External reference pricing policies, price controls, and international patent protection

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Abstract

We develop a two-country model to analyze how a country's *external reference pricing* (ERP) policy affects the international availability and pricing of a patented product sold by a local firm. In equilibrium, the country permits a level of international price discrimination that is just necessary to induce its firm to export and this policy maximizes joint welfare. By raising the minimum price above which the firm prefers to export, the ERP policy undermines the foreign price control (PC). There exist circumstances where tightening the PC is Pareto-improving. International cooperation is necessary to ensure that instituting patent protection abroad increases welfare.

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1 Introduction

Governments across the world utilize a variety of policies to combat the market power of firms selling patented pharmaceutical products. Two such commonly used policies are external reference pricing (ERP) and price controls. Under a typical ERP policy, the price that a country permits the seller of a patented product to charge in its market depends upon its prices in a well-defined set of foreign countries, commonly called its *reference basket*. For example, Canada's ERP reference basket includes France, Germany, Italy, Sweden, Switzerland, the UK and the USA while that of France includes Germany, Italy, Spain, and the UK. Furthermore, while some countries – such as France and Spain – permit a seller to charge only the lowest price in its reference basket, others – such as Canada and Netherlands – are willing to accept either the average or the median price in their reference baskets. In a recent report, the World Health Organization (WHO) notes that 24 of 30 OECD countries and approximately 20 of 27 European Union countries use ERP, with the use being mostly restricted to on-patent medicines (WHO, 2013).

Price controls on pharmaceuticals come in various shapes and forms: for example, governments may control the ex-manufacturer price, the wholesale markup, the pharmacy margin, the retail price, or use some combination of these measures. While few, if any, countries use all such measures, many use at least some of them. For example, Kyle (2007) notes that price controls in the pharmaceutical market are common in most major European countries where governments are fairly involved in the health-care sector. Similarly, many developing countries have a long history of imposing price controls on patented pharmaceuticals, many of which tend to be supplied by foreign multinationals. For example, India has been imposing price controls on pharmaceuticals since 1962 and, despite the existence of a robust domestic pharmaceutical industry, it recently chose to significantly expand the list of drugs subject to price controls.[1]

This paper addresses several inter-related questions pertaining to ERP policies: What are the underlying economic determinants of such policies? What type of international spillovers do they generate? What are their overall welfare effects? Does their use by one country reduce or increase the effectiveness of price controls in *other* countries? How does the degree of patent protection in foreign markets affect a country's ERP policy? What are the effects of strengthening patent protection when both types of price regulations are

[1] See "India Widens Price Control over Medicines" in *Wall Street Journal*, May 17, 2013 and "Government Notifies New Drug Price Control Order" in the *Indian Express*, May 17, 2013.

endogenously determined?

We address these questions in a simple model with two countries (home and foreign) where a single home firm produces a patented good, that it potentially sells in both markets. The firm enjoys monopoly status at home by virtue of its patent; whether or not it faces competition abroad depends upon the patent protection policy of the foreign country. The home market is assumed to have more consumers and a greater willingness to pay for the patented product, which in turn creates an incentive for the firm to price discriminate in favor of foreign consumers. The home government sets its ERP policy – defined as the ratio of the firm's domestic price to its foreign price – in order to maximize national welfare, which equals the sum of the firm's global profit and domestic consumer surplus.

From the firm's perspective, home's ERP policy is a constraint on the degree of international price discrimination that it is allowed to practice while from the domestic government's perspective it is a tool for lowering the price at home (while simultaneously raising it abroad).[2] While the home government internalizes the effects of its ERP policy on local consumers and the firm, it does not take into account the negative effect on foreign consumers. Since the domestic market is more lucrative for the firm, too tight an ERP policy at home creates an incentive for the firm to not sell abroad so that it can sustain its optimal monopoly price in the home market. This is an important mechanism in our model and there is substantial empirical support for the idea that the use of ERP policies on the part of rich countries can deter firms from serving low-price markets. For example, using data from drug launches in 68 countries between 1982 and 2002, Lanjouw (2005) shows that price regulations and the use of ERP by industrialized countries contributes to launch delay in developing countries. Similarly, in their analysis of drug launches in 15 European countries over 12 different therapeutic classes during 1992-2003, Danzon and Epstein (2008) find that the delay effect of a prior launch in a high-price EU country on a subsequent launch in a low-price EU country is stronger than the corresponding effect of a prior launch in a low-price EU country.[3]

In our two-country framework, while the firm only cares about its total global profit,

[2] In this sense, ERP policies are related to exhaustion policies that determine whether holders of IPRs are subject to competition from parallel imports or not. Unlike ERP policies. the economics of exhaustion policies has been investigated widely in the literature: see Malueg and Schwarz (1994), Richardson (2002), Li and Maskus (2006), Valletti (2006), Grossman and Lai (2008), and Roy and Saggi (2012).

[3] Further evidence consistent with launch delay spurred by the presence of price regulations is provided by Kyle (2007) who uses data on 1444 drugs produced by 278 firms in 134 therapeutic classes from 1980-1999 to study the pattern of drug launches in 21 countries.

home welfare also depends on the *source* of those profits, i.e., it matters whether profits come at the expense of domestic or foreign consumers. We find that in equilibrium, the home government sets its ERP policy at a level at which the firm is just willing to export. Furthermore, the more asymmetric is demand across countries or the higher are foreign trade barriers, the more lax is home's ERP policy.

Since home's ERP policy tends to induce the firm to raise its foreign price, we extend the core model to allow the foreign government to impose a price control in order to curtail the international spillover caused by home's ERP policy. An important result of this analysis is that home's ERP policy *undermines* the foreign price control since the minimum price at which the home firm is willing to sell abroad is higher when home has an ERP policy in place relative to when it does not.

If the two countries simultaneously choose their respective policies, there exist a continuum of equilibria: essentially any pair of policies that makes the firm indifferent between selling only at home and selling in both markets constitutes a Nash equilibrium. For example, a scenario where home allows unrestricted international price discrimination (i.e. uses no ERP policy at all) and foreign sets its price control equal to marginal cost is an equilibrium. But so is an outcome where home sets its ERP policy at a level that is optimal in the absence of a price control abroad and, in equilibrium, foreign refrains from imposing any price control. An interesting point is that even if the foreign price control is set exactly at the firm's optimal monopoly price p_F^* for that market, home's equilibrium ERP policy ends up being more lax relative to the case where the foreign price control is completely absent. The intuition for this result is that when there exists no price control abroad, home's optimal ERP policy actually causes the equilibrium foreign price (p_c^*) to *exceed* the firm's optimal monopoly price p_F^* for that market (i.e. $p_c^* > p_F^*$). As a result, in the presence of an endogenously chosen ERP policy at home, a price control set at p_F^* actually *binds* for the firm.[4]

A rather surprising insight of our model is that *a tightening of the foreign price control can raise welfare in both countries*. The intuition for this result is as follows. Whenever $p_c^* > p_F^*$ a reduction in the foreign price (i.e. a tightening of the price control) increases the firm's foreign profit even as it reduces its domestic profit due to the foreign price control spilling over to the home country via its ERP policy. For price controls in the range $[p_F^*, p_C^*]$, if the foreign country tightens its price control only a moderate adjustment

[4]This result supports Goldberg's (2010) intuitive argument that the use of ERP policies on the part of developed countries has the potential to generate significant negative spillovers for developing countries.

in home's ERP policy is required to ensure that the firm continues to export since foreign profits actually *increase* when the foreign price declines. Thus, due to home's ERP policy, not only does the foreign price control generate an international spillover, the nature of the spillover generated is such that a tightening of the foreign price control can even make both countries better off.

Price controls are not the only means for combating the market power of foreign firms selling patented and/or branded pharmaceuticals: to some extent governments can also lower local prices by weakening patent protection and promoting local generic production. However, there are several problems with this strategy. First, the quality of generic production can be subpar, especially in developing countries. Second, if a country encourages generic production by allowing imitation of a pharmaceutical product that is under patent in other countries, it can run afoul of existing multilateral rules and disciplines pertaining to the protection of intellectual property specified in the Agreement on Trade Related Aspects of Intellectual Property (TRIPS) that was ratified by the World Trade Organization (WTO) in 1995 and is binding upon all existing WTO members. Indeed, international frictions over widespread imitation of patented pharmaceuticals and various copyrighted products by firms in many developing countries were a major driver of TRIPS. Accordingly, we examine the implications of the degree of patent protection available to the firm abroad and show that the lack of such protection induces the home country to loosen its ERP policy. This result fits well with the observation that when choosing the reference basket for their ERP policies, most EU countries tend to include other EU countries that have similar levels of patent protection. Finally, we show that some degree of international cooperation – over either home's ERP policy or over foreign's price control or both – is necessary for ensuring that joint welfare increases due to the strengthening of foreign patent protection.

By explicitly bringing in international pricing considerations and policy interaction between national governments, our paper contributes to the rapidly developing literature on the economics of *internal* reference pricing policies, i.e. policies under which drugs are clustered according to some equivalence criteria (such as chemical, pharmacological, or therapeutic) and a reference price within the same market is established for each cluster. Brekke et. al. (2007) analyze three different types of internal reference pricing in a model of horizontal differentiation where two firms sell brand-name drugs while the third firm sells a generic version, that like in our model, is perceived to be of lower quality.[5] They compare

[5]See Gislandi (2011) for an analysis where insured consumers pay the difference between the price of a drug and the reference price R set by the regulator and generic producers can potentially collude to

generic and therapeutic reference pricing – with each other and with the complete lack of reference pricing – and show that the latter type of reference pricing generates stronger competition and lower prices. In similar spirit, Miraldo (2009) compares two different reference pricing policies in a two-period model of horizontal differentiation: one where reference price is the minimum of the observed prices in the market and another where it is a linear combination of those prices. In the model, the reference pricing policy of the regulator responds to the first period prices set by firms (which, in turn, the firms take into account while setting their prices). The key result is that consumer surplus and firm profits are lower under the "linear policy" since the first period price competition between firms is less aggressive under this policy.

Bardey et. a. (2010) analyze a model in which firms choose to invest in research and development (R&D) prior to negotiating prices with a regulator. In their model, reference pricing affects the bargaining game between an innovator that brings a new drug to the market and the regulator in the following way: if there are two drugs in a therapeutic class then consumers (i.e. patients) are reimbursed only the lower price in that class.[6] They show that the presence of reference pricing dampens R&D incentives.

Motivated by the Norwegian experience, Brekke et. al. (2011) provide a comparison of domestic price caps and reference pricing on competition and welfare and show that whether or not reference pricing is endogenous – in the sense of being based on market prices as opposed to an exogenous benchmark price – matters a great deal since the behavior of generic producers is markedly different in the two scenarios; in particular, generic producers have an incentive to lower their prices when facing an endogenous reference pricing policy in order to lower the reference price, which in turn makes the policy preferable from the viewpoint of consumers.[7] Using a panel data set covering the 24 most selling off-patent molecules, they also empirically examine the consequences of a 2003 policy experiment where a sub-sample of off-patent molecules was subjected to reference pricing, with the rest remaining under price caps. They find that prices of both brand names and generics fell due to the introduction of reference pricing while the market shares of generics increased.

determine the level of R.

[6] As an extension of our core analysis, in section 5 of the paper we derive the home country's optimal ERP policy when the firm's foreign price is determined by Nash bargaining between the firm and the foreign government.

[7] The price cap regulation Norway is an ERP policy where the reference basket is the following set of 'comparable' countries: Austria, Belgium, Denmark, Finland, Germany, Ireland, the Netherlands, Sweden, and the UK. Unlike us, Brekke et. al. (2011) focus on the domestic market and take foreign prices to be exogenously determined.

