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Universal access, parallel trade and incentives to innovate*

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Abstract

Governments often subsidize poorer groups in society to ensure their access to new drugs. We analyze the optimal income-based price subsidies in a strategic environment. We show that universal access is less likely to arise when price arbitrage prevents international price discrimination. When this is not the case, under some income ranges, bilateral universal coverage can be supported by equilibrium subsidies together with bilateral partial provision. In such a case, international health policy coordination becomes relevant. We also show that asymmetric universal access to medicines across countries can arise, even when countries are ex-ante symmetric, when international price discrimination is possible and governments cannot design subsidies proportional to either income or quality.

JEL Classification: D4, L1, I1.

Keywords: Health systems; Pharmaceuticals; Innovation; Income Based Subsidies; Price Discrimination

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1 Introduction

A consistent feature of most health care systems among developed countries is the availability of either payment exemptions or co-payment reduction for groups who might have difficulty facing the cost of their medication. Among the causes are low income, although age and disability are also considered.[1] In June, 2006, the Council of the European Union (EU) stated that the overarching values in EU Health Systems should be 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 countries aim to cooperate in the design of their health systems, a question immediately arises. Will such cooperation lead to higher welfare gains in the context of more integrated markets? The aspect of health systems we focus on in this paper refers to the provision of universal access to pharmaceutical innovations. We study the interaction between governments of similar countries choosing their provision of an income-based price subsidy for pharmaceuticals that would allow universal health access to drug innovations, which we will refer to as universal coverage. Second, we examine the impact of such subsidies on drug innovation and prices. Finally, we 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. By addressing these issues, this paper constitutes a first stepping stone in the analysis of the benefits that may accrue from international coordination in the design of health systems across similar countries.

Both parallel imports (PI) and external referencing can limit the ability of firms to implement international price discrimination. A useful early survey of issues related to PI can be found in Maskus (2001) and Ganslandt and Maskus (2007). Two papers that discuss implications of PI are Richardson (2002) and Malueg and Schwartz (1994). With no within-country income disparity, Richardson (2002) established that when the poor countries are unable to restrict PI, the richer countries undo price discrimination by a patent holder MNC by allowing PI of the patented drug from low-priced poor countries. In an earlier analysis, Malueg and Schwartz (1994) demonstrated that global welfare under discriminatory pricing is lower than that under uniform pricing (as a consequence of PI being allowed by the richer countries)

[1] See http://www.scotland.gov.uk/Resource/Doc/92240/0022048.pdf for a reasonably comprehensive country comparison. Examples of such policies are for instance Medicare Plan D in the United States or prescription charge exemptions in the United Kingdom.

for small cross-country demand dispersions, but, it is higher for very large dispersions because some markets are not served under uniform pricing. Regarding the impact of PI on firms' incentives to innovate, the literature generally concludes that PI reduce such incentives [see e.g., Szymanski and Valletti (2005), Valletti (2006) and Valletti and Szymanski (2006)]. But, as Ganslandt and Maskus (2007) point out, an under-researched branch of such literature is the design of price regulation and its effects on firms' decisions. Ganslandt and Maskus (2007) use a dynamic general equilibrium model to analyze the impact of price controls on the firm's incentives to innovate. On the other hand, Jelovac and Bordoy (2005) construct a model of optimal pricing of pharmaceuticals and PI with exogenous quality.[2] However, they do not consider income heterogeneity across patients. The heterogeneity comes entirely from the valuation of the pharmaceutical innovation in terms of its efficacy being different for each patient.

In contrast to these analyses, and the existing literature on price subsidies and regulations in the health care market, this paper focuses on income heterogeneity of buyers within each country, which is prevalent in developing and developed countries alike. Income heterogeneity within each country has two implications in our model. First, it creates scope for the national governments to provide income-based price subsidies. Second, facing income disparity among the potential buyers of a drug, the patent-holder MNC may not find it optimal to cater to the poor buyers in a country. In such an event, income-based price subsidies can ensure market access for the poor. This dimension of the subsidy policy that is brought out by the heterogeneous buyers considered here has remained less explored. In a recent empirical paper, Danzon et al. (2011) prove that within country income dispersion has an impact on pharmaceutical prices, especially in low and middle income countries with less evolved social security. Government policy choice to ensure market access to health care innovation for poorer patients has been analyzed in two recent papers elsewhere [Acharyya and García-Alonso (2011, 2012)]. In both these papers, strategic policy interactions between two national governments are considered, but the general concerns are altogether different from those of the present paper, as the focus was on the interaction between ex ante asymmetric countries in their income distributions, their ability to innovate and ability to commit to policy. In Acharyya and García-Alonso (2011), the efficiency issue of implementing Trade-Related Aspects of Intellectual Property Rights (TRIPS) agreement and at the same time allowing countries to set their own rules for international exhaustion of

[2] Felder (2004) and Felder (2006) also study price regulation in the presence of price discrimination across markets.

