasing at an increasing rate in the target level of quality of the innovated drug:

$$C = \frac{1}{2}s^2. \tag{1}$$

There is no other cost except for this innovation cost. Once the drug is developed, the MNC gets a patent that confers it with a monopoly right over its exclusive sales in different markets. Such monopoly right creates scope for market-based (price) discrimination (MBD) for the MNC. However, its ability to discriminate may be limited by parallel trading allowed by the countries. In principle we do not assign location of the multinational to any of the two countries, that is we assume that they are both importing the pharmaceutical innovation.[3]

The government in each country i can set an income based price subsidy (or tax) for the consumption of the pharmaceutical innovation. We consider

[3] As will be later explained, assigning location of the MNC to any of the two countries would not change our results.

it to be a specific subsidy γ_{ji}, $j = R, T$.

Consumers belonging to a particular income group in each country have identical valuations for a particular quality of the drug that is being developed by a pharmaceutical MNC. Without any loss of generality, this valuation is assumed to be linearly related to the income level. Each consumer buys, if at all, only one unit of the drug. Let the reservation utility of a buyer of income y_{ji} be zero. Thus, by the individually rational (IR) constraint, a representative consumer of type j in country i buys the drug if its gross utility is higher than the subsidized price:

$$y_j s \geq P_i - \gamma_{ji}. \tag{2}$$

The general timing for the model we consider is as follows. In the first stage, the governments in both countries simultaneously choose income based subsidy levels. Given such a subsidy choice, the firm chooses the quality and the price of the innovation. Finally, consumers in both countries choose whether to purchase the innovation or not. We solve themodel for the Subgame Perfect Nash Equilibrium. The government foresees the decisions of firms and consumers and decides on the optimal income based price subsidy.

Now if subsidies given by governments are different, price discrimination might still be a possibility. This ex ante possibility by itself makes subsidy choices significantly different.

The government in each country maximizes national welfare which consists of aggregate consumer surplus minus the cost of the subsidy. No location assignment of MNC is made, and thus the MNC's profit is not included in the national welfare levels. Thus, under universal coverage, it can be readily verified that the welfare of country i equals:

$$W_i = n_R \left(y_R s - P_i \right) + n_T \left(y_T s - P_i \right). \tag{3}$$

Note that the national welfare level is not directly dependent on the rate of subsidy. This follows from the fact that in this model with discrete consumer types, subsidies just redistribute incomes across the consumers and the government. The subsidies affect national welfare levels only through their effects on the innovation level and price of the drug. Also note that, given the profit-maximizing price choices of the MNC for any given quality of the drug, welfare is higher under universal coverage as long as it is positive. The reason is that when only rich consumers are catered for, the MNC will extract all their consumer surplus, hence leaving welfare at zero level. The only possible source of welfare increase is the impact that the subsidy may have on prices and quality. The MNC may be induced to lower prices to cater for poor consumers when these are given a price subsidy. The poor consumers will still be pushed to their reservation utility but the richer consumers benefit from a lower price under universal coverage compared to the higher price of the drug when the poor are not served. Thus, market access for the poor may means higher gross welfare. Net welfare though may be smaller than when subsidies are not offered depending on the level of subsidy that ensures full market coverage, as we will see later. In what follows we will use γ_i to refer to the subsidy given to the lower income group in country i.

It is important to note that the discussion above implicitly presumes that subsidies to the poor are required to induce the firm to cater for all income groups. For this to be the case within our model we require

$$y_R > \frac{n_R + n_T}{n_R} y_T \equiv y_R^*, \tag{4}$$

As will later be seen, this condition ensures that subsidies to induce universal coverage are positive.

3 Innovation and Subsidies

By the backward induction method, given the buyers' choice specified in equation (2), we begin with the quality decision of the MNC and then analyze the simultaneous subsidy choice of governments. As discussed in Acharyya and García-Alonso (2008), the MNC's choice of innovation level will depend on the extent of market coverage in each country. In the present context, this depends on whether countries price subsidize their poor or not. There are three market coverage, which yield different quality choices, and thus need to be analyzed separately.

As has been noted earlier, even with no cross-country income heterogeneity there may be ex ante possibility of price discrimination when the countries do not allow and parallel imports. We consider each of these possibilities – price discrimination is allowed, and is not allowed – in turn to examine how these policy choices themselves affect the optimal subsidies and hence governments' decision to provide universal coverage.

We assume, however, that the MNC will develop only one quality since given zero production costs, quality discrimination across buyers (and countries) is not profitable, and thus there will only be price discrimination, if that is possible at all.[4]

[4] See, for example, Acharyya (2005).

3.1 International price discrimination allowed

We first consider the case when ex ante price discrimination is allowed. We start with the quality choice of the firm. The first relevant case is the one where both governments subsidize their poor buyers such that it is profit maximizing for the MNC to cover all consumers across the world. We refer to this case as *bilateral universal coverage.* The optimal quality of the drug in this case will be the one that maximizes following profit:[5]

$$\pi_{FC}^{D} = (n_R + n_T)(y_T s + \gamma_1) + (n_R + n_T)(y_T s + \gamma_2) - \frac{1}{2}s^2, \tag{5}$$

resulting in a quality level equal to,

$$s_{FC} = 2(n_R + n_T)\, y_T, \tag{6}$$

where, the subscript FC denotes full coverage of both the markets. Note that the optimal innovation level does not depend on the subsidies given because of their specific (instead of proportional) nature.

Second, if only country i subsidizes its poor, it is profit maximizing for the MNC to provide universal coverage in country i only, we will also refer to this case as *unilateral universal coverage.* The optimal quality will be the one that maximizes:

$$\pi_{FCi}^{D} = (n_R + n_T)(y_T s + \gamma_{Ti}) + n_R y_R s - \frac{1}{2}s^2, \;\; i = 1, 2.$$

Thus,

$$s_{FCi}^{D} = (n_R + n_T)\, y_T + n_R y_R, \tag{7}$$

where subscript FCi denotes full coverage of country i market only. Note that by the assumed symmetry of countries, $s_{FC1}^{D} = s_{FC2}^{D}$.

Third, if none of the countries provide subsidy that ensures full coverage, it is profit maximizing to only cover richer consumers in both countries. We refer to this case as *bilateral partial coverage.* The optimal quality then will be the one that maximizes:

$$\pi_{PC}^{D} = 2n_R y_R s - \frac{1}{2}s^2.$$

Thus,

[5] Note that the to find ourselves in this case it must be the case subsidies are such that it is optimal for the firm to provide this level of coverage and hence set optimal quality accordingly. This will become more apparent when we analyze the optimal subsidies.

$$s_{PC} = 2n_R y_R, \tag{8}$$

where the subscript PC denotes partial coverage of both country markets.