The rest of this paper is structured as follows. We first introduce our two-country framework and analyze the optimal ERP policy of the home country as well as its welfare implications. Next, in section 3, we allow the foreign country to impose a price control and study interaction between home's ERP policy and the foreign price control. In section 4, we consider the interaction between these policies under a scenario where the foreign country does not offer patent protection so that the home firm faces competition from generic producers in (only) the foreign market. Here, we also examine the consequences of forcing the foreign country to offer patent protection to the home firm. In section 5, we extend the model to a scenario where the foreign price is determined by bargaining between the firm and the foreign government. Section 6 concludes while section 7 constitutes the appendix.

2 A benchmark model of ERP

We consider a world comprised of two countries: home (H) and foreign (F). There is a single home firm who sells a product (x) with a quality level s. The product is patented in both markets. Consumer in country i ($i = H, F$) buys at most 1 unit of the good at local price p_i. The number of consumers in country i equals n_i. If a consumer buys the good, her utility is given by $u_i = st - p_i$, where t measures the consumer's taste for quality. Utility under no purchase equals zero and the quality parameter s is normalized to 1. For simplicity, t is assumed to be uniformly distributed over the interval $[0, \mu_i]$ where $\mu_i \geq 1$.

From the firm's viewpoint, the two markets differ due to three underlying reasons.[8] First, home consumers value quality relatively more, that is, $\mu_H = \mu \geq 1 = \mu_F$. Second, the home market is larger: $n_H = n \geq 1 = n_F$. Third, trade is subject to barriers/transport costs where $0 \leq b < 1$ denotes the ad-valorem foreign trade barrier facing the firm's exports. As one might expect, given these conditions, the firm has an incentive to price discriminate internationally.

The home government sets an external reference pricing (ERP) policy that stipulates the maximum price ratio that its firm can set across countries. In particular, let p_H and p_F be prices in the home and foreign markets respectively *given* that the firm sells in both countries. Then, home's ERP policy requires that the firm's pricing abide by the following

[8] We later extend the model to allow for a foreign price control and for the imperfect protection of intellectual property abroad. Both of these features are highly relevant in the context of the pharmaceutical industry, which is where ERP policies occur most commonly.

constraint:

$$p_H \leq \delta p_F$$

where $\delta \geq 1$ reflects the rigor of home's ERP policy. A more stringent ERP policy corresponds to a lower δ which gives the firm less room for international price discrimination. Due to the assumed structure of demand in the two countries, the firm would never want to discriminate in favor of home consumers so there is no loss of generality in assuming $\delta \geq 1$. Note also that when $\delta = 1$ the firm does not have any room to price discriminate across markets.

2.1 Pricing under the ERP constraint

If the ERP constraint is absent altogether, the firm necessarily sells in both markets since doing so yields higher total profit than selling only at home. In particular, when the firm can freely chooses prices across countries, it sets a market specific price in each country to maximize its global profit as follows

$$\max_{p_H,\, p_F} \pi(p_H, p_F) \equiv \frac{n}{\mu} p_H(\mu - p_H) + \frac{p_F}{\tau}(1 - p_F) \tag{1}$$

where $\tau = 1/(1-b) > 1$. It is straightforward to show that the firm's optimal market specific prices are given by $p_H^* = \mu/2$ and $p_F^* = 1/2$. The associated sales in each market equal $x_H^* = n/2$ and $x_F^* = 1/2$. Global sales under price discrimination equal $x^* = x_H^* + x_F^* = (n+1)/2$. Observe that

$$p_H^*/p_F^* = \mu \geq 1$$

i.e. from the firm's viewpoint, the optimal degree of international price discrimination equals μ. Let the firm's global profit under optimal monopoly prices be denoted by $\pi^* \equiv \pi(p_H^*, p_F^*)$.

Now consider the firm's pricing problem when facing the ERP constraint $p_H \leq \delta p_F$. Since μ is the maximum price differential the firm charges across markets, in the core model we can restrict attention to $\delta \leq \mu$ without loss of generality.[9] Of course, we implicitly assume that the government has the ability to sustain whatever degree of international price discrimination that it chooses to permit (i.e. any price differentials that arise cannot be undercut via arbitrage by third parties).

[9] It is worth pointing out here that our model embeds two frequently utilized market structures in international trade, i.e. those of perfect market integration and segmentation, with the former scenario corresponding to $\delta = 1$ and the latter to $\delta = \mu$.

When faced with the ERP constraint, the firm can either choose to sell only at home and thereby free itself of the ERP constraint or sell in both markets and abide by it, in which case it solves:[10]

$$\max \pi(p_H, p_F) \text{ subject to } p_H \leq \delta p_F$$

Given a binding ERP constraint, the firm's optimal prices when it sells in both markets are

$$p_H^\delta = \frac{\mu\delta(n\tau\delta + 1)}{2(n\tau\delta^2 + \mu)} \text{ and } p_F^\delta = p_H^\delta/\delta \tag{2}$$

The sales associated with these prices can be recovered from the respective demand curves in the two markets and these equal

$$x_H^\delta = \frac{\delta^2 + (2\mu - \delta)n}{2(\delta^2 + \mu n)} \text{ and } x_F^\delta = \frac{n(2\delta^2 + (n - \delta)\mu}{2(\delta^2 + \mu n)}$$

Global sales under the ERP constraint equal $x^\delta = x_H^\delta + x_F^\delta$. Using the above formulae, it is straightforward to show the following:

Lemma 1: *Provided the firm sells in both markets, its global sales when facing an ERP policy at home exceed those under unrestricted international price discrimination:*

$$x^\delta - x^* = \frac{n(\delta - 1)(\mu - \delta)}{2(n\delta^2 + \mu)} \geq 0.$$

Observe from lemma 1 that when the firm is allowed no room to price discriminate (i.e. $\delta = 1$) then total sales under the ERP constraint are the same as those under price discrimination, i.e. $x^\delta = x^*$. As we will see below, Lemma 1 has important implications for the global welfare effects of home's ERP policy.

Using the prices p_H^δ and p_F^δ, the firm's global profit $\pi^\delta = \pi(p_H^\delta, p_F^\delta)$ when facing the ERP constraint is easily calculated

$$\pi^\delta = \pi(p_H^\delta, p_F^\delta) = \frac{\mu(n\tau\delta + 1)^2}{4\tau(n\tau\delta^2 + \mu)} \tag{3}$$

As one might expect,

$$\frac{\partial \pi^\delta}{\partial \delta} > 0$$

for $1 \leq \delta \leq \mu$, that is, the firm's global profit increases as home's ERP policy becomes looser.

[10] Within the context of our model, any foreign price that exceeds the choke off price abroad (i.e. $p_F \geq 1$) is tantamount to the firm not exporting since no foreign consumers are willing to buy the good if $p_F \geq 1$.

Of course, the firms always has the option to escape the ERP constraint by eschewing exports altogether. If it does so, it collects the optimal monopoly profit π_H^* in the home market where

$$\pi_H^* = \frac{n}{\mu} p_H^* (\mu - p_H^*) = n\mu/4 \tag{4}$$

Since (i) $\partial \pi^\delta / \partial \delta > 0$; (ii) $\pi^\delta \big|_{\delta \geq \mu} = \pi^* > \pi_H^*$; and (iii) π_H^* is independent of δ, we can solve for the critical ERP policy above which the firm prefers to sell in both markets relative to selling only at home. We have:

$$\pi^\delta \geq \pi_H^* \Longleftrightarrow \delta \geq \delta^* \text{ where } \delta^* \equiv \frac{1}{2}\left[\mu - \frac{1}{n\tau}\right] \tag{5}$$

We refer to δ^* as the *export inducing* ERP policy. The first main result can now be stated:

Proposition 1: *When facing the ERP constraint $p_H \leq \delta p_F$ the firm exports if and only if the ERP policy is less stringent than the export inducing ERP policy δ^* (i.e. $\delta \geq \delta^*$). Given that the firm exports (i.e. $\delta \geq \delta^*$), the following hold:*

(i) home's ERP policy reduces the local price relative to the optimal monopoly price whereas it raises the foreign price: $p_H^\delta \leq p_H^*$ and $p_F^\delta \geq p_F^*$;

(ii) the home price decreases in the stringency of home's ERP policy (i.e. $\partial p_H^\delta / \partial \delta > 0$ for $1 \leq \delta \leq \mu$) whereas the foreign price increases in it: $\partial p_F^\delta / \partial \delta < 0$;

(iii) prices in both markets increase if foreign trade barriers increase (i.e. $\partial p_i^\delta / \partial \tau > 0$), the home market gets larger (i.e. $\partial p_i^\delta / \partial n > 0$), or if home consumers start to value the product more (i.e. $\partial p_i^\delta / \partial \mu > 0$).

Proof: see appendix.

Part (i) says that the introduction of an ERP policy at home makes domestic consumers better off at the expense of foreign consumers. It is worth noting that home's ERP policy induces the firm to raise its price *above* its optimal monopoly price p_F^* in the foreign market since it wants to avoid lowering the price in the more lucrative domestic market too much. Along the same lines, given that an ERP policy is in place at home and the firm exports, a decrease in the stringency of this policy (i.e. an increase in δ) makes foreign consumers better off. Thus, the use of an ERP policy by the home country generates a *negative international spillover* for foreign consumers, a theme to which we return below when analyzing the optimal ERP policy from a joint welfare perspective.

Observe that the export inducing ERP policy δ^* is increasing in all three basic parameters of the model (i.e. μ, n, and τ) since an increase in any of these parameters makes the home market relatively more profitable for the firm thereby making it more reluctant to export under the ERP constraint. As a result, the more lucrative the home market, the greater the room to price discriminate that the firm requires in order to prefer selling in both markets to selling only at home.

2.2 Optimal ERP policy

Having understood the firm's pricing and export behavior, we are now in a position to derive the home country's optimal ERP policy. To do so, we assume that the objective of the home country is to maximize its national welfare, i.e., the sum of local consumer surplus and total profit of the firm:

$$w_H(p_H,\ p_F) = cs_H(p_H) + \pi(p_H,\ p_F) \tag{6}$$

where $cs_H(p_H)$ denotes consumer surplus in the home market and it equals

$$cs_H(p_H) = \frac{n}{\mu}\int_{p_H}^{\mu}(t - p_H)dt$$

An ERP policy is attractive for the home country since it can help reduce the deadweight loss associated with monopoly pricing (see part (i) of Proposition 1). On the other hand, too strict a ERP policy can induce the firm to eschew exports altogether, an outcome under which home consumers fare the same as they do in the complete absence of an ERP policy whereas the firm fares strictly worse (since it makes no export profit). *Thus, for any ERP policy for which the firm does not export, the home country is strictly better off not imposing any ERP constraint on the firm.* On the other hand, provided the firm exports, home welfare increases with a decline in domestic price which calls for a tighter ERP policy.

We can directly state the main result:

Proposition 2: *Let $\mu^* \equiv 2 + 1/n\tau$. The optimal ERP policy of the home country is δ^e where*

$$\delta^e = \begin{cases} 1 & \text{if } \mu \leq \mu^* \\ \delta^* & \text{otherwise} \end{cases}$$

Observe that for $\mu > \mu^*$, home's optimal ERP policy permits some degree of international price discrimination (i.e. $\delta^e = \delta^* > 1$) whereas for $\mu \leq \mu^*$ it calls for the firm to set a common international price (i.e. $\delta^e = 1$).[11] The logic behind this result is simple. In

[11] It is worth noting here that Proposition 2 continues to describe the Nash equilibrium if the home country and the firm were to make their decisions simultaneously.

terms of home welfare, discouraging the firm from exporting is even worse than not having an ERP policy whatsoever, as in both cases the firm makes monopoly profit π_H^* in the home market, but only in the latter case does the firm export and also collect monopoly profit π_F^* in the foreign market. In general, the *firm cares only about its total profit and not where it comes from.* By contrast, the home government also cares about the *source* of that profit so that the firm's export incentive is too weak relative to what is domestically optimal. The optimal ERP policy of the home government ensures that the firm does not refrain from exporting just so that it can charge its optimal monopoly price at home.