patent rights was examined. A poorer country chooses whether to enforce an International Patent Regime or not, and the richer country chooses whether to allow PI of on-patent drugs or market-based discrimination by the patent holder pharmaceutical multinational firm. In Acharyya and García-Alonso (2012), on the other hand, the policy options for the national governments that are considered are whether to allow PI of a patented drug and whether to provide an income-based price subsidy to the poorer buyers of the drug. Two major issues were addressed in the context of exogenously given innovation level of a health drug. First, what are the optimal national policies on universal access to health care – PI or subsidy or a combination of both – and second, whether the ability of the poorer country to allow PI changes the optimal policy of the richer country. In contrast to the ex ante asymmetry of countries in these papers, the present paper considers two economies that are identical ex ante in terms of within-country income and ability to commit to policy. Also, in order to preserve symmetry, we do not assign MNC location to any country. This ex ante symmetry is intended to analyze policy choice of similar member countries of the EU. However, choice of different levels of income-based price subsidies could make the countries ex post asymmetric. Also, in contrast to Acharyya and García-Alonso (2012), we endogenize the quality level of the drug in order to analyze how subsidy policy choices and the innovation levels are inter-related. Governments choose a general policy on whether or not to provide income-based price subsidies for drug innovations as a feature of their health policies. We consider that such policy commitment is not subject to changes on the basis of specific health innovations. However, we assume that governments advance the impact that such a policy feature has on drug innovation. This is reflected in the timing of decisions.

The general timing for the model we consider is as follows. In the first stage, the governments in both countries simultaneously choose income based price subsidy levels. Given such subsidy choices, a pharmaceutical firm chooses the quality and the price of the innovation. Finally, all consumers in both countries choose whether to purchase the innovation or not. We solve the model for the Subgame Perfect Nash Equilibrium (SPNE).

First, we find that the innovator firms' 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 a 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 government decisions to induce universal coverage will depend on the level of intra-country income distribution. We conclude that, when international price discrimination is not possible, a higher top income leads to less likely provision of universal coverage. However, and interestingly, when price discrimination is allowed, a higher top income may lead to a higher chance of universal coverage by a country alone. That is, the provision of universal coverage may be different across the two countries in such a case. 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. We also show that universal coverage arises under a wider range of incomes 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 important issue for policy makers. This result would still remain valid for subsidies proportional to quality and an alternative timing where the government does not commit to subsidies before quality investment takes place.

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. Section 4 discusses the sensitivity of the results. Finally, Section 5 concludes the paper.

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. 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. With this, we aim to maintain symmetry across countries. However, we do not expect that assigning location to one of the two countries would change our results qualitatively.[3]

The government in each country i sets a specific income-based price subsidy γ_{ji}, $j = R, T$, for the consumption of the pharmaceutical innovation. Consumers belonging to a particular income group in each country have identical valuations for a particular quality. Following the literature on quality choice, we assume that richer buyers attach an even higher valuation to a better quality drug relative to a lower quality drug than the poorer buyers. This means that the marginal willingness-to-pay for quality varies across different income levels in each country.[4] We assume that such a preference relationship is linear in income and quality so that if a consumer with income y_j purchases a drug of quality s, she gets a gross utility $V_j(y_j, s) = y_j s$. The net utility is assumed to be additively separable in quality and price of the drug. Each consumer buys, if at all, only one unit of the drug. Let the reservation utility of a buyer of income y_j 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:[5]

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

As already discussed, we consider the following timing of decisions. First, governments simultaneously choose income-based subsidy levels. Second, the firm chooses the quality and the price of the innovation. Finally, consumers

[3] We also intend to abstract from policy decisions being influenced by within-country redistribution of surplus across buyers (or patients) and producers of drugs, which, of course, may be important for drug exporting countries like the United States. In countries that are net importers of drug, most of the public policy debates in health markets are concerned with market access and patient welfare.

[4] See Gabszweicz and Thisse (1979) and Shaked and Sutton (1982) for differences in marginal willingness-to-pay for quality being related to differences in income levels. A similar specification has been used in health markets elsewhere [Acharyya and García-Alonso (2006, 2008)].

[5] Our linearization of marginal willingness-to-pay does not allow us to assume a non-binding purchasing power constraint as in the literature on quality choice (see Tirole (1992)). However, instead of considering a separate purchasing power constraint, we assume parametric configurations of our model such that the profit maximizing quality $s^* < 1$, so that whenever the above IR constraint in (2) is satisfied, the budget constraint $P_i - \gamma_{ji} \leq y_j$ is satisfied as well. See Acharyya (2005, 2008) for an explicit purchasing power constraint and how such a constraint by itself provides scope for a monopolist to discriminate.

in both countries choose whether to purchase the innovation or not. We find the SPNE using backwards induction.

Note that 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. This consists of aggregate consumer surplus minus the cost of the subsidy. As no location assignment of MNC is made, the MNC's profit is not included in the national welfare levels. 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 simply redistribute incomes across the consumers and the government. The subsidies affect national welfare levels only through their impact on the innovation level and price of the drug. Also, 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 they are given a price subsidy. The poor consumers will still be pushed to their reservation utility but the richer consumers will 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 mean 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 use γ_i to refer to the subsidy given to the lower income group in country i.