Lemma 1 *The MNC chooses the largest innovation level under bilateral partial coverage and least innovation under bilateral universal coverage.*

Proof. From equations (6)-(8) it can be readily verified that,

$$s_{PC} - s_{FCi}^D = s_{FCi}^D - s_{FC} = n_R y_R - (n_R + n_T) y_T.$$

Hence, given the assumption stated in equation (4), it follows that $s_{PC} > s_{FCi}^D > s_{FC}$. ■

The Lemma above evaluates the impact of quality of actually inducing the MNC to cover consumers it would not find profitable to cover without a subsidy (see equation (4)), these are consumers with a lower valuation of quality as this is linked to income. Hence, inducing full coverage in any one country actually reduces quality (although it reduces prices as well, of course) relative to partial coverage (s_{PC} is the highest quality possible). It is interesting to note that from the point of view of quality, it is better for a country providing universal coverage that the other country only provides partial coverage, $s_{FCi}^D > s_{FC}$. In this way, given that we have price discrimination is possible the firm price some of the consumers with the highest valuation for quality accordingly and this increases the firm's incentive to invest in quality.

Now, we consider the choice of subsidy levels by the governments in each of the two countries. The timing of our models implies that governments understand that for any given choice of quality, the subsidy influences the MNC's decision to include or exclude the poor. As the Lemma above states, once the governments condition the extent of market coverage, the MNC chooses the level of innovation and the quality of the drug accordingly.

To begin with, let us note that the common minimum subsidy that ensures that the firm achieves higher profit by fully covering both countries than just providing partial coverage everywhere is such that

$$2(n_R + n_T)(y_T s_{FC} + \gamma_T) - \frac{1}{2}(s_{FC})^2 \geq 2n_R y_R s_{PC} - \frac{1}{2}(s_{PC})^2, \tag{9}$$

using equations (6) and (8), we get the common minimum subsidy offered by each country which ensures bilateral universal coverage

$$\gamma^C = \frac{(n_R y_R)^2 - ((n_R + n_T) y_T)^2}{n_R + n_T}. \tag{10}$$

Note that this subsidy is positive as long as long as $y_R > y_R^*$. It can be readily verified that if the higher income is not too high compared to the lower income, in the sense defined in (4), setting a higher price and excluding the poor does not pay relative to setting a lower price and including the poor. Thus, for $y_R < y_R^*$, the MNC serves all even without any price subsidy. But for $y_R > y_R^*$, the MNC serves only the rich and price subsidies are required to ensure market access for the poor. In rest of the analysis, we shall confine ourselves with income distribution patterns defined in (4).

In addition, we can define two other critical subsidy levels similarly. First, γ^D is the subsidy level that ensures that the firm prefers full coverage in country i alone to partial coverage everywhere

$$(n_R + n_T)\left(y_T s_{FC1}^D + \gamma_{T1}\right) + n_R y_R s_{FC1}^D - \frac{1}{2}\left(s_{FC1}^D\right)^2 \geq 2 n_R y_R s_{PC} - \frac{1}{2}\left(s_{PC}\right)^2, \tag{11}$$

and it is hence given by

$$\gamma^D = \frac{\left(2 n_R y_R\right)^2 - \left(\left(n_R + n_T\right) y_T + n_R y_R\right)^2}{2\left(n_R + n_T\right)}. \tag{12}$$

Second, $\boldsymbol{\gamma}^{\min}$ is the minimum subsidy that ensures that the firms prefers full coverage everywhere to full coverage in one country alone

$$\begin{aligned} & (n_R + n_T)(y_T s_{FC}^D + \gamma_{T1}) + (n_R + n_T)(y_T s_{FC}^D + \gamma_{T2}) - \frac{1}{2}(s_{FC}^D)^2 \\ \geq \; & (n_R + n_T)(y_T s_{FCi}^D + \gamma_{T1}) + n_R y_R s_{FCi}^D - \frac{1}{2}(s_{FCi}^D)^2, \end{aligned} \tag{13}$$

and it is hence given by

$$\gamma^{\min} = \frac{\left(\left(n_R + n_T\right) y_T + n_R y_R\right)^2 - \left(2\left(n_R + n_T\right) y_T\right)^2}{2\left(n_R + n_T\right)}. \tag{14}$$

Note that $\gamma^{\min} = 2\gamma^C - \gamma^D$.

Given these subsidy levels, the following lemma specifies the set of subsidy pairs for which the MNC's optimal pricing of the innovated drug would be such as to provide market access to poorer groups everywhere:

Lemma 2 *The set of subsidy pairs that ensure bilateral universal coverage is such that*

$$\gamma_i \geq 2\gamma^C - \gamma_j$$

and

$$\gamma_i \geq \gamma^{\min} = 2\gamma^C - \gamma^D.$$

for $i = 1, 2$ *and* $j \neq i$.

Proof. To ensure universal coverage a country must ensure the above-mentioned two conditions (9) and (13) must be met. A little manipulation of condition (9), allowing for γ_{T1} and γ_{T2} to differ, we get

$$\gamma_1 \geq 2\frac{(n_R y_R)^2 - ((n_R + n_T) y_T)^2}{n_R + n_T} - \gamma_2 = 2\gamma^C - \gamma_{T2}.$$

For country 2, as long as $\gamma_1^D \geq \gamma_1 > 2\gamma^C - \gamma_2$ and $\gamma_2 > \gamma^{\min}$, the above will hold. However, for any $\gamma_1 > \gamma_1^D$, γ_{T2} must remain at a minimum of $2\gamma^C - \gamma_1^D = \gamma^{\min}$. ■

The above Lemma illustrates the fact that in when the MNC can price discriminate across countries, the subsidy provided by one country can be compensated with a higher subsidy provided by the other country to still persuade the firm to provide universal coverage in both countries as long as each individual subsidy is above a minimum level $\gamma^{\min}$. It is the firms ability to price discriminate together with the fact that the same quality is provided across both countries that generates this effect.

Note that since $\gamma^D > \gamma^C$, if both countries set the common minimum subsidy γ^C, this will ensure full coverage in both countries as they meet the conditions stated in the lemma above. However, the set of subsidy pairs that satisfy the two conditions stated in Lemma 2, need not necessarily be the set of SPNE subsidies. We also have to ensure that such subsidy levels improve the net welfare of both the countries. Otherwise countries would prefer not to induce universal coverage in their own country. The following two lemmas will help obtain the SPNE subsidies. The first lemma provides the condition for bilateral universal coverage to be welfare improving in each country. Note that since welfare is zero with partial coverage, it is enough to obtain the condition under which welfare is positive in each country under bilateral universal coverage.

Lemma 3 *a) A subsidy pair that ensures bilateral universal coverage will result in positive welfare in each country as long as*

$$\gamma_i < \gamma_{FC}^{\max} = 2n_R (y_R - y_T) y_T \tag{15}$$

for $i = 1, 2$.

b) The minimum common subsidy γ^C *is welfare improving* $\forall\ y_R \in (y_R^*, \widetilde{y}_R)$, *where*

$$\widetilde{y}_R = \frac{(n_R + n_T) y_T + y_T \sqrt{(n_R + n_T) 2n_T}}{n_R}. \tag{16}$$

Proof. See Appendix. ■

Intuitively, the above lemma implies that inducing bilateral universal coverage will not be welfare improving if the subsidy required is too high. This will be so when the level of income inequality (in our case this is the difference between y_R and y_T) is too high.

We are now in a position to specify the income range that will induce countries to independently support a system where universal coverage is ensured in both countries.