While our model abstracts from any fixed cost of exporting, it is worth noting that Proposition 2 continues to even hold if the firm must bear a fixed cost φ prior to exporting. Then, given the home country's ERP policy, the firm exports iff

$$\pi^{\delta} - \varphi \geq \pi_H^* \Longleftrightarrow \varphi \leq \varphi^*(\delta) \equiv \pi^{\delta} - \pi_H^* = \frac{\mu(2n\delta + 1 - n\mu)}{4(\delta^2 n + \mu)}$$

where $\varphi^*(\delta = \delta^*) = 0$ and $\varphi^*(\delta = \mu) = \pi_F^*$. Observe that if $\varphi > \pi_F^*$, the firm does not export even if it can perfectly price discriminate across countries. Since $\partial\varphi^*(\delta)/\partial\delta > 0$ for all $\delta \leq \mu$ the function $\varphi^*(\delta)$ can be inverted to obtain the minimum value of δ, denoted by $\delta^e(\varphi)$, above which the firm is willing to export. Given this, for $\varphi \in [0, \pi_F^*]$ the home country's optimal ERP policy is once again to allow just enough price discrimination to induce the firm to export, i.e., $\delta^*(\varphi) = \delta^e(\varphi)$, where $\delta^e(\varphi = 0) = \delta^*$ and $\partial\delta^e(\varphi)/\partial\varphi > 0$.[12] The logic is same as before: setting a policy more lax than $\delta^e(\varphi)$ lowers domestic welfare because it increases the firm's total profit at the expense of domestic consumers while setting a policy more stringent than $\delta^e(\varphi)$ leads the firm to not sell abroad.

Proposition 2 has substantial empirical support. When defining the set of foreign countries whose prices are used to determine the local price that a firm is allowed to charge, countries typically tend to include foreign countries with similar market sizes and per capita incomes.[13] In particular, we do not observe EU countries setting ERP policies on the basis of prices in low income developing countries. If lowering local prices were the sole motivation of ERP policies, European governments would have an incentive to use the lowest available foreign prices while setting their ERP policies. The insight provided by our model

[12]For $\varphi > \pi_F^*$, home country's ERP policy is irrelevant since the firm does not export for any ERP policy.

[13]Observe also that home's optimal ERP policy becomes less stringent as foreign trade barriers increase. Once again, this result corresponds quite well with the nature of ERP policies observed in the real world. For example, the set of countries that inform the ERP policies of a typical EU country tend to be other EU countries and trade within the EU is essentially subject to no policy barriers.

is that they do not do so because casting too wide a net while setting ERP policies can backfire by causing local firms to forsake foreign markets just so that they can sustain high prices in their domestic markets. In our model, demand size considerations are captured by parameters n and μ and home's optimal ERP policy becomes more lax with an increase in either of these parameters. Setting the ERP policy in this fashion is necessary for ensuring that the firm chooses to sell in both markets as opposed to selling only in its domestic market (at the monopoly price p_H^*).

Given that home's ERP policy affects the firm's export incentive as well as the price it sets abroad, we now investigate the properties of the jointly optimal ERP policy.

2.3 Joint welfare

Let joint welfare be defined by:

$$w(p_H, p_F) \equiv w_H(p_H, p_F) + cs_F(p_F) \text{ where } cs_F = \int_{p_F}^{1} (t - p_F)dt$$

The jointly optimal ERP policy maximizes

$$\max_{\delta} w(p_H,\ p_F) \text{ subject to } p_H \leq \delta p_F$$

We first state the result and then explain its logic:

Proposition 3: *Home's nationally optimal ERP policy δ^e also maximizes joint welfare.*

Proposition 3 is rather surprising since it argues that home's (subgame perfect) Nash equilibrium ERP policy is efficient in the sense of maximizing aggregate welfare even though home chooses its policy *without* taking into account its effects on foreign consumers. We now explain the logic behind this result.

An efficient ERP policy has to balance two objectives. One, it has to lower the international price differential as much as possible since the existence of such a differential implies that the marginal consumer in the high-price country values the last unit sold more than the marginal consumer in the low-price country so reallocating sales towards the high-price country raises welfare. Two, the ERP policy must ensure that foreign consumers have access to the good. For $\mu \leq \mu^*$, the firm exports even when it must charge the same price in both markets so that it is optimal to fully eliminate the international price differential (i.e. set $\delta = 1$). For $\mu > \mu^*$, incentivizing the firm to export requires that it be given some leeway to price discriminate internationally.

To see why δ^* maximizes joint welfare when $\mu > \mu^*$, simply note that starting at δ^* lowering δ (i.e. making the ERP policy more stringent) reduces foreign welfare to zero since the firm does not export while it also reduces home welfare since domestic price increases from p_H^δ to p_H^* while the firm's profit remains unchanged (i.e. it equals π_H^*). Thus, implementing an ERP policy that is more stringent than δ^* results in a *Pareto-inferior outcome* relative to δ^*.

Now consider increasing δ above δ^*. At $\delta = \delta^*$ if the home's ERP policy is relaxed (i.e. δ is raised) the firm continues to export but increases its price at home while lowering it abroad. Thus, starting at δ^*, an increase in δ makes the foreign country better off while making the home country worse off. Indeed, from the foreign country's viewpoint it would be optimal to eliminate the ERP constraint since that yields the lowest possible price in its market (i.e. p_F^*). However, since the international price differential increases with δ (i.e. $p_H^\delta / p_F^\delta = \delta$), joint welfare declines in δ for all $\delta > \delta^*$. In fact, given that the firm sells in both markets, we can show directly that

$$\frac{\partial w}{\partial \delta} = \frac{n\mu(\delta - \mu)(n\delta + 1)}{4(n\delta^2 + \mu)^2} < 0 \text{ for } \delta < \mu.$$

Thus, it is jointly optimal to lower the international price differential as much as possible while simultaneously ensuring that foreign consumers do not lose access to the patented product. This is exactly what the home country's Nash equilibrium ERP policy δ^e accomplishes.

[Figure 1 here]

Figure 1 provides further intuition regarding Proposition 3. It illustrates why δ^* is jointly optimal for the case where $\mu > \mu^*$. For $\delta \in [1, \delta^*)$, the firm does not export and foreign welfare is zero so that joint welfare simply equals domestic welfare which does not depend on δ (when the firms only sells at home). The horizontal line shows that for $\delta < \delta^*$, $w = w_H$. If home's ERP policy is relaxed beyond δ^*, the firm starts to export and joint welfare w exceeds home welfare w_H by the amount w_F. However, as the figure shows, both home welfare and joint welfare decline with further increases in δ so that it is jointly optimal to not increase δ beyond δ^*.

A well-known result in the existing literature is that for price discrimination to welfare dominate uniform pricing, a necessary condition is that the total output under discrimination be higher (Varian, 1985). However, in the present model, the total global output of the firm under price discrimination is *actually lower* than that which it produces when facing an ERP constraint (Lemma 1). As a result, it is jointly optimal to restrain price discrimination to the lowest level that is necessary for ensuring that foreign consumers do not go unserved.

In our benchmark model, the foreign country's government plays no role. In the real world, governments frequently impose price controls on patented pharmaceuticals in order to improve consumer access. Furthermore, in the context of our model, the use of an ERP policy generates a negative price spillover for the foreign country and therefore creates a natural incentive for a price control. We now allow the foreign country to directly control the price in its market in order to study interaction between home country's ERP policy and the foreign country's price control. Through-out the rest of the paper, we assume that there is sufficient asymmetry between markets that the home's optimal ERP policy allows some degree of discrimination (i.e. $\mu > \mu^*$ so that $\delta^e = \delta^*$).

3 ERP policy with a foreign price control

While price controls can take various forms, we model the foreign price control in the simplest possible manner: the foreign country directly sets the patented product's price (p_c) in its market. For expositional ease, through-out the rest of the paper we set $\tau = 1$ (i.e. no trade barriers). Since the foreign country is a pure consumer of the patented good, its objective is to secure access to the good at the lowest possible price. If home does not impose an ERP policy, it is optimal for the foreign country to set the price control equal to the firm's marginal cost (i.e. $p_c = 0$). In the absence of an ERP policy at home, the firm is willing to export for any foreign price greater than or equal to its marginal cost, and this allows the foreign country to impose its most desirable price control. It follows then that since the existence of an ERP policy at home causes the foreign price control to partly spill over to the home market thereby making the firm more reluctant to export, home's ERP policy *undermines* the effectiveness of the foreign price control.

3.1 Policy interaction and the firm's decision

To fully explore the nature of interaction between home's ERP policy and the foreign country's price control, we now analyze the following two-stage game:

Stage 1: home country chooses its ERP policy δ while the foreign country simultaneously sets its local price control p_c.

Stage 2: firm chooses its domestic price p_H.

If the firm chooses to export, it sets p_H to maximize aggregate profit while being subject to an ERP policy at home and a price control abroad:

$$\max_{p_H \,\leq\, \delta p_c} \frac{n}{\mu} p_H(\mu - p_H) + p_c(1 - p_c) \text{ where } p_c \in [0, 1] \tag{7}$$

Assuming that the ERP constraint $p_H \leq \delta p_c$ binds, the solution to the above problem requires the firm to set $p_H = \delta p_c$ so that its total profit equals:[14]

$$\pi^{\delta}(p_c) = \frac{n}{\mu}\frac{\delta p_c}{\mu}(\mu - \delta p_c) + p_c(1 - p_c) \tag{8}$$

In other words, when the firm faces an ERP policy at home and a price control abroad, it essentially has no freedom to choose prices if it opts to export: it charges p_c abroad and δp_c at home. If the firm chooses not to export, it charges its optimal monopoly price at home and earns π_H^*. Thus, when facing a price control abroad and an ERP policy at home, the firm exports iff

$$\pi^{\delta}(p_c) \geq \pi_H^* \tag{9}$$

This inequality yields the export inducing ERP policy as a function of the foreign price control:[15]

$$\delta(p_c) = \frac{\mu}{2p_c} - \frac{\sqrt{\eta\mu p_c(1 - p_c)}}{2\eta p_c} \tag{10}$$

Note that in the complete absence of policy intervention, the firm would charge its monopoly price p_F^* in the foreign market, which serves as the natural upper bound for p_c in the absence of an ERP policy at home. However, when an ERP policy is in place at home and it binds, the foreign price exceeds the monopoly level (i.e. $p_F^{\delta} \geq p_F^*$). Thus, in the presence of an ERP policy at home, the natural upper bound for the foreign price control is the choke-off price $p_c = 1$.

Lemma 2: *(i)* $\partial\delta(p_c)/\partial p_c < 0$ *for* $0 < p_c < p_c^*$ *where* $p_c^* \equiv p_F^{\delta}(\delta^*) = n\mu/(1 + n\mu)$ and $\lim_{p_c \to 0} \delta(p_c) = \infty$.

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[14] It will turn out that in any Nash equilibrium of the policy game, the ERP constraint necessarily binds.

[15] Observe that the ERP constraint necessarily binds so long as $p_H^* \geq \delta p_c$ which is the same as $\delta \leq \delta^b(p_c) \equiv p_H^*/p_c$. Now observe that the ERP policy that induces exporting can be written as $\delta(p_c) = p_H^*/p_c - \alpha(p_c)$ where $\alpha(p_c) \equiv \sqrt{\eta\mu p_c(1 - p_c)}/(2\eta p_c) \geq 0$. Therefore, $\delta(p_c) \leq \delta^b(p_c)$ which implies that the export inducing ERP policy binds.

(ii) $\partial\delta(p_c)/\partial p_c \geq 0$ *for* $p_c^* \leq p_c \leq 1$ *with* $\partial\delta(p_c)/\partial p_c = 0$ *for* $p_c = p_c^*$.

(iii) $\partial^2\delta(p_c)/\partial p_c^2 \geq 0$ *for* $0 \leq p_c \leq 1$.

(iv) $\delta(p_F^*) > \delta^*$.

Proof: see appendix.