The market access and net surplus realized from buying a drug should be distinguished here. The utility specification adopted here (which is standard in the literature on endogenous quality choice and further discussed in Acharyya and García-Alonso (2011)) does not allow such a distinction perse. By this specification the low type is always left with her reservation utility, whereas the higher types get more than their reservation utilities when the low types are served. But, the tie-breaking rule adopted here essentially captures the preference for low types buying the drug even when they receive their reservation utility (i.e., the same utility they would have had they not purchased the drug). Our results should hold qualitatively for any other specific form of the utility function, as long as the net utility is additively separable in quality and price. The interesting policy implication that emerges from our analysis and seemingly restrictive utility specification is that the government is not directly concerned with equity, yet it would want to ensure full coverage at least in some circumstances.

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

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

That is, the income disparity between the poor and rich consumers must be too wide in the above sense to make the MNC's choice of not catering to the poor patients more rewarding than catering to these patients along with the rich patients.[6]

3 Innovation and Subsidies

In this section, we obtain the SPNE innovation and subsidy levels when price discrimination is allowed and when it is not.[7] Using backwards induction, we start with the firm's profit maximizing choices for given governments' subsidies. We will then be able to analyze the impact of price discrimination on the decisions of governments regarding the provision of universal access to health innovations and their quality.

[6] For details of pricing and market coverage decisions of an MNC in the face of income disparity, see Acharyya and Garcia-Alonso (2008).

[7] We assume 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 be only price discrimination, if that is possible at all (see, for example, Acharyya (2005)).

3.1 International price discrimination allowed

We first consider the case when ex ante price discrimination is allowed.[8] 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 profit function for this case is[9]

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

where subscript FC denotes full coverage of both the markets. Note that the firm sets prices so as to make the poorer group with each country indifferent between buying or not, however, as within country price discrimination is never possible, the richer group will also have access to this price. 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 refer to this case as *unilateral universal coverage.* The profit function for this case is

$$\pi^D_{FCi} = (n_R + n_T)(y_T s + \gamma_{Ti}) + n_R y_R s - \frac{1}{2}s^2, \quad i = 1, 2, \tag{6}$$

where subscript FCi denotes full coverage in country i market only. Note that by the assumed symmetry of countries, $s^D_{FC1} = s^D_{FC2}$. In this case, the firm's ability to price discriminate means that it is able to set the price in the country where universal coverage is not being implemented equal to the shadow price for the rich group, whereas the poor are excluded from consumption. As will later be seen, it is in this case that the difference between the price discrimination allowed and not allowed will become more apparent. If the firm cannot set two different prices in this scenario, it will have to set a unique price equal to $(y_T s + \gamma_{Ti})$ in both countries. Finally, if none of the countries provides a subsidy that ensures full coverage, it is

[8] Here, we assume that the cost of implementing price arbitrage is zero, however, one could argue that if price arbitrage happens through PI, transport costs might make the zero cost assumption unreasonable. Our results would still stand for small transport costs. For a sufficiently high cost of implementing price arbitrage, the two cases presented in the paper would collapse into the case where firms are able implement price discrimination. However, as mentioned in the introduction, in pharmaceutical markets, external referencing pricing is a tool governments often use to impose an upper bound on drug prices without actually having to implement PI. Both PI and external referencing enable price arbitrage and hence, limiting the firm's ability to price discriminate across countries.

[9] Note that to find ourselves in this case, subsidies must be 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.

profit maximizing to cover only richer consumers in both countries. We refer to this case as *bilateral partial coverage.* The profit function for this case is

$$\pi_{PC}^{D} = 2n_R y_R s - \frac{1}{2}s^2. \tag{7}$$

where subscript PC denotes partial coverage of both country markets. Here, only the rich in each country have access to the innovation. The profit maximizing quality levels for each of these three coverage cases are

$$s_{FC} = 2\left(n_R + n_T\right) y_T, \tag{8}$$

$$s_{FCi}^{D} = \left(n_R + n_T\right) y_T + n_R y_R \tag{9}$$

and

$$s_{PC} = 2n_R y_R, \tag{10}$$

respectively. Note that the optimal innovation level does not depend on the subsidies given because of their specific (instead of proportional) nature.

Lemma 1 *The MNC chooses the largest innovation level under bilateral partial coverage and the least innovation under bilateral universal coverage* $(s_{PC} > s_{FCi}^{D} > s_{FC})$.

Lemma 1 evaluates the impact on quality of inducing the MNC to cover consumers it would not cover otherwise (see equation (4)). As these are consumers with a lower valuation of quality, inducing full coverage in any one country reduces quality (although it reduces prices as well) relative to partial coverage. 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 price discrimination is possible, the firm prices some of the consumers with the highest valuation for quality accordingly and this increases the firm's incentive to invest in quality.