Proposition 1 *As long as* $y_R \in (y_R^*, \widetilde{y}_R)$, *the Subgame Perfect Nash Equilibrium subsidy pairs* (γ_1, γ_2) *is described by*

$$\gamma_1 + \gamma_2 = 2\gamma^C \text{ and } \gamma_i \leq \min\left\{\gamma^D, \gamma_{FC}^{\max}\right\} \quad for \quad i = 1, 2.$$

This set of SPNE subsidies will induce bilateral universal coverage.

Proof. To check for the SPNE, we construct the Best Response Function in subsidies for country 1. Country 2's Best Response Function will be similar. For country 1 for instance:
1. If $\gamma_{T2} < 2\gamma^C - \gamma_1^D$, the best response is to set γ_1 at γ_1^D as long as this results in positive welfare.

2. If $\gamma_2^D \geq \gamma_2 > 2\gamma^C - \gamma_1^D$, it is best to set $\gamma_1 = 2\gamma^C - \gamma_2$ to ensure full coverage as long as this results in positive welfare $\gamma_i < \gamma_{FC}^{\max}$.

3. If $\gamma_2 > \gamma_2^D$, the best response it to set $\gamma_1 = 2\gamma^C - \gamma_2^D$, otherwise country 1 would not be fully covered as long as this results in positive welfare, $\gamma_i < \gamma_{FC}^{\max}$. ■

The implication of this proposition is immediate: bilateral universal coverage can be implemented in a non cooperative environment. Note that full coverage in one country alone is not a SPNE. However, the interesting point to note is that the set of SPNE subsidy pairs involve both the same subsidy levels γ^C, the symmetric equilibrium, and different subsidy levels $\gamma_1 \neq \gamma_2$, the asymmetric equilibrium, even though the countries are symmetric in market sizes and income levels. Because full coverage in any one country makes the other country necessarily worse off compared to universal full coverage, each country attempts to ensure that it gives just enough subsidy, for any given subsidy of the other country, such that $\gamma_1 + \gamma_2 = 2\gamma^C$, and the MNC is induced to provide universal full coverage, provided of course $\gamma_i \leq \min\left\{\gamma^D, \gamma_{FC}^{\max}\right\}$. For example, if country i chooses $\gamma_i > \gamma^D$, country j being aware that only $\gamma_j \geq 2\gamma^C - \gamma_i^D$ would ensure universal full coverage and otherwise only country i market will be fully served making country j

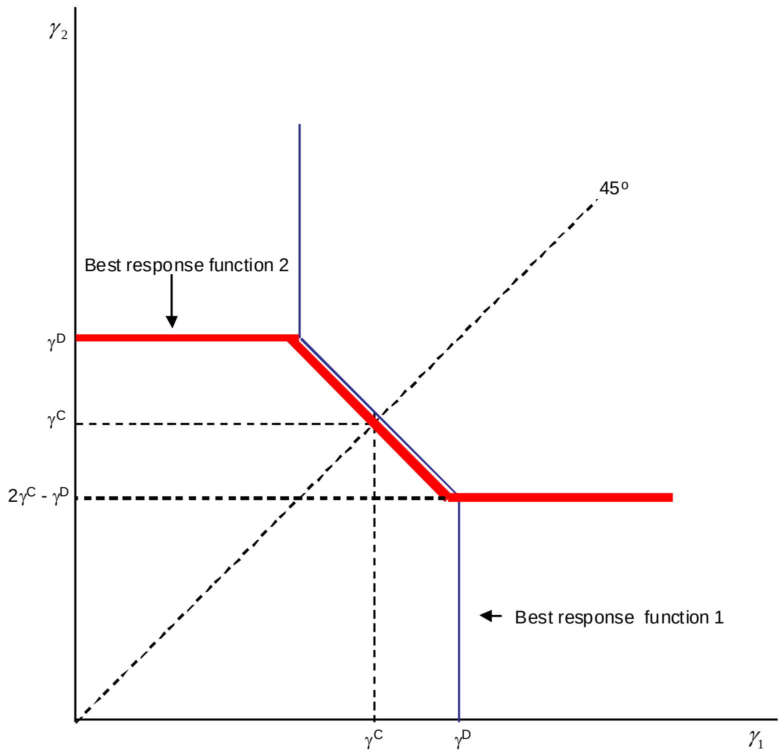

Figure 1: Government best response functions when international price discrimination is allowed and $\boldsymbol{\gamma}^D < \boldsymbol{\gamma}_{FC}^{\max}$.

worse-off, country j sets the minimum subsidy $\gamma_{Tj} = 2\gamma^C - \gamma_i^D$, provided of course, $\gamma_j = 2\gamma^C - \gamma_i^D < \gamma_{FC}^{\max}$. And since $\boldsymbol{\gamma}^D > \gamma^C \ \forall \ y_R > y_R^*$, $\gamma_j < \gamma_i$.

The best response functions when $\boldsymbol{\gamma}^D < \boldsymbol{\gamma}_{FC}^{\max}$ are illustrated in Figure 1, there, we can see the subsidy set that would implement bilateral universal coverage as all being the SPNE set of subsidies. As inequality increases we have that $\gamma^D > \gamma_{FC}^{\max}$ and the range of SPNE subsidies becomes a subset of the subsidies implementing bilateral universal coverage. Of course, it could be the case that none of the subsidy pairs that implement universal full coverage fulfill the positive welfare condition for both countries. This will depend on the income distribution. The following lemma defines the income range for which such subsidies result in positive welfare for both countries and are hence part of the SPNE subsidies.

Lemma 4 *The minimum common subsidy enforcing universal coverage* γ^C *is a SPNE subsidy pair as long as* $y_R \in (y_R^*, \widetilde{y}_R)$.

Proof. For this it is sufficient to note that $\gamma^C < \gamma^D < 2\gamma^C \ \forall \ y_R > y_R^*$, and by lemma 3, $\gamma^C < \gamma_{FC}^{\max} \ \forall \ y_R \in (y_R^*, \widetilde{y}_R)$. Hence the claim. □ ■

Interestingly the same income range supports different subsidy levels chosen by the two countries as SPNE. To see this note that as we had pointed out in lemma 3, $\gamma^{\max}(s_{FC})$ is larger than γ^C by a greater margin when actual y_R is closer to the lower limit of this income range, y_R^*. Similar is the case for the difference $(\gamma^D - \gamma^C)$. Hence, regardless of the condition whether $\gamma_{FC}^{\max}$ is smaller or larger than γ^D, we can conclude that $\gamma^C < \min\left\{\gamma^D, \boldsymbol{\gamma}_{FC}^{\max}\right\}$ for $y_R^* < y_R < \widetilde{y}_R$. There are other higher subsidies than γ^C which are less than $\min\left\{\gamma^D, \gamma_{FC}^{\max}\right\}$. The countries being symmetric, this means there exists (γ_1, γ_2) such that $\gamma^C < \gamma_i < \min\left\{\gamma^D, \gamma_{FC}^{\max}\right\}$ and $2\gamma^C - \gamma_i < \gamma_j < \gamma^C$. The line segment AB in Figure 2 is the focus of such SPNE subsidy pairs including the symmetric subsidy pair (γ^C, γ^C). Of course, higher is the value of y_R (within the above specified range), a smaller set of (γ_1, γ_2) will be SPNE. The line segment AB describing the set of SPNE subsidy pairs will converge to the mid-point E (such that $\gamma_1 = \gamma_2 = \gamma^C$) in such a case.