The first part of Lemma 2 says that if the foreign price control lies in the interval $0 \leq p_c < p_c^*$ a tightening of the price control requires the home country to relax its ERP policy if the firm is to continue to export. When $p_c < p_c^*$, the foreign price control is below the firm's optimal price $p_F^\delta(\delta^*)$ for the foreign market. A tighter price control lowers the firm's global profit under exporting, so the home's ERP policy has to be relaxed to offset the negative effect on the firm's incentive to export.

This result is noteworthy since it shows that, over the range $0 \leq p_c < p_c^*$, the foreign price control generates an international spillover by undermining the home country's ability to implement its most desirable ERP policy. Indeed, $\delta(p_c)$ tends to infinity as p_c falls to zero: an extremely stringent price control ($p_c \approx 0$) translates into a zero home price for any finite δ, so that there exists no ERP policy that can provide the firm sufficient incentive to export.

The second part of Lemma 2 highlights a region (i.e. $p_c^* \leq p_c \leq 1$) where home's ERP policy actually becomes *tighter* as the foreign price control becomes more stringent. When $p_c \geq p_c^*$, the foreign price control is *above* the firm's optimal price for the foreign market.[16] Thus, a tightening of the price control actually increases the firm's incentive to export which in turn allows the home country to tighten its ERP policy. Thus, when $p_c^* \leq p_c \leq 1$, prices in both countries fall if the foreign price control becomes tighter. Since the firm's total profit remains unchanged (i.e. continues to equal π_H^*) while consumers in both countries gain from a reduction in p_c, *it is Pareto improving to lower* p_c *as long as* $p_c^* \leq p_c$. Finally, the third inequality of Lemma 2 says that $\delta(p_c)$ is convex in p_c, indicating that the home's ERP policy must adjust to a larger extent as the price control abroad becomes stricter. This property of $\delta(p_c)$ plays an important role in determining the jointly optimal pair of policies, an issue that we address in section 2.1 below.

Part (iv) of Lemma 2 points out that even if the foreign price control is set at the firm's optimal monopoly price (i.e. $p_c = p_F^*$) for that market, the home country's ERP policy is more lax than the export inducing policy in the absence of a price control. The intuition for this is that in the absence of a foreign price control, the home country's optimal ERP

[16] We show below that such a price control can indeed arise in Nash equilibrium.

policy actually causes the foreign price to exceed the firm's optimal monopoly price (i.e. $p_F^\delta(\delta^*) > p_F^*$) for that market so that, in the presence of an endogenous ERP policy in the home country, a foreign price control set at p_F^* actually binds for the firm.

3.2 Equilibrium

It is clear that, given p_c, the optimal ERP for the home country is the export inducing policy $\delta(p_c)$. We now characterize the foreign country's optimal price control given a certain ERP policy in the home country. If the firm does not export, the foreign country has no access to the good and its welfare equals zero. Moreover, conditional on the firm exporting, a more lax price control policy is counter-productive as it simply raises the local price. Hence, for a given ERP policy, the foreign country picks the lowest possible price control that just induces the firm to export. For $p_c \in [0, p_c^*]$ since the $\delta(p_c)$ function is monotonically decreasing in p_c, its inverse $p_c(\delta)$ yields the best response of the foreign country to a given ERP policy of the home country. For $p_c \in [p_c^*, 1]$ since the $\delta(p_c)$ function is increasing in p_c, there exist two possible price controls that yield the firm the same level of global profit for any given ERP policy. However, since it is optimal for the foreign country to pick the lower of these two price controls, the best response of the foreign country can never exceed p_c^*. Thus, $p_c(\delta)$ is strictly decreasing in δ so that foreign's best response curve coincides with the downward sloping part of the $\delta(p_c)$ curve. This implies that all points to left of p_c^* on the $\delta(p_c)$ curve (plotted in Figure 2) constitute a Nash equilibrium.

[Figure 2 here]

We can state the following:

Proposition 4: *Any pair of export inducing policies $\{p_c, \delta\}$ where $p_c \leq p_c^*$ and $\delta \geq \delta^*$ constitutes a Nash equilibrium. In all Nash equilibria, the firm's global profit equals π_H^*. For Nash equilibria in which $p_c \in [0, p_F^*]$, the home price declines in the foreign price control (i.e. $\partial p_H^\delta(p_c)/\partial p_c = \partial[\delta(p_c)p_c]/\partial p_c < 0$) whereas for Nash equilibria in which $p_c \in [p_F^*, p_c^*]$, it increases with it (i.e. $\partial p_H^\delta(p_c)/\partial p_c \geq 0$).*[17] *Furthermore, $p_H^\delta(p_c \to 0) = p_H^*$.*[18]

[17] It is worth noting that there also exist Nash equilibria where the foreign country's equilibrium price control lies above the optimal monopoly price for its market. Obviously, this happens when the home sets a very stringent ERP policy so that a high price in the foreign market is necessary to induce the firm to export.

[18] As $p_c \to 0$ the home price converges to the monopoly price p_H^* because the home country is forced to completely drop its ERP policy (i.e. $\delta^*(p_c)$ tends to $+\infty$) when $p_c \to 0$.

Proposition 4 says that when the foreign price control is lax (i.e. $p_F^* < p_c \leq p_c^*$), a tightening of the foreign price control (i.e. a reduction in p_c) lowers the home price through the adjustment of home's ERP policy whereas when the price control is relatively stringent ($p_c \leq p_F^*$), a further decline in p_c raises the home price. The response of home's ERP policy to changes in the foreign price control (described in Proposition 4) is crucial to understanding the non-monotonicity of $p_H^\delta(p_c)$. To see why, note that

$$\frac{\partial p_H^\delta(p_c)}{\partial p_c} = \delta(p_c) + p_c \frac{\partial \delta(p_c)}{\partial p_c} \tag{11}$$

so that if $\partial\delta(p_c)/\partial p_c \geq 0$ then the home price would necessarily increase with the foreign price control since $\delta(p_c) > 0$. However, as Lemma 2 notes $\partial\delta(p_c)/\partial p_c < 0$ whenever $0 < p_c < p_c^*$, i.e., for this range of the foreign price control, the home country tightens its ERP policy as the foreign price control relaxes. This adjustment in the home's ERP policy tends to reduce the home price p_H^δ. Next, note that since $\partial^2\delta(p_c)/\partial p_c^2 \geq 0$, the home's ERP policy adjusts to a larger extent when the foreign price control is stricter. Indeed, we can see this more directly by considering the elasticity of home's ERP policy with respect to the foreign price control, which is defined as

$$\varepsilon_\delta \equiv -\frac{\partial \delta(p_c)}{\partial p_c} \frac{p_c}{\delta}$$

Observe that

$$\frac{\partial p_H^\delta(p_c)}{\partial p_c} \leq 0 \Longleftrightarrow \varepsilon_\delta \geq 1 \tag{12}$$

It is straightforward to show that

$$\varepsilon_\delta \geq 1 \text{ iff } p_c \leq p_F^* \tag{13}$$

As a result, the home price declines in p_c for all $p_c \in (0, p_F^*]$ whereas it increases with it for $p_c \in (p_F^*, p_c^*)$.

We have shown that policy interaction between the two countries leads to multiple Nash equilibria that lie along the downward sloping part of the $\delta(p_c)$ curve. We now show that these equilibria have different welfare properties.

3.3 Welfare

Recall that the firm's total profit does not play a role in the welfare analysis, since in any Nash equilibrium the firm's profit equals its monopoly profit under no exporting (π_H^*), i.e., the firm is indifferent between selling only at home and selling in both markets. This is a convenient property which allows us to focus on each country's consumer surplus when discussing welfare. We directly state the main result and then explain its logic:

Proposition 5:

(i) For all Nash equilibria in which $p_c \in (p_F^*, p_C^*]$ *tightening the foreign price control (i.e. reducing* p_c*) makes both countries better off.*

(ii) For $p_c \in (0, p_F^*]$*, reductions in* p_c *make the foreign country better off at the expense of the home country.*

(iii) There exists a unique pair of policies $\{\delta^w, p_c^w\}$ *that maximizes joint welfare, where*

$$p_c^w < p_F^* \text{ and } \delta^w > \delta^*.$$

Figure 2 is useful for explaining the logic of Proposition 5. This figure plots the $\delta(p_c)$ curve in (p_c, δ) space. The equilibrium in the absence of a foreign price control is given by point **A1** in Figure 2 the coordinates of which are (p_c^*, δ). To understand the intuition behind Proposition 5 first consider the case where $p_c \in (p_F^*, p_c^*]$. Over this range, a reduction in the foreign price requires the home country to make its ERP policy less stringent ($\frac{\partial \delta(p_c)}{\partial p_c} < 0$) to ensure that the firm's export incentive is preserved. But since $\frac{\delta(p_c)}{\partial p_c}$ is relatively small in magnitude in this region, the direct decline in p_c dominates the increase in $\delta(p_c)$ so that $p_H^\delta(p_c) = \delta(p_c)p_c$ declines as p_c falls. Thus, *both countries gain* from a tighter foreign price control when $p_c \in (p_F^*, p_c^*]$.

When $p_c \in (0, p_F^*]$, any further reductions in the foreign price control require a sharp increase in the home's ERP policy in order to preserve the firm's export incentive. Here, a tightening of the foreign price control increases the home price (due to the sharp adjustment in its ERP policy) so that the home country loses while the foreign country gains from reducing p_c.

It is clear that a jointly optimal pair of policies must lie on the $\delta(p_c)$ curve in Figure 2. Any combination of policies above this curve lowers welfare by creating an international price differential while any policy pair below the curve has the same effect by inducing the firm to not export. Furthermore, from the above discussion it is also clear that any jointly optimal price control has to lie in the range $(0, p_F^*]$. The jointly optimal pair of policies solves the following problem

$$\max_{\delta,\ p_c} w(\delta p_c,\ p_c) \tag{14}$$

Substituting $\delta(p_c)$ into (14) and maximizing over p_c yields the jointly optimal price control:[19]

$$p_c^w = p_F^* \left[1 - \theta(n, \mu)\right] \tag{15}$$

where

$$\theta(n, \mu) = \frac{1}{\sqrt{1 + n\mu}} \tag{16}$$

Observe that

$$\frac{p_F^* - p_c^w}{p_F^*} = \theta(n, \mu) \tag{17}$$

Since $0 < \theta(n, \mu) \leq 1$, the jointly optimal price control is strictly smaller than the firm's monopoly price for the foreign market (i.e. $p_c^w < p_F^*$). Indeed, $\theta(n, \mu)$ measures the percentage reduction in the firm's monopoly price abroad that is jointly optimal to impose. Since $\theta(n, \mu)$ is decreasing in n as well as μ, the more lucrative the firm's domestic market (i.e. the higher are n or μ), the less binding is the foreign price control. When either n or μ become arbitrarily large, $\theta(n, \mu)$ approaches 0 so that it becomes jointly optimal to let the firm charge its monopoly price in the foreign market. The jointly optimal ERP policy δ^w can be recovered by substituting $p_c^w = p_c^w$ in equation (10). Since $p_c^* < p_F^*$ we must have $\delta^w > \delta^*$, i.e., the jointly optimal ERP policy in the presence of an optimally chosen foreign price control is *more lax* than when the foreign price control is absent. Thus, the foreign price control allows the home country to also implement a more desirable ERP policy provided the two countries coordinate their policies.

3.4 Discussion: timing of moves

Since the time horizon for the implementation and adjustment of an ERP policy may not be same as that for a price control, in this section we discuss alternative timing scenarios where one of the countries moves first.

Suppose home can commit to an ERP policy before foreign chooses its price control. It is clear that if home has the first move then it will choose its most preferred point on the $\delta(p_c)$ curve in Figure 2. From Proposition 5, this point is given by $(p_F^*, \delta(p_F^*))$ and it is denoted by point **H** on Figure 2, which lies Southeast of the welfare maximizing policy pair (p^w, δ^w) denoted as point **W**. The reason point **H** is home's most preferred policy pair is that home price $p_H^\delta(p_c) = \delta(p_c)p_c$ declines in p_c when $p_c \in (0, p_F^*]$ whereas it increases with it for $p_c \in (p_F^*, p_c^*)$ so that, subject to the firm exporting, home price is minimized at point

[19] It is easy to verify that the second-order condition holds at p_c^*.