We now consider the choice of subsidy levels by the governments in each of the two countries. To begin with, note that the common minimum subsidy that ensures that the firm achieves higher profit by fully covering both countries rather than just providing partial coverage everywhere is such that

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

using equations (8) and (10), we get the common minimum subsidy offered by each country, γ^C, which ensures bilateral universal coverage

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

Subsidy γ^C is positive as long as $y_R > y_R^*$ (defined in (4)). For $y_R < y_R^*$, the MNC serves all, even without any subsidy. But, for $y_R > y_R^*$, the MNC serves only the rich and subsidies are required to ensure market access for the poor. In the rest of the analysis, we shall confine ourselves to the latter case. We now define two other critical subsidy levels. First, γ^D is the minimum subsidy that ensures that the firm prefers full coverage in country i alone to partial coverage everywhere:

$$(n_R + n_T)\left(y_T s_{FC1}^D + \gamma_{T1}\right) + n_R y_R s_{FC1}^D - \frac{1}{2}\left(s_{FC1}^D\right)^2 \geq 2 n_R y_R s_{PC} - \frac{1}{2}\left(s_{PC}\right)^2, \tag{13}$$

and it is hence given by

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

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

$$\begin{aligned} & (n_R + n_T)(y_T s_{FC}^D + \gamma_{T1}) + (n_R + n_T)(y_T s_{FC}^D + \gamma_{T2}) - \frac{1}{2}(s_{FC}^D)^2 \\ \geq\ & (n_R + n_T)(y_T s_{FCi}^D + \gamma_{T1}) + n_R y_R s_{FCi}^D - \frac{1}{2}(s_{FCi}^D)^2, \end{aligned} \tag{15}$$

and it is hence given by

$$\gamma^{\min} = \frac{((n_R + n_T) y_T + n_R y_R)^2 - (2(n_R + n_T) y_T)^2}{2(n_R + n_T)}. \tag{16}$$

Note that $\gamma^{\min} = 2\gamma^C - \gamma^D$. The following lemma specifies the set of subsidy pairs for which the MNC provides 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. See Appendix. ■

The above lemma illustrates the fact that when the MNC can price discriminate across countries, a lower 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 firm's 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 conditions stated in Lemma 2 need not necessarily be the set of SPNE subsidies. For that, we must also ensure that such subsidy levels improve the net welfare in both countries. Otherwise governments would prefer not to induce universal coverage in their own country. The following lemma will help obtain the SPNE subsidies. The first part of the lemma provides the condition for bilateral universal coverage to be welfare improving in each country.[10]

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

$$\gamma_i < \gamma_{FC}^{\max} = 2n_R\,(y_R - y_T)\,y_T \tag{17}$$

for $i = 1, 2$.

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

$$\widetilde{y}_R = \frac{(n_R + n_T)\,y_T + y_T\sqrt{(n_R + n_T)\,2n_T}}{n_R}. \tag{18}$$

Proof. See Appendix. ■

The above lemma implies that inducing bilateral universal coverage will not be welfare improving if the subsidy required is too high. This will be the case when the difference between y_R and y_T is too big. 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 *For all $y_R \in (y_R^*, \widetilde{y}_R)$, the SPNE subsidy pairs (γ_1, γ_2) will be such that $\gamma_1 + \gamma_2 = 2\gamma^C$ and $\gamma_i \leq \min\left\{\gamma^D, \gamma_{FC}^{\max}\right\}$ for $i = 1, 2$. These SPNE subsidies will induce bilateral universal coverage.*

Proof. To check for the SPNE, we construct the Best Response Function in subsidies, say, for country 1. Country 2's Best Response Function will be similar:

[10] 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.

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 is 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, $\gamma_i < \gamma_{FC}^{\max}$. ■

[INSERT FIGURE 1 HERE]

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 $\gamma_i \leq \min\left\{\gamma^D, \gamma_{FC}^{\max}\right\}$.[11]

The best response functions when $\boldsymbol{\gamma}^D < \boldsymbol{\gamma}_{FC}^{\max}$ are illustrated in Figure 1, where we can see the subsidy set that would implement bilateral universal coverage is the SPNE set of subsidies. As the top income increases we have $\gamma^D > \gamma_{FC}^{\max}$ and the range of SPNE subsidies becomes a subset of the subsidies implementing bilateral universal coverage. Of course, it could be that none of the subsidy pairs that implement bilateral universal 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 bilateral universal coverage,* $\left(\gamma^C, \gamma^C\right)$, *is a SPNE as long as* $y_R \in (y_R^*, \widetilde{y}_R)$.

[11]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 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 $\boldsymbol{\gamma}^D > \gamma^C$ $\forall$ $y_R > y_R^*$, $\gamma_j < \gamma_i$.

Proof. 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 stated 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 $\gamma^C < \min\{\gamma^D, \gamma_{FC}^{\max}\}$ for $y_R^* < y_R < \widetilde{y}_R$. There are other higher subsidies than γ^C which are less than $\min\{\gamma^D, \gamma_{FC}^{\max}\}$. As countries are symmetric, this means that there exists a (γ_1, γ_2) pair such that $\gamma^C < \gamma_i < \min\{\gamma^D, \gamma_{FC}^{\max}\}$ and $2\gamma^C - \gamma_i < \gamma_j < \gamma^C$. The line segment AB in Figure 2 represents such SPNE subsidies, including the symmetric subsidy pair (γ^C, γ^C). Of course, the higher the value of y_R (within the above specified range), the smaller the set SPNE subsidies. The line segment AB describing the set of SPNE subsidies will converge to the mid-point E (such that $\gamma_1 = \gamma_2 = \gamma^C$).