For $y_R > \widetilde{y}_R$, we there is an income range that would support unilateral coverage as a SPNE. Anywhere else in the income distribution, partial coverage every where will be the only SPNE outcome. The following Proposition makes a more precise statement.

Proposition 2 *There is an income range* $y_R \in (\widehat{y}_R, y_R^D)$, *where* $\widehat{y}_R > \widetilde{y}_R$, *in which there would be two possible SPNE each corresponding to unilateral coverage by each of the two countries.*

Proof. See Appendix. ■

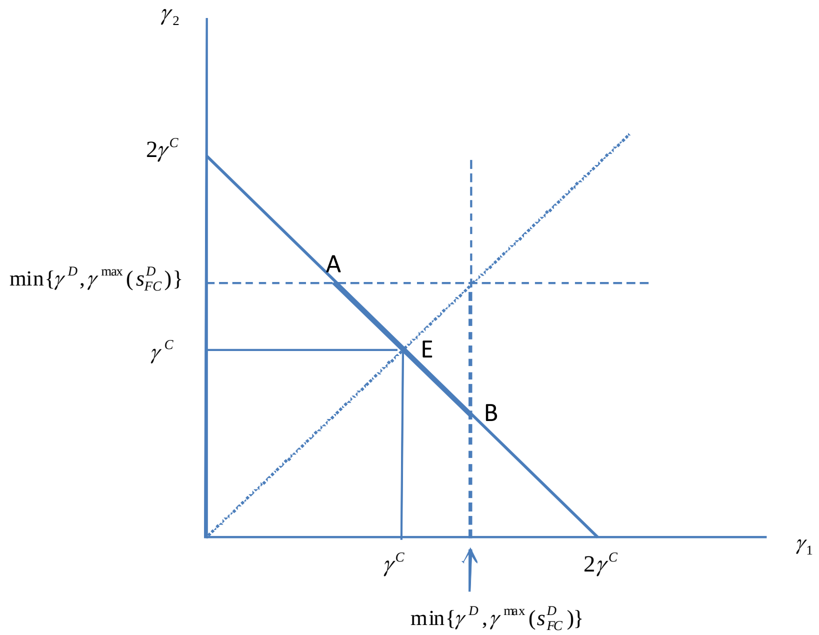

Figure 2: Example of SPNE subsidies for $y_R^* < y_R < \widetilde{y}_R$

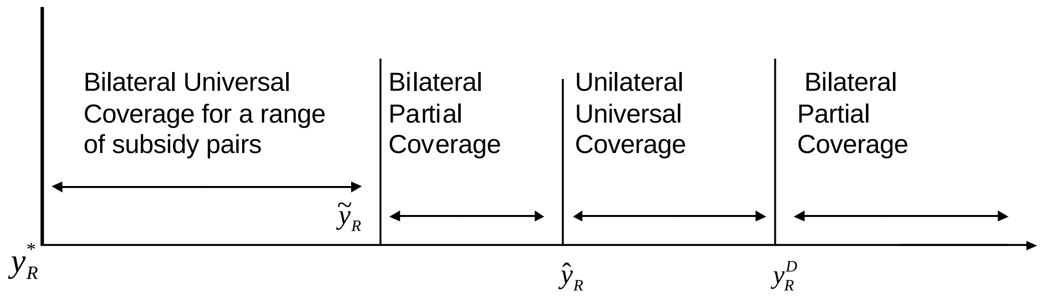

Figure 3: Coverage scenarios when international price discrimination is allowed.

Note that for incomes $y_R \in (\widetilde{y}_R, \widehat{y}_R)$ and $y_R > y_R^D$, the only SPNE outcome will be for none of the countries to provide subsidies resulting in partial coverage.

From the above results we can conclude that depending on the level of within country inequality we can have different coverage scenarios as the SPNE. These are summarized in Figure 3. First, for relatively low within country inequality, $y_R \in (y_R^*, \widetilde{y}_R)$, there is a range of SPNE subsidies all implementing bilateral universal coverage. As inequality grows, bilateral partial coverage becomes the unique SPNE coverage result, as both countries find it welfare decreasing to provide even the minimum subsidy that would implement bilateral full coverage. However, for an even higher level of inequality $y_R \in (\widehat{y}_R, y_R^D)$, we find that asymmetric health systems (in terms of their universal coverage provision) arise as a result of the SPNE subsidies (even though countries are ex-ante symmetric in all respects). The intuitive reason behind this result is that even though bilateral universal coverage is welfare decreasing at this point even for the lowest possible unilateral subsidy that implements it, unilateral universal coverage is still welfare improving since quality is higher and that can overcompensate for a very large subsidy required to implement unilateral universal coverage. However, as the inequality becomes even higher not even unilateral universal coverage can arise and we are left with bilateral partial coverage.[6]

3.2 International price discrimination not allowed

We now consider the situation where price discrimination across countries is not possible possibly due to the allowance of parallel imports. As in the

[6]As already stated, for richer group income lower that y_R^*, bilateral universal coverage would happen without the need of subsidies.

previous sections, we have three possible quality levels depending on the extent of market coverage in the two countries. However, it is easy to check that the profit-maximizing innovation level and quality choices remain the same as before the bilateral universal coverage and bilateral partial coverage cases. However, things change for the case of unilateral universal coverage. International price arbitrage will force the MNC to charge the same price in country 2 (say) as in country 1 even when it fully covers only say only country 1's market. Had price discrimination been allowed, as in the previous subsection, the MNC would charge $y_T s + \gamma_{T1}$ in country 1 and $y_R s$ in country 2 for any given quality. But, if price discrimination is not allowed, the MNC is forced to charge $y_T s + \gamma_{T1}$ everywhere. Hence, in the case when it is not profit-maximizing for the MNC to fully cover say country 2 market, the optimal quality will be the one that maximizes:

$$\pi_{FC1} = (2n_R + n_T)(y_T s + \gamma_1) - \frac{1}{2}s^2, \tag{17}$$

that is,

$$s_{FC1}^{ND} = s_{FC2}^{ND} = (2n_R + n_T)\, y_T. \tag{18}$$

Note that the full coverage everywhere and partial coverage qualities remain the same as in the previous section s_{FC} and s_{PC} (see equation (8)). Comparing equation (18) with equation (6) and (7), it follows that $s_{FC1}^{ND} = s_{FC2}^{ND} < s_{FC}$, and $s_{FC1}^{ND} < s_{FC1}^{D}$. We can now state the following lemma,

Lemma 5 *When price discrimination is not allowed and only country i's market is fully served, the MNC chooses a lower innovation level than when price discrimination is allowed. Moreover, unlike in the price discrimination case, this quality level is least compared to the quality levels under bilateral universal and bilateral partial coverage.*

Proof. This follows from the above discussion. ■

Note that since both countries share the same income distribution, the subsidy the ensures that the firm prefers bilateral universal coverage to bilateral partial coverage remains the same as in the previous section, γ^C. On the other hand, the subsidy that ensures universal coverage in country 1 when the subsidy in country 2 is not enough to cover all must satisfy the following constraint:

$$(2n_R + n_T)\left(y_T s_{FC1}^{ND} + \gamma\right) - \frac{1}{2}\left(s_{FC_1}^{ND}\right)^2 \geq 2n_R y_R s_{PC} - \frac{1}{2}\left(s_{PC}\right)^2.$$