H. Intuitively, since the firm has the strongest incentive to export when its foreign price equals the optimal monopoly price p_F^*, by choosing to implement the policy $\delta(p_F^*)$ home can induce foreign to pick the price control p_F^*. In the absence of a foreign price control, point **H** is unattainable for home since if it were to announce the policy $\delta(p_F^*)$ the firm would export and its price abroad would equal $p_F^\delta(\delta = \delta(p_F^*)) > p_F^*$ and its total profit would exceed π_H^*. But when the foreign price control exists and responds endogenously to home's ERP policy, home can implement $\delta(p_F^*)$ knowing that foreign will impose the lowest price consistent with the firm exporting, which equals p_F^*. Thus, when it moves first, home is able to utilize the foreign price control to obtain a level of welfare that cannot be achieved in its absence.

Since the foreign price equals p_F^*, from the viewpoint of foreign consumers the outcome when home moves first coincides with that which obtains when the firm is completely free to set its optimal prices in both markets. Even though the firm charges its optimal monopoly price p_F^* abroad when home implements $\delta(p_F^*)$, the ability of home to commit to an ERP policy also makes foreign consumers *better off* relative to the case where there is no price control because the foreign price under δ^* is strictly higher than that under $\delta(p_F^*)$ (i.e. $p_c^* > p_F^*$).

Further note that $\delta(p_F^*) > \delta^*$: i.e. when it moves first, home's most preferred ERP policy in the presence of a foreign price control is *more lax* than its ERP policy when there is no price control abroad. The intuition for this result is clear: absent the foreign price control, the firm raises its price abroad to p_c^* (which exceeds p_F^*) forcing home to set a stricter ERP policy to keep the domestic price low while preserving the firm's export incentive.

Finally, observe that $\delta(p_F^*) < \delta^w$ so that when moving first home selects an ERP policy that is more stringent than the welfare maximizing policy δ^w because it ignores the effect of its decision on foreign consumers.

Now suppose foreign selects the price control before home chooses its ERP policy. In such a scenario, foreign would set its price control equal to the marginal cost of production (i.e. $p_c \simeq 0$) knowing that home will then impose no ERP policy on the firm in order to induce it to export. Price at home would then equal the optimal monopoly price p_F^*. Thus, the outcome when foreign chooses the price before home chooses its ERP policy coincides with that which obtains when home has no ERP policy in place at all.

4 Lack of patent protection abroad

We now extend the model to a scenario where the home firm's patent is not protected abroad. As in Saggi (2013), the lack of foreign patent protection is assumed to result in the establishment of a competitive generic industry that produces a product whose quality equals γ where $\gamma \in [0,1]$. The larger is γ, the closer is the perceived quality of the generic to that of the patented good so that γ captures the intensity of generic competition faced by the firm. Since the generic industry is competitive in nature, the price of the generic equals its marginal cost of production (which equals zero). Note, however, that since the firm's patent is protected at home, generic sales are limited to the foreign market.

4.1 Foreign patent protection and home's ERP policy

Given a price p for the firm's patented product, foreign consumers can be partitioned into two groups: those in the range $[0, t_h(p;\gamma)]$ buy the low quality whereas those in $[t_h(p;\gamma), 1]$ buy the high quality where $t_h(p;\gamma) = p/(1-\gamma)$ defines the marginal consumer who is indifferent between the patented good and the generic. If not constrained by government policies, the patent-holder chooses its price p to maximize

$$\max \pi_I(p;\gamma) = p[1 - t_h(p;\gamma)]$$

which yields the firm's profit maximizing price when facing generic competition as

$$p_F^*(\gamma) = (1-\gamma)/2 = (1-\gamma)p_F^*$$

We first investigate how the home country's optimal ERP policy changes due to the lack of patent protection abroad. When facing the ERP policy constraint $p_H \leq \delta p_F(\gamma)$, if the firm sells in both markets it solves

$$\max_{p_H,\, p_F} \pi(p_H, p_F;\gamma) = \frac{n}{\mu} p_H(\mu - p_H) + p_F(1 - \frac{p_F}{1-\gamma}) \text{ subject to } p_H \leq \delta p_F$$

which yields the optimal prices as

$$p_H^\delta(\gamma) = \frac{\mu\delta(n\delta+1)(1-\gamma)}{2[n\delta^2(1-\gamma)+\mu]} \text{ and } p_F^\delta(\gamma) = p_H^\delta(\gamma)/\delta \tag{18}$$

It is straightforward to shown that

$$\frac{\partial p_H^\delta}{\partial \gamma} < 0 \text{ and } \frac{\partial p_F^\delta}{\partial \gamma} < 0$$

That is, given that the firm sells in both markets when facing an ERP policy at home, generic competition abroad lowers prices in both markets, with the home price falling due to the constraint imposed by the ERP policy. Furthermore, the firm's global profit now becomes

$$\pi^{\delta}(\gamma) = \frac{\mu(n\delta + 1)^2(1-\gamma)}{4[n\delta^2(1-\gamma) + \mu]} \tag{19}$$

As one might expect,

$$\frac{\partial \pi^{\delta}(\gamma)}{\partial \gamma} < 0$$

i.e. the stronger the intensity of generic competition abroad, the lower the firm's global profit. This simple observation has important implications for the determination of home's optimal ERP policy. Following our earlier logic, home sets its ERP policy in order to just induce the firm to export. Solving $\pi^{\delta}(\gamma) = \pi_H^*$ for δ yields the export inducing policy in the presence of generic foreign competition as:

$$\delta^*(\gamma) = \frac{1}{2}\left[\frac{\mu}{1-\gamma} - \frac{1}{n}\right] \tag{20}$$

We can now state:

Proposition 6: *The lack of patent protection in the foreign market induces the home country to relax its ERP policy: $\delta^*(\gamma) > \delta^*$ for all $\gamma > 0$. Furthermore, the stronger the intensity of generic competition abroad, the more lax is home's ERP policy: $\partial\delta^*(\gamma)/\partial\gamma > 0$.*

The intuition for Proposition 6 is clear: the more intense is generic competition abroad, the lower is the firm's export profit for any given ERP policy which in turn requires home to loosen its ERP policy in order to maintain the firm's export incentive. Proposition 6 fits well with the observed nature of ERP policies in the world since countries that are chosen as references by EU countries tend to other EU countries that tend to maintain relatively high levels of patent protection.

Since the ratification of TRIPS by the WTO, many member countries have had to strengthen their patent protection and eliminate local imitation in order to make their patent regimes TRIPS compliant. What are the effects of shutting down foreign imitation on prices and welfare when the home's ERP policy adjusts endogenously? Given that the foreign price control is absent, shutting down foreign imitation moves the equilibrium ERP policy from $\delta^*(\gamma)$ to δ^* while the equilibrium price in the foreign market increases from $p_c^*(\gamma)$ to p_c^*. Shutting down imitation hurts the foreign country through two channels: the price of the high quality patented product in its market increases and local consumers lose access to the generic product.

Now consider the effect of TRIPS on the home country. The home price in the presence of foreign imitation equals

$$p_H^*(\delta^*) = \delta^*(\gamma)p_c^*(\gamma)$$

which implies

$$\frac{\partial p_H^*(\delta^*)}{\partial \gamma} = \frac{\partial \delta^*(\gamma)}{\partial \gamma}p_c^*(\gamma) + \delta^*(\gamma)\frac{\partial p_c^*(\gamma)}{\partial \gamma}$$

where

$$\frac{\partial \delta^*(\gamma)}{\partial \gamma} > 0 \text{ and } \frac{\partial p_c^*(\gamma)}{\partial \gamma} < 0$$

However, it turns out that

$$\frac{\partial p_H^*(\delta^*)}{\partial \gamma} > 0$$

i.e. *the equilibrium price at home increases with the intensity of foreign competition.*

Since TRIPS eliminates foreign competition (i.e. lowers γ to 0), the equilibrium price in the home market falls due to the endogenous tightening of the home's ERP policy that occurs in response. Intuitively, by increasing the firm's profit abroad and therefore its incentive to export, TRIPS allows the home country to tighten its ERP policy to a degree that the domestic price actually declines when foreign imitation is eliminated. Thus, home consumers necessarily gain from TRIPS and, in fact, it turns out that their gain exactly offsets the loss of foreign consumers so that aggregate welfare is unaffected:

Lemma 3: *Shutting down foreign imitation lowers the equilibrium price in the home market whereas it raises it abroad while having no effect on aggregate welfare.*[20]

4.2 Price control without patent protection

We are now ready to consider policy interaction between home's ERP policy (δ) and foreign's price control (p_c) in the presence of generic competition abroad. Following earlier derivations, we can directly find the export inducing ERP policy as a function of the foreign price control:

$$\delta(p_c;\gamma) = \frac{\mu}{2p_c} - \frac{\sqrt{\eta\mu p_c(1-\gamma)(1-\gamma-p_c)}}{2\eta p_c(1-\gamma)}$$

where $\partial\delta(p_c,\gamma)/\partial\gamma > 0$. In other words, the locus of home's export inducing ERP policy $\delta(p_c;\gamma)$ as a function of foreign's price control in the presence of foreign competition lies

[20] If home's ERP policy were to be absent, the foreign country would set its price control at zero (i.e. marginal cost of production of the patent good) so that, once again, TRIPS would have no welfare effects since, due to the higher quality of the patented good, consumers abroad would strictly prefer it to the generic when both are sold at the same price.

above the locus $\delta(p_c)$ when such competition is absent. The intuition is plain: competition in the foreign market lowers export profits and, for a given foreign price control, home's ERP policy has to be relaxed to preserve the firm's export incentive.

The second effect of foreign imitation is to lower the threshold level of price control above which the export inducing ERP is increasing in p_c. It is straightforward to show that $\partial\delta(p_c;\gamma)/\partial p_c < 0$ for $0 < p_c < p_c^*(\gamma)$ where

$$p_c^*(\gamma) \equiv p_F^\delta(\delta^*, \gamma) = \frac{n\mu(1-\gamma)}{1+n\mu-\gamma}$$

and $\lim_{p_c \to 0} \delta(p_c;\gamma) = \infty$. Furthermore, $\partial\delta(p_c;\gamma)/\partial p_c \geq 0$ for $p_c^*(\gamma) \leq p_c \leq 1/(1-\gamma)$ with $\partial\delta(p_c;\gamma)/\partial p_c = 0$ for $p_c = p_c^*(\gamma)$.

Consider now the jointly optimal pair of policies in the presence of foreign competition. As before, it can be shown that the jointly optimal price control in the presence of foreign competition is given by

$$p_c^w(\gamma) = p_F^*(\gamma)[1-\theta(n,\mu,\gamma)] \text{ where } \theta(n,\mu,\gamma) \equiv \frac{1-\gamma}{\sqrt{1+n\mu-\gamma}} \tag{21}$$

The above can be rewritten as

$$\frac{p_F^*(\gamma) - p_c^w(\gamma)}{p_F^*(\gamma)} = \theta(n,\mu,\gamma) \tag{22}$$

so that $\theta(n,\mu,\gamma)$ measures the degree to which it is jointly optimal to constrain the firm's foreign price when it faces generic competition in the foreign market. Note that $\partial\theta(n,\mu,\gamma)/\partial\gamma < 0$ so that, *the stronger the intensity of generic foreign competition, the weaker the need for constraining the firm's price abroad.* Furthermore since $\theta(n,\mu,1) = 0$, the socially optimal price control becomes non-binding on the firm: when the quality of the foreign generic equals that of the patented product, the firm's foreign price $p_F^*(\gamma)$ equals its marginal cost (i.e. zero).