[**INSERT FIGURE 2 HERE**]

For $y_R > \widetilde{y}_R$, there is an income range that would support unilateral coverage as a SPNE. Anywhere else in the income distribution, partial coverage everywhere 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. ■

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 bilateral partial coverage.

[**INSERT FIGURE 3 HERE**]

We can conclude that depending on income levels, we have different coverage scenarios in the SPNE. These are summarized in Figure 3. First, for $y_R \in (y_R^*, \, \widetilde{y}_R)$, there is a range of SPNE subsidies all implementing bilateral universal coverage. As the top income 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 top income

$y_R \in (\widehat{y}_R,\, y_R^D)$, 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 top income becomes even higher, not even unilateral universal coverage can arise and we are left with bilateral partial coverage.[12] Note that, by the assumed pattern of income distribution in each country, the MNC caters only to the high income buyers if no government intervention takes place. An income subsidy effectively raises the income of the poorer buyers and makes uniform pricing and full coverage profitable for the MNC. The higher profit also induces it to raise the innovated quality of the drug. The welfare of the richer buyers thus rises because of the lower uniform price (that leaves them with strictly positive net surplus) and higher innovated quality. However, the amount of subsidy itself is a dead-weight loss as it is a transfer from the government to the MNC. Thus, an income subsidy has both its benefits and costs. The larger the income disparity (as ensured by the larger value of y_R for any given value of y_T), the higher the amount of subsidy required to make full coverage profitable for the MNC. Accordingly, the welfare cost of subsidy is larger. A very large income disparity (such as $y_R > \widehat{y}_R$) makes the net gain from the minimum subsidy required to ensure bilateral full coverage negative. However, the net gain from minimum subsidy required to ensure unilateral full coverage is still positive since the innovated quality is higher for such unilateral full coverage than under bilateral full coverage. This higher quality (resulting in a higher net surplus for richer buyers) overcompensates for the dead-weight loss of a larger subsidy for $y_R \in (\widehat{y}_R,\, y_R^D)$.

3.2 International price discrimination not allowed

We now consider the situation where PI prevents price discrimination across countries. As in the previous section, we have three possible quality levels depending on the extent of market coverage in the two countries. It is easy to check that the profit-maximizing innovation level remains the same as before in the bilateral universal coverage and bilateral partial coverage cases (hence, we still denote them s_{FC} and s_{PC}). However, things change for

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

the case of unilateral universal coverage. International price arbitrage will force the MNC to charge the same price in both countries, even when it fully covers, say, country i's market alone. Had price discrimination been allowed, as in the previous subsection, the MNC would charge $y_T s + \gamma_{Ti}$ in country i and $y_R s$ in the other country for any given quality. However, when price discrimination is not allowed, the MNC is forced to charge $y_T s + \gamma_{Ti}$ everywhere. Hence, in the case when it is not profit maximizing for the MNC to fully cover both countries, the profit function will be

$$\pi_{FCi}^{ND} = (2n_R + n_T)(y_T s + \gamma_i) - \frac{1}{2}s^2, \tag{19}$$

resulting in quality level

$$s_{FCi}^{ND} = (2n_R + n_T)\, y_T. \tag{20}$$

Comparing equation (20) with quality levels in the previous section, we obtain 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 ($s_{FCi}^{ND} < s_{FCi}^{D}$). Moreover, unlike in the price discrimination case, this quality level is least compared to the quality levels under bilateral universal and bilateral partial coverage.*

Note that since both countries share the same income distribution, the subsidy which 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 i, when the subsidy in the other country is not enough to cover all, must satisfy the following constraint:

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

The strict equality yields a minimum subsidy:

$$\gamma^{ND} = \frac{\left(2n_R y_R\right)^2 - \left((2n_R + n_T)\, y_T\right)^2}{2\left(2n_R + n_T\right)}. \tag{21}$$

Note that $\gamma^{ND} > \gamma^C$. Hence, since $s_{FCi}^{ND} < s_{FC}$, the condition that ensures positive welfare for country i when both countries set subsidy γ^C is not sufficient to ensure positive welfare for country i when it alone implements full coverage at γ^{ND}.[13] Note that

$$W_i^{FCi} = n_R \left(y_R s_{FCi}^{ND} - \left(y_T s_{FCi}^{ND} + \gamma^{ND} \right) \right) - n_T \gamma^{ND}. \tag{22}$$

Hence, $\frac{\partial W_i^{FCi}}{\partial y_R} < 0 \; \forall \; y_R > y_R^*$ and the highest root to the above equation, y_R^{ND}, will give the relevant condition for income range resulting in positive welfare

$$y_R^{ND} = \frac{(2n_R + n_T) y_T \left[(2n_R + n_T) + \sqrt{(4n_R + 5n_T) n_T} \right]}{4n_R (n_R + n_T)}. \tag{23}$$

It is straightforward to prove that $\widetilde{y}_R > y_R^{ND}$. We can then 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.