The strict equality yields a minimum subsidy:

$$\gamma^{ND} = \frac{(2n_R y_R)^2 - ((2n_R + n_T) y_T)^2}{2(2n_R + n_T)}. \tag{19}$$

Note that $\gamma^{ND} > \gamma^C$. Hence, since $s_{FC1}^{ND} < s_{FC}$, the condition that ensures positive welfare when both countries set subsidy γ^C is not sufficient to ensure positive welfare for country 1 when they alone implement full coverage at γ^{ND}. Recall that $W^{FC} > 0$ for $\forall\ y_R \in (y_R^*, \widetilde{y}_R)$, this contrasts with the results in the previous section. Note that

$$W_1^{FC1} > 0 \Longleftrightarrow W_1^{FC1} = n_R \left(y_R s_{FC1}^{ND} - \left(y_T s_{FC1}^{ND} + \gamma^{ND} \right) \right) - n_T \gamma^{ND} > 0 \tag{20}$$

Note that $\frac{\partial W_1^{FC1}}{\partial y_R} < 0\ \forall\ y_R > y_R^*$, hence the highest root to the above equation will indicate the relevant condition for income range resulting in positive welfare. This is equivalent to

$$\frac{2(n_R)^2}{2n_R + n_T}(y_R)^2 - \frac{(2n_R + n_T) y_T n_R}{n_R + n_T} y_R + (2n_R + n_T)(y_T)^2 \left[\frac{n_R - n_T}{2(n_R + n_T)} \right] = 0.$$

and the relevant root is then

$$y_R^{ND} = \frac{(2n_R + n_T) y_T \left[(2n_R + n_T) + \sqrt{(4n_R + 5n_T) n_T} \right]}{4n_R (n_R + n_T)}.$$

It is straightforward to check that $\widetilde{y}_R > y_R^{ND}$. We can now state the following proposition.

Proposition 3 *When price discrimination is not allowed, the unique SPNE is for both countries to set* γ^C *as long as* $y_R \in \left(y_R^*, y_R^{ND}\right)$*. However, if* $y_R \in \left(y_R^{ND}, \widetilde{y}_R\right)$*, we have an additional SPNE in which none of the countries implement full coverage. Finally, when* $y_R > \widetilde{y}_R$*, bilateral partial coverage will be the unique SPNE.*

Proof. See Appendix. ■

The intuition behind the second SPNE now inducing bilateral partial coverage is that unlike the case in the previous section, the income range that supports positive welfare for unilateral coverage is smaller than the income range that supports bilateral universal coverage leading to positive welfare. The quality comparison stated in lemma 5 explains this.

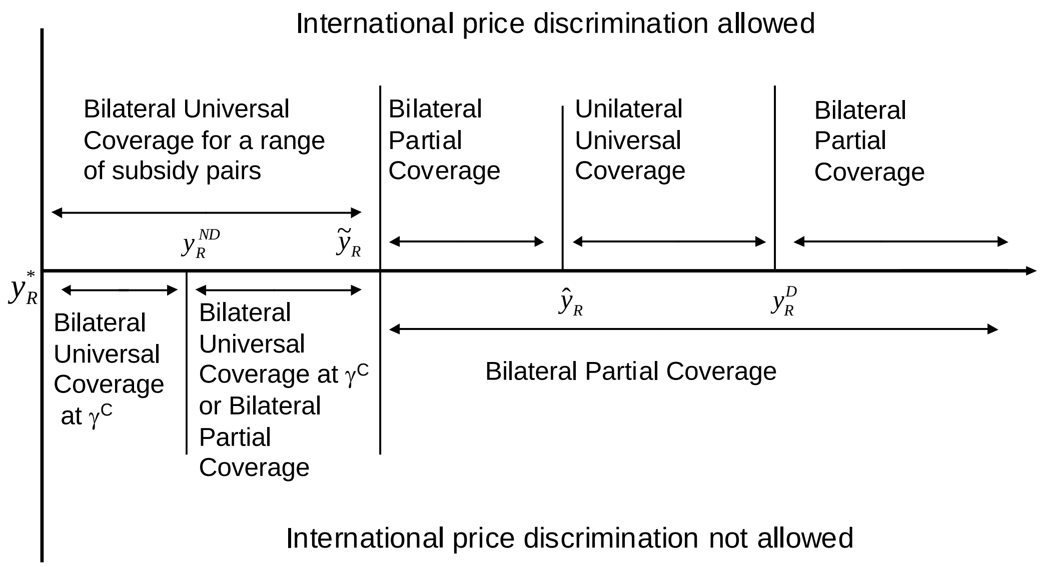

Figure 4: Impact of not allowing international price discrimination on universal coverage.

To conclude this section we can first reflect on the impact of inequality on universal coverage when international price discrimination is not allowed. For relatively low levels of inequality, $y_R \in \left(y_R^*, y_R^{ND}\right)$, there is a unique SPNE unique subsidy which results in bilateral universal coverage. A income inequality raises though $y_R \in \left(y_R^{ND}, \widetilde{y}_R\right)$, the bilateral partial coverage arises as an alternative SPNE outcome, and indeed this becomes the unique SPNE for sufficiently high inequality $y_R > \widetilde{y}_R$.

We are now in a position to compare the results of the two sections and hence assess the impact of ability of the MNC to price discriminate across countries on the coverage scenarios. Figure 4 will assist us in such comparison.

First of all, we can observe that unilateral universal coverage is never an equilibrium outcome when price discrimination is not allowed, but it becomes a possible SPNE when international price discrimination is possible even though countries are ex ante symmetric. Second, bilateral universal coverage can be ensured only by the common minimum subsidy γ^C offered by the two governments when price discrimination is not allowed. However, when price discrimination is allowed, there is a set of SPNE subsidy pairs which ensures bilateral universal coverage. That is, only under parallel imports, we have unique SPNE subsidy pair that ensures universal full market coverage. And looking at the whole income range we can also say that achieving bilateral universal coverage or even unilateral universal coverage becomes less likely when international price discrimination is not possible.

4 Conclusions

One of the defining characteristics of a health system is its level of provision of universal access to health care. In this paper, we have investigated how the interaction between health systems may influence both their provision of universal access to health innovations and the level of quality that any MNC is willing to provide. Using a simple model of vertical differentiation where countries are ex ante identical in all ways, there is within country income inequality among consumers but, income distributions are the same across countries. We aim to capture the strategic interactions between similar governments choosing their provision of universal coverage and the health innovator. We obtain a number of interesting results. First, we find that the MNC's ability to implement international price discrimination only affects the level of quality provision when unilateral universal coverage is preferred by the firm, as in that case, quality is higher when international price discrimination is feasible and indeed higher than the quality provided when bilateral universal coverage is preferred by the firm. Second, we find that whether countries provide universal coverage or not will depend crucially on the level of intra-country inequality. When international price discrimination is not possible, more inequality leads to less likely provision of universal coverage. However, and interestingly, when price discrimination is allowed increase in inequality may actually lead to a higher chance of universal coverage by a country alone. Indeed, we show that when international price discrimination is possible, asymmetric health systems (in their provision of universal coverage) may be supported by the SPNE price subsidies even when countries are ex-ante completely symmetric. Finally, our results show that universal coverage arises under a wider range inequality levels and price subsidy pairs when international price discrimination is possible. When this is not the case, under some income ranges bilateral universal coverage can be supported by SPNE subsidies together with bilateral partial provision, country coordination of the Pareto optimum equilibrium becomes an issue for policy makers.