However, since $p_F^*(\gamma) < p_F^*$ for all $\gamma > 0$ we obtain the following:

Proposition 7: *The jointly optimal price control $p_c^w(\gamma)$ decreases in the intensity of foreign competition γ, i.e. $\partial p_c^w(\gamma)/\partial\gamma \leq 0$ whereas the corresponding ERP policy $\delta^w(\gamma) = \delta(p_c^w;\gamma)$ increases in it, i.e. $\partial\delta^w(\gamma)/\partial\gamma \geq 0$. Furthermore, the home price under jointly optimal policies is increasing in the intensity of foreign competition, i.e., $\partial p_H^w(\gamma)/\partial\gamma \geq 0$ where $p_H^w(\gamma) = \delta^w(\gamma)p_c^w(\gamma)$.*

We are now in a position to examine the consequences of shutting down imitation abroad when both policies (i.e. an ERP policy at home and a price control abroad) are in place .

4.3 If foreign country must offer patent protection

It is straightforward to show that if the domestic ERP policy and the foreign price control were to remain fixed then the shutting down of foreign imitation makes home better off by increasing the firm's total profit while it lowers joint welfare by creating a deadweight loss: foreign consumers lose access to the low quality good and their loss dominates the firm's gain. However, the effect of TRIPS when both home's ERP policy and foreign's price control are endogenous are a bit more subtle. In Figure 3, the equilibrium pair of policies in the presence of foreign imitation lie on the higher curve labelled $\delta(p_c;\gamma)$ whereas, in its absence, they lie on the lower curve $\delta(p_c)$). Thus, if the foreign country is forced to shut down imitation, the equilibrium pair of policies could, in principle, change from any point on the $\delta(p_c;\gamma)$ curve to any point on the $\delta(p_c)$ curve.

[Figure 3 here]

The following lemma (proof in the appendix) is a useful first-step for understanding the effects of TRIPS when both policies can adjust:

Lemma 4: *Shutting down foreign imitation while holding constant the foreign price control increases joint welfare.*

Lemma 4 follows from the following:

$$\frac{\partial w(\gamma;p_c)}{\partial\gamma} = -\frac{\mu\eta p_c^2}{4(1-\gamma)\sqrt{\mu\eta p_c(1-\gamma)(1-\gamma-p_c)}} < 0$$

Intuitively, imitation plays two important roles in the model. One, it provides variety to foreign consumers. Two, it helps lower the price of the patented good through competition provided by the generic. On the negative side, imitation makes the home country implement a more lax ERP policy which lowers welfare by increasing the international price differential. Holding the price of the patented good constant helps minimize the negative welfare effect of shutting down imitation since the adverse price effect in the foreign market is no longer operative. As a result, the positive effect of a more stringent ERP policy made possible by the elimination of imitation ends up dominating, leading to an overall welfare gain.

We are now ready to examine how joint welfare under the jointly optimal policy pair $\{\delta^w(\gamma), p_c^w(\gamma)\}$ varies with the intensity of foreign competition. We can state:

Proposition 8: *Joint welfare under the optimal policy pair $\{\delta^w(\gamma), p_c^w(\gamma)\}$ decreases with the intensity of generic foreign competition created by the lack of patent protection abroad: $\partial w(\delta^w(\gamma), p_c^w(\gamma))/\partial\gamma < 0$.*

This result has an important policy implication: if the two countries could jointly select their respective policies and also decide whether or not to allow foreign imitation then they would choose to not allow it (i.e. set $\gamma = 0$) and they would implement the policy pair $\{\delta^w, p_c^w\}$, i.e. they would prefer point **W1** on the $\delta(p_c)$ curve to the point **W0** on the $\delta(p_c; \gamma)$ curve in Figure 3. However, even under such coordination, the foreign country loses from eliminating imitation: not only does the price of the high quality product increase in its market from $p_c^w(\gamma)$ to p_c^w, its consumers also lose access to the low quality generic product. The home country gains because the price in its market drops due to a tightening of its ERP policy, which is also the reason that joint welfare increases.

Proposition 8 is supportive of TRIPS but it also rests on a degree of international coordination that may not be always feasible. It is worth asking if there exist a less stringent set of circumstances under which the elimination of generic foreign competition can increase total welfare. This is particularly so because TRIPS does not involve any international coordination over price controls or ERP policies.[21] In this context, it is worth noting that the welfare result in *Proposition 8 would continue to hold even if the two countries could coordinate their choices over patent protection abroad and only one of the other two policies (i.e. home's ERP policy or the foreign price control).* To see why, suppose the two countries coordinate their decisions over patent protection abroad and home's ERP policy, leaving the choice of the price control entirely in the hands of the foreign country. Then, given that coordination precedes the setting of the price control, they can still attain the welfare maximizing outcome by agreeing to implement patent protection abroad and setting the home's ERP policy at δ^w. Then, at the next stage, the foreign country would find it optimal to select the price control p_c^w since this is the lowest price at which the firm would choose to export. An analogous logic applies for the case where they coordinate over patent protection and foreign's price control, leaving the home free to set its own ERP policy.

We now discuss the effects of TRIPS when policy coordination is completely absent. The following result argues that in the absence of policy coordination, TRIPS has the

[21] While TRIPS does not explicitly mention ERP policies, Article 6 of TRIPS states that "nothing in this Agreement shall be used to address the issue of the exhaustion of intellectual property rights." Exhaustion policies are quite similar to ERP policies since they determine whether or not attempts at international price discrimination on the part of holder of IPRs can be undone by the parallel trade across countries. Indeed, it appears that TRIPS essentially leaves countries free to use ERP policies and other price control measures when these are deemed necessary for curtailing the market power enjoyed by holders of IPRs or for achieving domestic objectives such as safeguarding public health by making necessary pharmaceuticals more widely available.

potential to increase aggregate welfare although it does not necessarily do so:

Proposition 9: *Given an initial pair of policies $\{p_c^0, \delta^0\}$ on the $\delta(p_c; \gamma)$ curve, there exists an interval of price controls $[p_c^1, p_c^2]$ on the $\delta(p_c)$ curve, where $p_c^0 \in [p_c^1, p_c^2]$, such that welfare over $[p_c^1, p_c^2]$ is strictly higher than at $\{p_c^0, \delta^0\}$.*

Figure 4 illustrates Proposition 9.

[Figure 4 here]

Suppose foreign imitation is allowed and let $\mathbf{E0} \equiv \{p_c^0, \delta^0\}$ be the initial equilibrium point on the $\delta(p_c; \gamma)$ curve such that $p_c^0 > p_c^w$ (which is greater than $p_c^w(\gamma)$). If the foreign country is forced to shut down imitation, the new equilibrium pair of policies could in principle lie anywhere on the $\delta(p_c)$ curve. Suppose, for the moment, that the new equilibrium **E1** on the $\delta(p_c)$ curve lies vertically below **E0** (i.e. the foreign price control remains fixed at p_c^0). Then, from Lemma 4 it follows that welfare must be higher at **E1** relative to **E0**. Note also that, starting at **E1**, welfare declines as the foreign price control is increased since we move further away from the welfare-maximizing foreign price p_c^w. Furthermore, world welfare at points **A0** and **A1** is equal since these are cases where the foreign price control is not binding (or missing) (see Lemma 2). Thus, we have

$$w(\mathbf{A0}) = w(\mathbf{A1}) < w(\mathbf{E0}) < w(\mathbf{E1})$$

By continuity, there must exist a unique point **E2** on the $\delta(p_c)$ curve lying between **E1** and **A1** that yields the same welfare as point **E0** on the $\delta(p_c; \gamma)$ curve. Any pair of policies between **E1** and **E2** on the $\delta(p_c)$ curve yields strictly higher welfare than **E0** on the $\delta(p_c; \gamma)$ curve. On the other hand, starting at point **E1**, as the price control is reduced along the $\delta(p_c)$ curve, we eventually hit a point **E3** where the price control is so low that welfare at **E2** is the same as that at **E0**. We can be sure that **E2** exists because at welfare at **E0** is strictly higher than it is at the limiting case where the price control equals zero. Thus, we have shown that, given $p_c^0 > p_c^w$, there exists a range of policy pairs without imitation that yield higher welfare than the initial equilibrium **E0** with imitation.[22]

4.4 Global generic competition

It is worth asking how our major conclusions change if the product sold by the firm is off-patent so that it faces generic competition in both markets. This question is useful for

[22] To avoid redundancy we do not discuss the cases where $p_c^w(\gamma) < p_c^0 < p_c^w$ or $p_c^0 < p_c^w(\gamma)$. The arguments for why Proposition 9 holds in these cases are analogous to those presented above.

examining whether and how the optimal ERP policy for products that are under patent differs from those that are off patent.

Suppose the firm faces generic competition of quality γ in both markets.[23] When the product is not under patent, questions related to patent protection are moot. Consider then the home's optimal ERP policy when generic competition exists in both markets. Using earlier derivations, the firm's optimal monopoly prices in the two markets are $p_F^*(\gamma) = (1-\gamma)/2$ and $p_H^*(\gamma) = \mu p_F^*(\gamma)$. Using these prices and following previous derivations, it is straightforward to show that the home country's optimal ERP policy continues to be defined by Proposition 2. This has an interesting implication: while the lack of patent protection in only the foreign market forces home to weaken its ERP policy (Proposition 6), the lack of such protection in both markets (i.e. the product coming off patent given that it has been protected in both markets) does not. Intuitively, in our model, generic competition in both markets causes optimal prices to decline in both markets in a way that its optimal degree of price discrimination does not change, i.e., $p_H^*(\gamma)/p_F^*(\gamma) = p_H^*/p_F^* = \mu$. As a result, since the optimal ERP policy targets international price discrimination, it too remains unaltered. For analogous reasons, we find that the jointly optimal price control continues to be defined by equation (15) when generic competition exists in both markets.

5 Price bargaining

We now discuss the case where the price abroad is a result of bargaining between the foreign government and the firm. The timing of moves is as follows. First, home chooses its ERP policy. Next, the firm and the foreign government bargain over price. We utilize the generalized Nash bargaining solution as the outcome of the bargaining subgame where the firm's payoff under the disagreement point equals π_H^* (i.e. its monopoly profit at home) while that of the foreign government equals zero. We first discuss the case where the two parties cannot use transfers or side payments and then the case where they can do so.

5.1 Bargaining without transfers

It is clear that, given the ERP policy set by home, the range of prices over which the firm and the foreign government can find a mutually acceptable price is given by $[p_c(\delta),\, p_F^\delta(\delta)]$

[23]In other words, we assume that the generic market is a single global market. It is straightforward to extend the model to allow for generic local competition in each country. To avoid redundancy, we do not discuss this case here.

where the $p_c(\delta)$ is the foreign government's most preferred price since it maximizes local consumer surplus $cs_F(p)$ (subject to the price being high enough to induce the firm to export) whereas $p_F^\delta(\delta)$ is that of the firm since it maximizes its global profit $\pi^\delta(p)$.

The price under Nash bargaining solves

$$\max_p \beta \ln[cs_F(p)] + (1-\beta)\ln[\pi^\delta(p;\delta) - \pi_h^*] \tag{23}$$

where $\beta \in [0,1]$ can be interpreted as the bargaining power of the foreign government relative to the firm. The first order condition for this problem is

$$\frac{\beta}{cs_F(p)}\frac{dcs_F(p)}{dp} + \frac{1-\beta}{\pi^\delta(p;\delta) - \pi_h^*}\frac{d\pi^\delta(p;\delta)}{dp} = 0$$

Using the relevant formulae, this first order condition can be rewritten as

$$\frac{2\beta}{1-p} = \frac{A(\delta,p)(1-\beta)}{pA(\delta,p) - n\mu/4}$$

where

$$A(\delta,p) \equiv [(n\delta+1) - [2(n\delta^2+\mu)]\frac{p}{\mu}]$$

It is straightforward to show that the solution to this equation is a price $p(\beta,\delta) \in [p(1,\delta), p(0,\delta)]$ where $p(1,\delta) = p_c(\delta)$; $p(0,\delta) = p_F^\delta(\delta)$; and $\partial p(\delta,\beta)/\partial\beta < 0$.