Using Figure 4, it is easy to compare the results of the two sections and hence assess the impact of the ability of the MNC to price discriminate across countries on the coverage scenarios.

[INSERT FIGURE 4 HERE]

First, note that unilateral universal coverage is never a SPNE equilibrium outcome when price discrimination is not allowed. 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. We can also conclude that, unlike in the case where price discrimination is possible, there is an income range under PI where we have two SPNE: bilateral universal coverage and bilateral partial coverage. As the latter results in lower welfare

[13] This contrasts with the previous section (recall $W^{FC} > 0$ for all $y_R \in (y_R^*, \widetilde{y}_R)$).

for each country, there is a clear incentive for countries to coordinate in the provision of universal coverage.

More specifically, we now reflect on the impact of income distribution on universal coverage across the two cases. When international price discrimination is not possible, for relatively low levels of top income, $y_R \in \left(y_R^*, y_R^{ND}\right)$, there is a unique SPNE subsidy which results in bilateral universal coverage. For higher levels of top income $\left(y_R \in \left(y_R^{ND}, \widetilde{y}_R\right)\right)$, the rich group becomes more important to the MNC and hence universal coverage becomes more difficult to implement, the bilateral partial coverage arises then as an alternative SPNE outcome, and indeed this becomes the unique SPNE for sufficiently high top income $y_R > \widetilde{y}_R$. This contrasts with the price discrimination case in two ways. First, bilateral universal coverage was induced for all top incomes below $\widetilde{y}_R$ as a unique equilibrium. Second, an increase in the top income did in one instance improve the chances of at least unilateral universal coverage (when it goes from $y_R \in (\widetilde{y}_R, \widehat{y}_R)$ to $y_R \in \left(\widehat{y}_R, y_R^D\right)$).

Regarding changes in bottom income level, an increase in y_T increases the chances of unilateral universal coverage $\left(\frac{\partial y_R^D}{\partial y_T} - \frac{\partial \widehat{y}_R}{\partial y_T} > 0\right)$ and bilateral universal coverage $\left(\frac{\partial \widetilde{y}_R}{\partial y_T} > 0\right)$, it also increases the range of top incomes over which bilateral universal coverage is a unique SPNE under PI $\left(\frac{\partial y_R^{ND}}{\partial y_T} > 0\right)$. Hence, the impact of an increase in the poor income seems consistent across cases and reflects the intuition that an increase in the importance of the poor group (reflected in a higher poor income) makes it easier for the firm to be induced to fully cover and hence, more likely that the government will want to implement universal coverage.

4 Discussion

In the previous sections, we have assumed first that the government can fully commit to subsidies and second that the subsidy that the government gives to the poorer individuals is not dependent on quality. The model can be easily extended to both these cases. Whenever price discrimination is possible, the unique SPNE in both these cases, which is not elaborately worked out here to shorten the length of the paper, is the bilateral universal coverage. When price discrimination is not possible, the bilateral universal coverage is still a SPNE for all the relevant income range. However, for rich group incomes higher than a certain threshold (which is the same whether we consider alternative timing or subsidy proportional to quality and calculated in the same way as y_R^{ND}), we will have a second SPNE in which bilateral partial coverage is the outcome. Therefore, the importance of coordinating on universal coverage provision still remains and also it is still the case that an increase in the importance of the rich group, reflected in a higher top income, decreases the chances of bilateral universal provision unless there is successful policy coordination. For the case when price discrimination is possible, our results highlight the importance of linking subsidies to quality. Indeed, when the alternative assumptions are made, the equilibrium quality becomes identical across all possible equilibria. It is the inability of the government to link the subsidy to the quality that generates the possibility of asymmetric universal coverage provision and bilateral partial coverage under price discrimination. As universal coverage is more likely to be implemented when subsidy is linked to quality, it will also be the case that a higher welfare level will be achieved as the firm then lowers prices so as to reach the two groups of patients and, hence, there is a lower deadweight loss. Unsurprisingly, even when we compare welfare levels for the same bilateral universal coverage inducing income across the cases (our benchmark model and the suggested alternatives), welfare seems to be lower when subsidies are not linked to quality. These results may provide some justification for why a proportional subsidy or subsidy of drugs based on their assessed usefulness, as implemented by France, may be relevant. At the same time, our results reveal the problem of policy coordination for other countries in the EU that do not always link subsidies to their assessed usefulness. An alternative modelling assumption would be to make the subsidy given to the poor group proportional to income. The impact of this on our results would be very similar to what we have described above.

However, the ease with which bilateral universal coverage is implemented under these alternative assumptions needs to be taken with caution. Our model uses a standard modelling of government subsidies (as in the strategic trade literature) where governments do not have a budget constraint and the subsidy cost is simply a (negative) component of welfare.[14] An upper limit on subsidies will obviously constrain the ability to provide universal coverage in cases where the rich group's income is very high. In addition, although countries seem to provide subsidies only to medicines that achieve a minimum quality requirement, this decision is sometimes complex and depends on matters other than those considered here, such as the efficacy of the drug for different patient groups (see García-Alonso and García-Mariñoso (2008)). Hence, our assumption regarding subsidies not depending on quality would still make sense in those countries as long as a minimum quality threshold is

[14]See Brander and Spencer (1985) for a similar welfare measure in the context of an export-subsidy rivalry game between two national governments.

achieved.