Relaxing the assumption of same income distribution by allowing different income across countries for the rich group would not change our results significantly as long as income distributions are not allowed to differ too much. Also, even if we assign the profits of the MNC to anyone country the results will remain the same, this may change if we allow for the existence of two firms competing for the international market each placed in a different country, as this would open the door to using the subsidy policy as a strategic trade policy, this is an issue we intend to explore in future research.

References

[1] Acharyya, R. (2005) Quality discrimination among income constrained consumers, *Economic Letters,* 86, 245-251.

[2] Acharyya, R. and García-Alonso, M.D.C. (2008) Parallel imports, innovations and national welfare: role of the sizes of the income classes and national markets for health care, *Singapore Economic Review*, 53(1): 1-23 .

[3] Acharyya, R. and García-Alonso, M.D.C. (2006) Self-interested motives for international income redistribution and access to health care innovation, *European Journal of Political Economy*, 22, 2, 322-336.

[4] Felder, S. (2004) Drug price regulation under consumer moral hazard: Two-part tariffs, uniform price, or third-degree price discrimination, *European Journal of Health Economics*, 49, 324-329.

[5] Felder, S. (2006) Third-degree price discrimination in the presence of subsidies, *German Economic Review*, 7, 419-426.

[6] García-Alonso, M.D.C. and García-Mariñoso, B. (2008) The strategic interaction between firms and formulary committees: effects on the prices of new drugs, *Journal of Health Economics*, 27, 2, 377-404.

[7] Ganslandt, M. and Maskus, K.E. (2007) Intellectual property rights, parallel imports and strategic behavior, *IFN working paper*, 704.

[8] Garber, A.M., Jones, C.I. and Romer, P.M. (2006) Insurance and incentives for medical innovation, NBER working paper 12080.

[9] Grossman, G. and Lai, E.L.C. (2004) International protection of intellectual property, *American Economic Review* 94, 1635-1653.

[10] Jelovac, I. and C. Bordoy (2005) Pricing and welfare implications of parallel imports in the pharmaceuticals industry, *International Journal of Health Care Finance and Economics*, 5, 5-21.

5 Appendix

5.1 Proof of Lemma 3

Note that

(a) A pair of subsidy (γ_1, γ_2) which ensures bilateral universal coverage results in positive welfare for country i if,

$$W_i(\gamma_1, \gamma_2) = n_R(y_R s_{FC} - P_i) + n_T(y_T s_{FC} - P_i) > 0$$

$$\Longleftrightarrow n_R(y_R s_{FC} - (y_T s_{FC} + \boldsymbol{\gamma}_i)) + n_T(y_T s_{FC} - (y_T s_{FC} + \gamma_i)) > 0$$

Note that a requirement for the above to be positive is that the MNC fixes a price below that of the reservation price of the individuals in the wealthy group.

$$\Leftrightarrow \gamma_{FC}^{\max} = 2n_R(y_R - y_T)y_T > \gamma_i.$$

(b) Condition $\gamma^C < \gamma_{FC}^{\max}$ corresponds to an income range $y_R \in (y_R^*, \ \widetilde{y}_R)$ where y_R^* is as defined in equation (4) and $\widetilde{y}_R$ is the critical income defined in (16) above that would make γ^C exactly equal to $\boldsymbol{\gamma}_{FC}^{\max}$. Note that

$$\gamma^C = \gamma_{FC}^{\max} = 2n_R(y_R - y_T)y_T \Longleftrightarrow$$

$$(n_R y_R)^2 - 2n_R(n_R + n_T)y_R y_T + (n_R - n_T)(n_R + n_T)(y_T)^2 = 0.$$

The above is a convex function with roots

$$y_R = \frac{y_T(n_R + n_T) \pm y_T\sqrt{2n_T(n_R + n_T)}}{n_R}.$$

Of the two roots found, it can be easily proved that the higher root is higher than y_R^*, whereas the lower root is smaller, i.e.,

$$\frac{(n_R + n_T)y_T - y_T\sqrt{(n_R + n_T)2n_T}}{n_R} < y_R^* < \widetilde{y}_R = y_T\frac{(n_R + n_T) + \sqrt{(n_R + n_T)2n_T}}{n_R}.$$

Moreover, since $\frac{\partial\left[\gamma^C < \boldsymbol{\gamma}_{FC}^{\max}\right]}{\partial y_R} > 0$, so we have $\gamma^C < \gamma_{FC}^{\max}\ \forall\ y_R \in (y_R^*, \ \widetilde{y}_R)$, with $\gamma_{FC}^{\max}$ being larger and larger (smaller and smaller) than γ^C as y_R is closer to the lower (higher) limit. Hence the claim.

5.2 Proof of Proposition 2

Note that the condition for positive welfare under unilateral coverage is weaker than such condition for full coverage even at minimum possible subsidy $\left(2\gamma^{C}-\gamma^{D}\right)$, so we may find an income range for which the welfare of the country providing unilateral coverage is positive $W_1^{FC1} > 0$, but the welfare of the other country if it ensured full coverage when the other country sets subsidy γ^D is negative $W_1^{FC}\left(\gamma_1 = 2\gamma^C - \gamma^D\right) < 0$. This would then enable the possibility of unilateral coverage being a SPNE. To see this, we first prove note that

$$W_1^{FC}\left(\gamma_1 = 2\gamma^C - \gamma^D\right) < W_1^{FC1}$$

Substituting

$$W_1^{FC}\left(\gamma_1 = 2\gamma^C - \gamma^D\right) = n_R\left(y_R - y_T\right)s_{FC}^D - \left(n_R + n_T\right)\left(2\gamma^C - \gamma^D\right)$$

and

$$W_1^{FC1} = n_R\left(y_R - y_T\right)s_{FC1}^D - \left(n_R + n_T\right)\gamma^D$$