Now consider home's ERP policy decision. Home sets its ERP policy taking into account the price $p(\delta,\beta)$ that emerges from the bargaining that follows. When $\beta = 1$, the home's ERP policy is given by point **H** in Figure 2. In this case, since the firm has zero bargaining power, the foreign government effectively controls the price and the home's most preferred policy is set to ensure that the firm charges its optimal monopoly price abroad and therefore has the strongest incentive to export. When $\beta = 0$, the firm is free to pick any price abroad and home is able to set a much more stringent ERP policy and the equilibrium outcome is denoted by point **A1** in Figure 2. Observe that home is strictly better off when the bargaining power lies totally in the hands of the foreign government relative to the case where it lies with the firm. In fact, as argued earlier, total world welfare is also higher in the former scenario. When bargaining power is split between the two parties, the firm earns strictly positive rents in the bargaining subgame and $p(\delta,\beta) > p_c(\delta)$. At the first stage, home simply chooses its most preferred point on this curve which will generally differ from point **A1**.

5.2 If transfers can be used

Now consider the case where the firm and the foreign government can use transfers when bargaining over price so that the foreign price is chosen to maximize the joint welfare of the two parties.[24] Thus, given home's ERP policy, the foreign price is chosen to maximize the sum of the firm's global profit and consumer surplus abroad:

$$\max_p S(p) \equiv \pi^\delta(p) + cs_F(p)$$

It is straightforward to show that the solution to the above problem is

$$p^b(\delta) = \frac{n\mu\delta}{\mu + 2n\delta^2} \text{ where } 0 < p^b(\delta) < 1$$

Observe that $p^b(\delta)$ is increasing in n and μ. As the home's ERP policy becomes more lax, it is optimal to lower the price abroad whereas when the home market becomes more lucrative for the firm (either due to an increase in n or μ), the two parties agree to a higher price in the foreign market. Furthermore, note that

$$\frac{\partial p^b(\delta)}{\partial \delta} < 0 \text{ iff } \delta < \delta_m \equiv \sqrt{\frac{\mu}{2n}}$$

The non-monotonicity of the jointly optimal foreign price $p^b(\delta)$ in δ can be understood as follows: when δ is small (i.e. near 1), the price in the home market is quite far from the firm's optimal home price so that its global profit is well below its maximum value. Starting at $\delta \simeq 1$, the jointly optimal foreign price $p^b(\delta)$ increases in order to raise the firm's profit even though consumer surplus in the South declines. But once δ hits the threshold value of δ_m, the jointly optimal foreign price decreases with δ because the relatively lax ERP policy allows the firm to charge a fairly high price in the home market even though the foreign price is low. Furthermore, note that $p^b(\delta)$ goes to zero as δ approaches infinity – i.e. if there is no ERP policy at home, the two parties agree to set price equal to marginal cost.

As before, we assume that the joint surplus is allocated between the two parties according to the Nash bargaining rule. Under this rule, the firm's payoff from bargaining equals

$$\pi^B = \pi_H^* + (1 - \beta)[S(p^b(\delta)) - \pi_H^*]$$

while that of the foreign government equals

$$w_F^B = \beta[S(p^b(\delta)) - \pi_H^*]$$

[24] This assumption implies that the two parties can make side-payments to each other to ensure that the jointly optimal price is charged in the foreign market.

where $\beta \in [0,1]$ represents the bargaining power of the foreign government.

When setting its ERP policy, home takes into account that the firm will export iff its payoff from doing so is at least as large as its domestic profit in the absence of exporting: $\pi^B \geq \pi_H^*$. Given that the firm exports, home welfare is decreasing in δ so that the home's most preferred ERP policy is one where the above inequality binds, which implies

$$(1-\beta)[S(p^b(\delta)) - \pi_H^*] = 0$$

Solving this yields

$$\delta^b = \frac{\sqrt{n\mu(n\mu-2)}}{2n}$$

Proposition 10: *Suppose the firm and the foreign government choose the foreign price to maximize their joint welfare $S(p)$. Then, regardless of how the total surplus is split between the two parties, the home country's optimal ERP policy is δ^b where $\partial\delta^b/\partial\mu > 0$; $\partial\delta^b/\partial n > 0$; and $\delta^b < \delta^*$.*

Several points are worth noting about the above result. First, since the home country moves first, it is able to extract all of the surplus created by bargaining between its firm and the foreign country by setting an ERP policy at which the total surplus available to the two parties at their jointly optimal price equals the firm's profit from not exporting (i.e. $S(p^b(\delta)) = \pi_H^*$). Second, the home country is able to implement a tighter ERP policy when negotiations between the firm and the foreign country yield the efficient price $p^b(\delta)$ as opposed to the profit-maximizing price $p_F^\delta(\delta)$ (i.e. $\delta^b < \delta^*$). Since total welfare is decreasing in δ (conditional on the firm exporting), efficient price negotiations increase welfare by resulting in a more stringent ERP policy even though they make the foreign country worse off relative to a situation where the price is chosen unilaterally by the firm. Intuitively, when price is not negotiated, the home country is limited in its ability to extract rent from the firm and the foreign country since, as argued earlier, the bargained price in the absence of transfers must lie in the interval $[(p_c(\delta), p_F^\delta(\delta)]$ over the $\delta(p_c)$ curve.

6 Conclusion

This paper sheds light on the economics of external reference pricing (ERP) and how such a policy interacts with price controls abroad. We consider a model in which a single firm sells a patented product in potentially two markets (home and foreign) where, owing to differences in the structure of demand across countries, it has an incentive to price discriminate in favor of foreign consumers.

We model home's ERP policy as the degree to which the firm's foreign price is allowed to be lower than its domestic price and show that home's optimal policy is to tolerate a level of international price discrimination at which the firm is just willing to sell abroad. In other words, the home country balances the interests of local consumers against the export incentive of the firm. Intuitively, an ERP policy that is so stringent that it becomes profit maximizing for the firm to not sell abroad in order to charge its optimal monopoly price at home is never optimal for the home country. This result helps define the limits of ERP policies and it suggests that countries with large domestic markets (such as the USA or Germany) should use relatively less stringent ERP polices or else they can risk creating a situation where their firms choose to not sell abroad just so that they can charge high prices at home. We also show that an increase in foreign trade barriers induces the home country to loosen its ERP policy. The practical implication of this result is that when defining its reference basket, a country ought to pay closer attention to prices in geographically proximate markets. As we noted earlier, real world ERP policies indeed seem to have this characteristic.

Almost by design, home's ERP policy generates a negative price spillover for foreign consumers in our model. However, quite surprisingly, we find that the home country's optimal ERP policy maximizes aggregate welfare even though its sets the policy not taking into account the interests of foreign consumers. Intuitively, since the home market is larger and its consumers have a greater willingness to pay for the firm's product, it is jointly optimal to reduce international price discrimination to the lowest possible level subject to the firm selling in both markets. This is exactly what home's nationally optimal ERP policy accomplishes in equilibrium. This result suggests that while ERP policies create international price spillovers, their use does not necessarily create an argument for international coordination. It is noteworthy in this regard that the TRIPS agreement of the WTO is silent on the subject of ERP policies for patented products and it also leaves member countries free to adopt exhaustion policies of their choosing, another type of policy that creates international price spillovers via the flow of parallel trade across countries.

Another insight provided by the model is that home's ERP policy reduces the effectiveness of the foreign price control since it increases the minimum price at which the home firm is willing to export. On the flip side, the presence of an ERP policy at home leads the foreign price control to generate an international spillover for home consumers although the nature of this spillover is not necessarily negative. Indeed, we demonstrate that there exist circumstances where a tighter foreign price control raises welfare in both countries. Furthermore, our welfare analysis shows that it is jointly optimal to restrict the firm's foreign price below its optimal monopoly price for that market while simultaneously granting it greater room to price discriminate internationally than the home country is willing to provide in the absence of a price control abroad.

We also consider a scenario where the lack of patent protection abroad generates local competition from a competitively priced generic version of the patented product. Such competition induces the home country to implement a more lax ERP policy: since competition reduces foreign profits, the firm has to be given more room to price discriminate in order for it to export. Finally, we show that some degree of international cooperation – over either home's ERP policy or over foreign's price control or both – is necessary for ensuring that joint welfare increases due to the strengthening of foreign patent protection. Absent such cooperation, stronger patent protection abroad is not necessarily welfare-improving.

7 Appendix

Proof of Proposition 1

We first prove (ii). It can be shown that $\frac{\partial p_H^\delta}{\partial \delta} = \frac{\mu(2\mu n\tau\delta - n\tau\delta^2+\mu)}{2(n\tau\delta^2+\mu)^2}$. Hence the sign of $\frac{\partial p_H^\delta}{\partial \delta}$ depends on the term $2\mu n\tau\delta - n\tau\delta^2 + \mu$, which is always positive when $\delta \geq \delta^*$. This implies $\frac{\partial p_H^\delta}{\partial \delta} > 0$. As for the foreign price, we have $\frac{\partial p_F^\delta}{\partial \delta} = -\frac{\mu n\tau(n\tau\delta^2+2\delta-\mu)}{2(n\tau\delta^2+\mu)^2}$ and $\frac{\partial p_F^\delta}{\partial \delta}|_{\delta^*} = -\frac{2n^2\tau^2\mu(n\tau\mu-3)}{(1+n\tau\mu)^3}$. Since $\tau \geq 1 > \frac{3}{n\mu}$ under the assumption $\mu > 2 + \frac{1}{n}$, we have $\frac{\partial p_F^\delta}{\partial \delta}|_{\delta^*} < 0$. Moreover, $\frac{\partial p_F^\delta}{\partial \delta} < 0$ for $\delta \geq \delta^*$ because $\frac{\partial p_F^\delta}{\partial \delta}$ is decreasing in δ.

To prove (i), first note that $p_H^\delta|_{\delta=\mu} = p_H^* = \frac{\mu}{2}$. As p_H^δ increases in δ, we must have $p_H^\delta \leq p_H^*$ for $1 \leq \delta \leq \mu$. As for the foreign price, note that $\frac{\partial p_F^\delta}{\partial \delta} > 0$ for $1 < \delta < \widehat{\delta}$ and $\frac{\partial p_F^\delta}{\partial \delta} < 0$ for $\widehat{\delta} < \delta \leq \mu$ where $\widehat{\delta} = \frac{\sqrt{1+\mu n\tau}-1}{n\tau}$. This implies that p_F^δ first increases and then decreases in δ for $1 \leq \delta \leq \mu$. Moreover, since $p_F^\delta|_{\delta=1} = \frac{\mu(n\tau+1)}{2(n\tau+\mu)} > p_F^* = \frac{1}{2}$ and $p_F^\delta|_{\delta=\mu} = p_F^* = \frac{1}{2}$, it follows that $p_F^\delta \geq p_F^*$ for $1 \leq \delta \leq \mu$.

To verify (iii), we directly calculate $\frac{\partial p_H^\delta}{\partial \tau} = \frac{n\mu\delta^2(\mu-\delta)}{2(n\tau\delta^2+\mu)^2} > 0$, $\frac{\partial p_F^\delta}{\partial \tau} = \frac{n\mu\delta(\mu-\delta)}{2(n\tau\delta^2+\mu)^2} > 0$, $\frac{\partial p_H^\delta}{\partial n} = \frac{\mu\tau\delta^2(\mu-\delta)}{2(n\tau\delta^2+\mu)^2} > 0$, $\frac{\partial p_F^\delta}{\partial n} = \frac{\mu\tau\delta(\mu-\delta)}{2(n\tau\delta^2+\mu)^2} > 0$, $\frac{\partial p_H^\delta}{\partial \mu} = \frac{\mu\tau\delta^3(n\tau\delta+1)}{2(n\tau\delta^2+\mu)^2} > 0$ and $\frac{\partial p_F^\delta}{\partial \mu} = \frac{\mu\tau\delta^2(n\tau\delta+1)}{2(n\tau\delta^2+\mu)^2} > 0$.
■

Proof of Lemma 2

(i) We have $\frac{\partial \delta(p_c)}{\partial p_c} = \frac{\mu(p_c-h(p_c))}{2h(p_c)p_c^2}$, where $h(p_c) \equiv \sqrt{n\mu p_c(1-p_c)}$. Observe that the sign of $\frac{\partial \delta(p_c)}{\partial p_c}$ depends on the term $p_c - h(p_c)$. It is easy to check that $p_c - h(p_c) < 0$ when

$0 < p_c < p_c^*$, hence $\frac{\partial \delta(p_c)}{\partial p_c} < 0$. Moreover, as $p_c \longrightarrow 0$, both $\frac{\mu}{2p_c}$ and $\frac{h(p_c)}{2\eta p_c}$ tend to infinity but $\frac{\mu}{2p_c}$ converges at a faster rate. Hence, we have $\lim_{p_c \to 0} \delta(p_c) = \infty$.