5 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 strategic interactions between similar governments may influence both their provision of universal access to pharmaceutical innovations and the level of quality that any MNC is willing to provide. We use a simple model where countries are assumed to be ex ante identical in all ways. There is within-country income inequality but, income distributions are the same across countries. We aim to capture the strategic interactions between similar governments choosing their provision of universal coverage.

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 depends crucially on income levels. When international price discrimination is not possible, a higher top income leads to less likely provision of universal coverage. However, and interestingly, when price discrimination is allowed, an increase in the top income 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 of top income 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. Then, country coordination of the Pareto optimum equilibrium becomes an issue for policy makers. Our results have been discussed against alternative modelling assumptions, such as firms being able to commit to quality before the government sets the policy and subsidy being proportional to quality or the poor group income. In such cases the importance of policy coordination still remains, and also the fact that bilateral universal coverage is more likely (indeed certain) under price discrimination.

We finally return to the original motivation of the paper. We started by highlighting the EU's commitment to universality as one of the main values in EU Health Systems.

In our paper universal coverage is more likely if price discrimination is allowed, yet, PI and external reference prices are standard tools within the EU which would impair the pharmaceutical firm's ability to price discriminate. But, it is in the non-discrimination case that we find that the need to coordinate on a common universal access policy becomes relevant. Therefore, our results support the need for such statements on policy values.

An alternative way of using the model to understand real life is the United States (US) versus EU example. As the US has a no PI policy, pharmaceutical companies can discriminate between the US and the EU. At the same time, universal access does not prevail in the US like it does in Europe. Our results would explain such asymmetry in this context. However, we have to acknowledge as well that our model does not assign MNC location, and hence national interests in promoting strategic pharmaceutical sectors are not analyzed. This could also be behind some of the policy differences.

Both in this paper and other related papers (Acharyya and García-Alonso, 2011, 2012), the focus is on drug innovations and hence MNCs which are monopolists due to patents. As stated in Danzon et al. (2011), most of the PI literature uses this assumption. In Acharyya and García-Alonso (2011), there is a consideration of an in-patent drug being faced with competition from an imitator based in a country where patent rights are not respected. Generic competition once patent term has expired would be a way, extensively researched in the health economics literature, to put downward pressure on pharmaceutical prices, however, here we focus on price arbitrage and income-related subsidies as policies which may put pressure on in-patent drug prices. A different issue, however, would be that of competition in patent protected therapeutic substitutes. We intend to explore this in our future research.

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Appendix

Proof of Lemma 2

To ensure universal coverage a country must ensure

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

and

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

are met. A little manipulation of the above conditions, allowing for γ_{T1} and γ_{T2} to differ, results in

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

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 $2\gamma^C-\gamma_1^D=\gamma^{\min}$.

Proof of Lemma 3

Note that

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

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

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

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

(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 $\gamma_{FC}^{\max}$. Note that

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

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

The above is a convex function with roots

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

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.,

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

Moreover, since $\frac{\partial\left[\gamma^C<\gamma_{FC}^{\max}\right]}{\partial y_R} > 0$, 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.

Proof of Proposition 2

Note that the condition for positive welfare under unilateral coverage is weaker than such condition for full coverage even at the 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, note that

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

and

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

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

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

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

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 :

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

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

We take the highest root:

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

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 $\widehat{y}_R$

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

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

We take the highest root:

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

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 $y_R^D > \widehat{y}_R > \widetilde{y}_R$. 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.

Proof of Proposition 3

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)

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

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 no better response than γ^C.

(d) If $\gamma_{T2} = \gamma^{ND}$, there 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:

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

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 prove this below

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

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

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

Let $\overline{\overline{y}}_R$ be the critical value for which $W_1^{FC} = W_1^{FC2}$. Note that $\frac{\partial \left[W_1^{FC} - W_1^{FC2} \right]}{\partial y_R} < 0 \ \forall \ y_R > y_R^*$. Here, $\overline{\overline{y}}_R$ 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

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

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

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 $\gamma^{ND} < \gamma_2$.