We obtain that $W_1^{FC}\left(\gamma_1 = 2\gamma^C - \gamma^D\right) < W_1^{FC1} \Longleftrightarrow$

$$n_R\left(y_R - y_T\right)s_{FC}^D - 2\left(n_R + n_T\right)\gamma^C < n_R\left(y_R - y_T\right)s_{FC1}^D - 2\left(n_R + n_T\right)\gamma_T^D \Longleftrightarrow$$

$$2\left(n_R + n_T\right)\left(\gamma^D - \gamma^C\right) < n_R\left(y_R - y_T\right)\left(s_{FC1}^D - s_{FC}^D\right) \Longleftrightarrow$$

$$2\left(\tfrac{4n_R^2y_R^2 - [(n_R+n_T)y_T + n_Ry_R]^2}{2} - \left(n_R^2y_R^2 - \left(n_R + n_T\right)^2 y_T^2\right)\right) <$$

$$n_R\left(y_R - y_T\right)\left(\left(n_R + n_T\right)y_T + n_Ry_R - 2\left(n_R + n_T\right)y_T\right) \Longleftrightarrow$$

$$2n_R^2y_R^2 + 2\left(n_R + n_T\right)^2 y_T^2 - \left[\left(n_R + n_T\right)y_T + n_Ry_R\right]^2 <$$
$$n_R\left(y_R - y_T\right)\left(n_Ry_R - \left(n_R + n_T\right)y_T\right) \Longleftrightarrow$$

$$n_R^2y_R^2 + \left(\left(n_R + n_T\right)y_T\right)^2 - 2\left(n_R + n_T\right)y_T n_R y_R <$$
$$n_R\left(y_R - y_T\right)\left(n_Ry_R - \left(n_R + n_T\right)y_T\right) \Longleftrightarrow$$
$$\left(n_Ry_R - \left(n_R + n_T\right)y_T\right)^2 < n_R\left(y_R - y_T\right)\left(n_Ry_R - \left(n_R + n_T\right)y_T\right) \Longleftrightarrow$$

$$\left(n_Ry_R - \left(n_R + n_T\right)y_T\right) < n_R\left(y_R - y_T\right).$$

Hence, $W_1^{FC} < W_1^{FC1}$. Now, to identify the income range for which $W_1^{FC}\left(\gamma_1 = 2\gamma^C - \gamma^D\right) < 0$ but $W_1^{FC1} > 0$, we need to find the roots to $W_1^{FC1} = 0$ and $W_1^{FC}\left(\gamma_1 = 2\gamma^C - \gamma^D\right) = 0$.

We already know the root of the first, which we denote y_R^D is going to be above $\widetilde{y}_R$ and also above the root of the second, which we denote $\widehat{y}_R$ (itself above $\widetilde{y}_R$). If $y_R \in (\widehat{y}_R, y_R^D)$, we will have two possible SPNE consisting of the two possible unilateral coverage situations.

We first obtain y_R^D :

$$W_1^{FC1} = n_R (y_R - y_T) s_{FC1}^D - (n_R + n_T) \gamma_T^D > 0 \Leftrightarrow$$

$$n_R (y_R - y_T) ((n_R + n_T) y_T + n_R y_R) -$$
$$- (n_R + n_T) \frac{(2n_R y_R)^2 - ((n_R + n_T) y_T + n_R y_R)^2}{2 (n_R + n_T)} > 0 \Leftrightarrow - (n_R)^2 (y_R)^2 +$$

$$[(n_R + 2n_T) 2y_T n_R] y_R + (n_T - n_R) (n_R + n_T) (y_T)^2 > 0.$$

We take the highest root:

$$y_R = \frac{-((n_R+2n_T)2y_T n_R) - \sqrt{((n_R+2n_T)2y_T n_R)^2 + 4(n_R)^2 [n_T - n_R] y_T (n_R+n_T) y_T}}{-2n_R^2} =$$

$$y_R^D = \frac{y_T \left(n_R + 2n_T + \sqrt{(5n_T + 4n_R) n_T}\right)}{n_R}.$$

Note that the smallest root is bellow y_R^*, hence we can say that for $y_R < y_R^D$, $W_1^{FC1} > 0$. Next we obtain $\widehat{y}_R$

$$W_1^{FC} \left(\gamma_1 = 2\gamma^C - \gamma^D\right) = n_R (y_R - y_T) s_{FC}^D - (n_R + n_T) \left(2\gamma^C - \gamma^D\right) < 0$$

$$n_R (y_R - y_T) 2 (n_R + n_T) y_T - (n_R + n_T) \left(\frac{((n_R+n_T)y_T + n_R y_R)^2 - (2(n_R+n_T)y_T)^2}{2(n_R+n_T)}\right) < 0,$$

$$4n_R (y_R - y_T) (n_R + n_T) y_T - ((n_R + n_T) y_T + n_R y_R)^2 + (2 (n_R + n_T) y_T)^2 < 0,$$

$$\left[- (n_R)^2\right] (y_R)^2 + [2n_R (n_R + n_T) y_T] y_R + \left[(3n_T - n_R) (n_R + n_T) (y_T)^2\right] < 0.$$

We take the highest root:

$$y_R = \frac{2n_R(n_R+n_T)y_T + 2n_R y_T \sqrt{(n_R+n_T)^2 + [(3n_T - n_R)(n_R+n_T)]}}{2(n_R)^2} =$$

$$\widehat{y}_R = \frac{y_T \left((n_R + n_T) + 2\sqrt{(n_R + n_T) n_T}\right)}{n_R}.$$

Note that the smallest root is bellow y_R^*, hence we can say that for $y_R > \widehat{y}_R$, $W_1^{FC}\left(\gamma_1 = 2\gamma^C - \gamma^D\right) < 0$.

Finally note that $y_R^D > \widehat{y}_R$ since

$$y_R^D > \widehat{y}_R \Leftrightarrow \frac{y_T\left(n_R+2n_T+\sqrt{(5n_T+4n_R)n_T}\right)}{n_R} > \frac{(n_R+n_T)y_T+2y_T\sqrt{(n_R+n_T)n_T}}{n_R}.$$

Also, $\widehat{y}_R > \widetilde{y}_R$ since

$$\widehat{y}_R > \widetilde{y}_R \Leftrightarrow \frac{(n_R+n_T)y_T+2y_T\sqrt{(n_R+n_T)n_T}}{n_R} > \frac{(n_R+n_T)y_T+y_T\sqrt{(n_R+n_T)2n_T}}{n_R}.$$

We can then conclude that there is an income range $y_R \in (\widehat{y}_R, y_R^D)$, where $\widehat{y}_R > \widetilde{y}_R$, in which there would be two possible SPNE each corresponding to unilateral coverage by each of the two countries.

5.3 Proof of Proposition 3

Once again, we construct the Best Response Function in subsidies for country 1 (country 2's will be symmetric). There are three main cases:

(a) If $\gamma_2 < \gamma^C$, the optimal response is to set $\gamma_1 = \gamma^{ND}$ this is the minimum subsidy at which universal coverage in country 1 is ensured, which increases welfare as long as $y_R \in \left(y_R^*, y_R^{ND}\right)$, a higher subsidy would not be an optimal response as it would just increase the price without affecting quality. Note however that it may be the case that welfare at γ^{ND} is negative, in such case, the best response would be to set no or low subsidy and stay at partial coverage. If $y_R > y_R^{ND}$, the best response will be to provide no subsidy.

(b) If $\gamma_2 = \gamma^C$, the optimal response is to set $\gamma_1 = \gamma^C$ as long as $y_R \in (y_R^*, \widetilde{y}_R)$. A lower subsidy would not ensure universal coverage, at higher one would just have a positive impact on prices (strictly positive if $\gamma_1 > \gamma^{ND}$). Note that responding to $\gamma_2 = \gamma^C$, with a subsidy $\gamma^{ND} > \gamma_1 > \gamma^C$ will have no impact on producer prices or quality. However, responding with a subsidy $\gamma_1 = \gamma^{ND}$, will actually affect quality and prices. Since $\gamma^C < \gamma^{ND}$, this will have a direct positive impact on prices. However, quality will be lower since $s_{FC1} = (2n_R + n_T)\, y_T < s_{FC} = 2\,(n_R + n_T)\, y_T$. Further increases in the subsidy will not affect quality and will just directly increase prices (although this is due to the fact that we have a specific subsidy in our model).