1

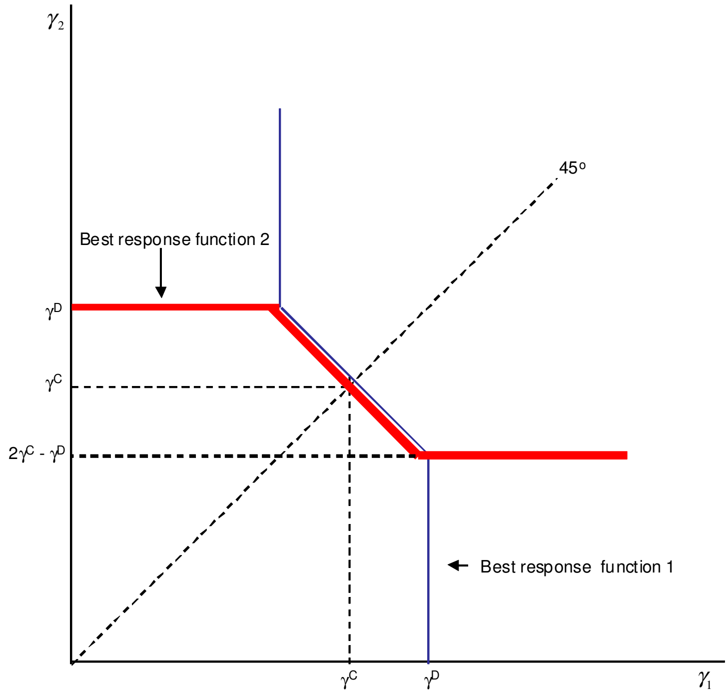

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Figure 1: Government best response functions when international price discrimination is allowed and $\boldsymbol{\gamma}^D < \boldsymbol{\gamma}_{FC}^{\max}$.

Figure 2

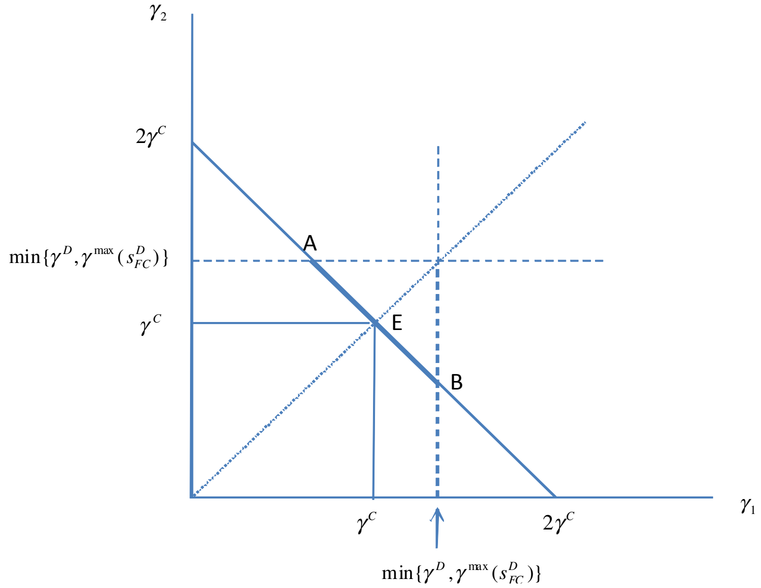

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Figure 2: Example of SPNE subsidies for $y_R^* < y_R < \widetilde{y}_R$

3

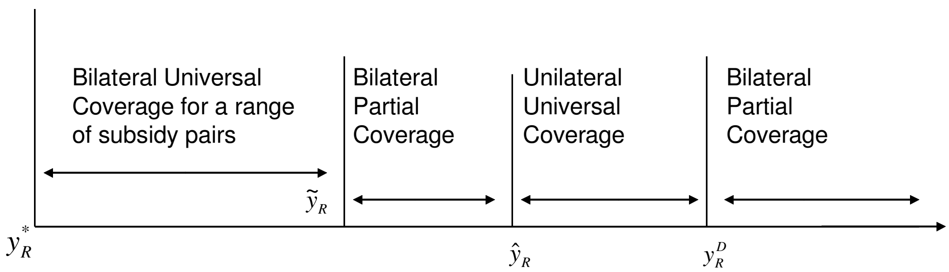

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Figure 3: Coverage scenarios when international price discrimination is allowed.

Figure

4

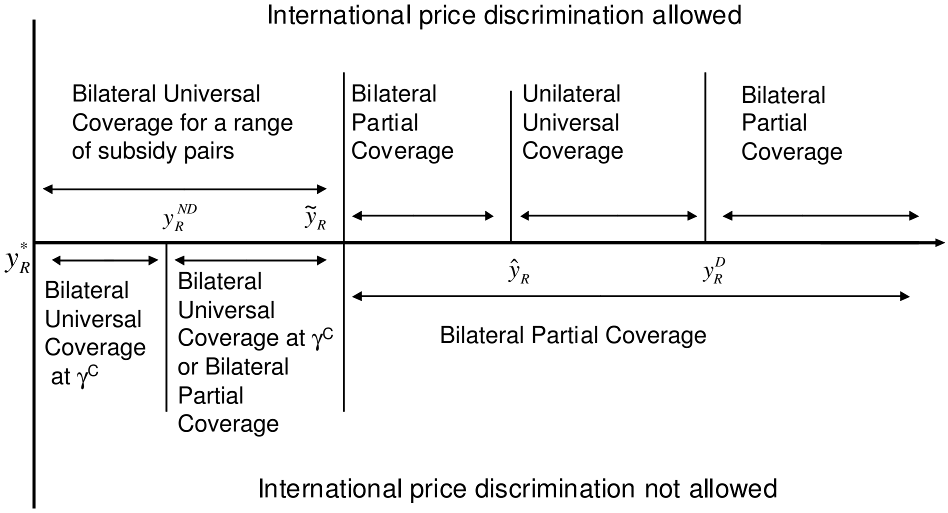

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Figure 4: Impact of not allowing international price discrimination on universal coverage.