(c) If $\gamma^C < \gamma_{T2} < \gamma^{ND}$, the optimal response is to set γ^C, as lower subsidy would not ensure universal coverage and a higher one would just increase prices in both countries (note that in this case it is still γ^C that

determines prices). Just remember that welfare for universal coverage under no discrimination is (γ here will be the lowest of the two countries' subsidies)

$$W_1^{FC} = n_R\left(y_R s - (y_T s + \gamma)\right) + n_T\left(y_T s - (y_T s + \gamma_T)\right) = n_R\left(y_R s - y_T s - \gamma\right) - n_T \gamma.$$

in case 3, the firm will take γ_1 as price determinant as long as $\gamma_1 < \gamma_2$, matching γ_2 will not affect quality, it will just increase prices and setting γ^{ND}, as already discussed, is not better response than γ^C.

(d) If $\gamma_{T2} = \gamma^{ND}$, the are two candidates for best response, either $\gamma_1 = \gamma^C$, which would implement universal coverage and result in welfare W_1^{FC}, or any $\gamma_1 < \gamma^C$, which would result in only country 2 being fully covered, welfare for country 1 would then be:

$$W_1^{FC2} = n_R\left(\left(y_R - y_T\right) s_{FC2}^{ND} - \gamma^{ND}\right) > W_1^{PC} = 0.$$

We must then compare W_1^{FC2} and W_1^{FC} to obtain the best response to $\gamma_2 = \gamma^{ND}$. It is possible to prove that the income range for which $W_1^{FC2} > W_1^{FC}$ falls outside the income range for which $W_2^{FC2} > W^{PC}$, hence, this will not be part of the SPNE subsidy pairs. We proof this below

$$W_1^{FC} - W_1^{FC2} = n_R\left(\left(y_R - y_T\right) s_{FC} - \gamma^C\right) - n_T\gamma^C - n_R\left(\left(y_R - y_T\right) s_{FC2}^{ND} - \gamma^{ND}\right) =$$

$$= \left[s_{FC} - s_{FC2}^{ND}\right] n_R\left(y_R - y_T\right) - \left(n_R + n_T\right)\gamma_T^C - n_R\gamma_T^{ND} =$$

$$= n_T y_T n_R\left(y_R - y_T\right) - \left(n_R + n_T\right)\frac{\left(n_R y_R\right)^2 - \left(\left(n_R + n_T\right) y_T\right)^2}{n_R + n_T} + n_R\frac{\left(2n_R y_R\right)^2 - \left(\left(2n_R + n_T\right) y_T\right)^2}{2\left(2n_R + n_T\right)} =$$

$$= \frac{2n_T n_R(2n_R+n_T)(y_R y_T - y_T^2) - 2n_R^2(2n_R+n_T)y_R^2 + 2(2n_R+n_T)(n_R+n_T)^2 y_T^2 + 4n_R^3 y_R^2 - n_R(2n_R+n_T)^2 y_T^2}{2(2n_R+n_T)} =$$

$$= \frac{-2n_R^2 n_T y_R^2 + 2n_T n_R(2n_R+n_T)y_R y_T + n_T(2n_T+n_R)(2n_R+n_T)y_T^2}{2(2n_R+n_T)}.$$

Let $\overline{\overline{y}}_R$ be the critical value for which $W_1^{FC} = W_1^{FC2}$. Note that $\dfrac{\partial\left[W_1^{FC} - W_1^{FC2}\right]}{\partial y_R} < 0 \ \forall \ y_R > y_R^*$. $\overline{\overline{y}}_R$ has two roots and the higher root $\frac{(2n_R+n_T)y_T + y_T\sqrt{(2n_R+n_T)(4n_R+5n_T)}}{2n_R}$ falls in the relevant range, i.e., $\overline{\overline{y}}_R = \frac{(2n_R+n_T)y_T + y_T\sqrt{(2n_R+n_T)(4n_R+5n_T)}}{2n_R} > y_R^*$. Hence, $W_1^{FC} > W_1^{FC2} \ \forall \ y_R \in [y_R^*, \overline{\overline{y}}_R]$.

It is also possible to check that $\overline{\overline{y}}_R > y_R^{ND}$.Hence, for the income range $y_R \in [y_R^*, y_R^{ND}]$, $W_1^{FC} > W_1^{FC2}$. Hence,this case will not be part of the SPNE.

(e) If $\gamma^{ND} < \gamma_2$, γ^C will not be enough to ensure universal coverage in country 1 as prices will now be determined by γ_2, this can be seen in the inequality below that holds for $\gamma^{ND} < \gamma_2$ and $\gamma_1 = \gamma^C$

$$2(n_R + n_T)(y_T s_{FC} + \gamma_1) - \frac{1}{2}(s_{FC})^2 \leq (2n_R + n_T)\left(y_T s_{FC2}^{ND} + \gamma_2\right) - \frac{1}{2}\left(s_{FC2}^{ND}\right)^2$$

Hence, to ensure universal coverage in country 1, γ_{T1} must be such that

$$2\left(n_R + n_T\right)\left(y_T s_{FC} + \gamma_1\right) - \frac{1}{2}\left(s_{FC}\right)^2 \geq \left(2n_R + n_T\right)\left(y_T s_{FC2}^{ND} + \gamma_2\right) - \frac{1}{2}\left(s_{FC2}^{ND}\right)^2 \Leftrightarrow$$

$$\left[2\left(n_R + n_T\right) y_T - \tfrac{1}{2} s_{FC}\right] s_{FC} + 2\left(n_R + n_T\right)\gamma_1 >$$
$$> \left(\left(2n_R + n_T\right) y_T - \tfrac{1}{2} s_{FC2}^{ND}\right) s_{FC2}^{ND} + \left(2n_R + n_T\right)\gamma_2 \Leftrightarrow$$

$$\Leftrightarrow \gamma_1 > \tfrac{1}{2}\frac{\left(\left(2n_R + n_T\right) y_T\right)^2 - \left(2\left(n_R + n_T\right) y_T\right)^2}{2\left(n_R + n_T\right)} + \frac{\left(2n_R + n_T\right)}{2\left(n_R + n_T\right)}\gamma_2 \Leftrightarrow$$
$$\gamma_1 > -\frac{1}{2}\frac{4n_R + 3n_T}{2\left(n_R + n_T\right)} n_T \left(y_T\right)^2 + \frac{2n_R + n_T}{2\left(n_R + n_T\right)}\gamma_2.$$

The subsidy that ensures universal coverage ex ante in this case is to set γ_1 as above. However, it might be better to just set a lower or no subsidy resulting in country 2 alone providing full coverage along the lines of the statement in point 4. However this part of the best response function will not be part of a SPNE as it will never be the best response to this for country 2 to set a $\gamma^{ND} < \gamma_2$.