(ii) By virtue of (i) as $p_c^* \leq p_c \leq 1$, $p_c - h(p_c) \geq 0$ indicating $\frac{\partial \delta(p_c)}{\partial p_c} \geq 0$. Also, substituting p_c^* into $\frac{\partial \delta(p_c)}{\partial p_c}$ we obtain $\frac{\partial \delta(p_c)}{\partial p_c}|_{p_c^*=0} = 0$.

(iii) We have $\frac{\partial^2 \delta(p_c)}{\partial p_c^2} = \frac{\mu f(p_c)}{4[h(p_c)p_c]^3}$ where $f(p_c) \equiv n\mu p_c^2 (4p_c - 3) + 4(h^3(p_c))$. It follows that the sign of $\frac{\partial^2 \delta(p_c)}{\partial p_c^2}$ depends on the sign of $f(p_c)$. To establish the result we need to show that $b(p_c) > 0$ for $0 < p_c < 1$. Note that $f(p_c)|_{p_c=0} = 0$ and $f(p_c)|_{p_c=1} = \eta\mu > 0$. Moreover, using

$$\frac{\partial f(p_c)}{\partial p_c} = 6n\mu(1 - 2p_c)[h(p_c) - p_c]$$

it is easy to see that there exist two inflection points for $f(p_c)$ at $p_c = \frac{1}{2}$ and $p_c = p_c^* = \frac{n\mu}{n\mu+1}$. It can be shown that $f(p_c) > 0$ at both these inflection points. Continuity of $f(p_c)$ implies that we must have $f(p_c) > 0$ for $0 < p_c < 1$ and therefore $\frac{\partial^2 \delta(p_c)}{\partial p_c^2} > 0$.

(iv) We have $\delta(p_F^*) - \delta^* = \frac{n\mu - 2\sqrt{n\mu} + 1}{2n} > 0$ because $n\mu > 3$. ■

Proof of Proposition 7

We have

$$\frac{\partial p_c^w(\gamma)}{\partial \gamma} = -\frac{2(1+\sigma-\gamma)\sqrt{(1-\gamma)(1+\sigma-\gamma)} - 3\sigma(1-\gamma) - 2\gamma^2 + 4\gamma - 2}{4(1+\sigma-\gamma)\sqrt{(1-\gamma)(1+\sigma-\gamma)}}$$

where $\sigma \equiv n\mu$. As the denominator of $\frac{\partial p_c^w(\gamma)}{\partial \gamma}$ is positive, to show that $\frac{\partial p_c^w(\gamma)}{\partial \gamma} \geq 0$ we only need to show the numerator of $\frac{\partial p_c^w(\gamma)}{\partial \gamma}$ is positive.

Note that the numerator of $\frac{\partial p_c^w(\gamma)}{\partial \gamma}$ can be rewritten as

$$\begin{aligned} & 2(1+\sigma-\gamma)^{\frac{3}{2}}\sqrt{(1-\gamma)} - 3\sigma(1-\gamma) - 2(1-\gamma)^2 \\ = \; & 2(1+\sigma-\gamma)^{\frac{3}{2}}\sqrt{(1-\gamma)} - (3\sigma + 2 - 2\gamma)(1-\gamma) \end{aligned}$$

As $(1-\gamma) \in [0, 1)$, we have $\sqrt{(1-\gamma)} \geq (1-\gamma)$. Also note that $\sigma \equiv n\mu > 3$ since by assumption $\mu > 2 + \frac{1}{n}$. Therefore we only need to show $d(\gamma) > 0$ for all $\sigma > 3$ and $\gamma \in [0, 1)$ where

$$d(\gamma) \equiv 2(1+\sigma-\gamma)^{\frac{3}{2}} - (3\sigma + 2 - 2\gamma)$$

We have

$$\frac{\partial d(\gamma, \sigma)}{\partial \sigma} = 3\sqrt{1+\sigma-\gamma} - 3 > 0 \text{ for any } \sigma \geq 3$$

Therefore, as long as $d(\gamma, \sigma) \geq 0$ at $\sigma = 3$, we know $d(\gamma, \sigma) \geq 0$ for all $\sigma > 3$. To this end, note that

$$d(\gamma, \sigma)|_{\sigma=3} = 2(4-\gamma)^{\frac{3}{2}} - (11 - 2\gamma)$$

is a decreasing function of γ because

$$\frac{\partial(d(\gamma,\sigma)|_{\sigma=3})}{\partial\gamma} = -3\sqrt{4-\gamma}+2 < 0$$

Hence we can obtain the desirable result if $d(\gamma,\sigma)|_{\sigma=3} \geq 0$ at $\gamma = 1$. This is indeed the case since we have

$$d(\gamma,\sigma)|_{\gamma=1,\sigma=3} = 6\sqrt{3} - 9 > 0.$$

Now note that

$$\frac{\partial\delta^w(\gamma)}{\partial\gamma} = \frac{\partial\delta^w(\gamma)}{\partial p_c^w}\frac{\partial p_c^w}{\partial\gamma}$$

We have already shown that $\frac{\partial p_c^w}{\partial\gamma} < 0$. We must also have $\frac{\partial\delta^w(\gamma)}{\partial p_c^w} < 0$ due to the fact that the ERP policy has to adjust to maintain sufficient profits for the firm to export. This completes the proof.

Finally, we can write

$$\frac{\partial p_H^w(\gamma)}{\partial\gamma} = \frac{\partial p_H^w(\gamma)}{\partial p_c^w}\frac{\partial p_c^w}{\partial\gamma}$$

We know $\frac{\partial p_H^w(\gamma)}{\partial p_c^w} < 0$ and similar reasoning to above yields the desired result (i.e. $\frac{\partial p_H^w(\gamma)}{\partial\gamma} \geq 0$). ■

References

[1] Bardey David, Bommier Antoine and Jullien Bruno, 2010. “Retail Price Regulation and Innovation: Reference Pricing in the Pharmaceutical Industry.” *Journal of Health Economics* 29 (2), 303-316.

[2] Bond Eric W., Saggi Kamal, 2014. “Bargaining over Entry with a Compulsory License Deadline: Price Spillovers and Surplus Expansion.” Mimeo, Vanderbilt University.

[3] Brekke Kurt R., Konigbauer Ingrid and Straume Odd R., 2007. “Reference Pricing of Pharmaceuticals.” *Journal of Health Economics* 26, 613-642.

[4] Brekke Kurt R., Holmas Tor H. and Straume Odd R., 2011. “Reference Pricing, Competition, and Pharmaceutical Expenditures: Theory and Evidence from a Natural Experiment.” *Journal of Public Economics* 95, 624–638.

[5] Chaudhuri Shubham, Goldberg Pinelopi K. and Jia Panle, 2006. “Estimating the Effects of Global Patent Protection in Pharmaceuticals: a Case Study of Quinolones in India.” *American Economic Review*, 96 (5), 1477-1514.

[6] Cockburn Iain M., Lanjouw Jean O. and Schankerman Mark, 2014. “Patents and the Global Diffusion of New Drugs.” NBER Working Paper 20492, Cambridge, MA.

[7] Danzon Patricia M., Epstein Andrew J., 2008. “Effects of Regulation on Drug Launch and Pricing in Interdependent Markets.” National Bureau of Economic Research Working Paper No. 14041.

[8] Danzon Patricia M., Wang Richard Y. and Wang Liang, 2005. “The Impact of Price Regulation on the Launch Delay of New Drugs.” *Journal of Health Economics* 14, 269-292.

[9] Gislandi Simone, 2011. “Competition and the Reference Pricing Scheme for Pharmaceuticals.” *Journal of Health Economics* 30, 1137-1149.

[10] Goldberg Pinelopi K., 2010. “Intellectual Property Rights Protection in Developing Countries: the Case of Pharmaceuticals.” *Journal of the European Economic Association* 8, 326-353.

[11] Grossman Gene M., Lai Edwin, 2008. "Parallel Imports and Price Controls." *Rand Journal of Economics* 39, 378-402.

[12] Ivus Olena, 2010. "Do Stronger Patent Rights Raise High-tech Exports to the Developing World?" *Journal of International Economics* 81, 38-47.

[13] Kanavos Panos, Costa-i-Font Joan, Merkur Sherry and Gemmill-Toyama Marin, 2004. "The Economic Impact of Pharmaceutical Parallel Trade in European Member States: a Stakeholder Analysis." Special Research Paper, LSE Health and Social Care, London School of Economics and Political Science.

[14] Kyle Margaret, 2007. "Pharmaceutical Price Controls and Entry Strategies." *The Review of Economics and Statistics* 89 (1), 88-99.

[15] Lanjouw Jean O., 2005. "Patents, Price Controls and Access to New Drugs: How Policy Affects Global Market Entry." National Bureau of Economic Research Working Paper No. 11321.

[16] Li Changying, Maskus Keith E., 2006. "The Impact of Parallel Imports on Investments in Cost- Reducing Research and Development." *Journal of International Economics* 68 (2), 443-455.

[17] Malueg David A., Schwartz Marius, 1994. "Parallel Imports, Demand Dispersion, and International Price Discrimination." *Journal of International Economics* 37, 167-195.

[18] Maskus Keith E., 2000. "Parallel Imports." *World Economy* 23, 1269-1284.

[19] Miraldo Marisa, 2009. "Reference Pricing and Firms' Pricing Strategies." *Journal of Health Economics* 28, 176–197.

[20] National Economic Research Associates (NERA), 1999. The Economic Consequences of the Choice of Regime of Exhaustion in the Area of Trademarks. Final Report for DG XV of the European Commission.

[21] Richardson Martin, 2002. "An Elementary Proposition Concerning Parallel Imports." *Journal of International Economics* 56, 233-245.

[22] Roy Santanu, Saggi Kamal, 2012. "Equilibrium Parallel Import Policies and International Market Structure." *Journal of International Economics* 87, 262-276.

[23] Ruggeri Kai, Nolte Ellen, 2013. "Pharmaceutical Pricing: the Use of External Reference Pricing." The RAND Corporation.

[24] Saggi Kamal, 2013. "Market Power in the Global Economy: The Exhaustion and Protection of Intellectual Property." *Economic Journal* 123, 131-161.

[25] Schmalensee Richard, 1981. "Output and Welfare Implications of Monopolistic Third-degree Price Discrimination." *American Economic Review* 71, 242-247.

[26] Smith Pamela J., 1999. "Are Weak Patent Rights a Barrier to US Exports?" *Journal of International Economics* 48, 151–177.

[27] Valleti Tommaso M., 2006. "Differential Pricing, Parallel Trade, and the Incentive to Invest." *Journal of International Economics* 70, 314-324.

[28] Valleti Tommaso M., Szymanski Stefan, 2006. "Parallel Trade, International Exhaustion and Intellectual Property Rights: a Welfare Analysis." *Journal of Industrial Economics* 54, 499-526.

[29] Varian, Hal, 1985. "Price Discrimination and Social Welfare." *American Economic Review* 75, pp. 870-875.

[30] World Health Organization. 2013. Guideline on Country Pharmaceutical Pricing Policies. Geneva: WHO.

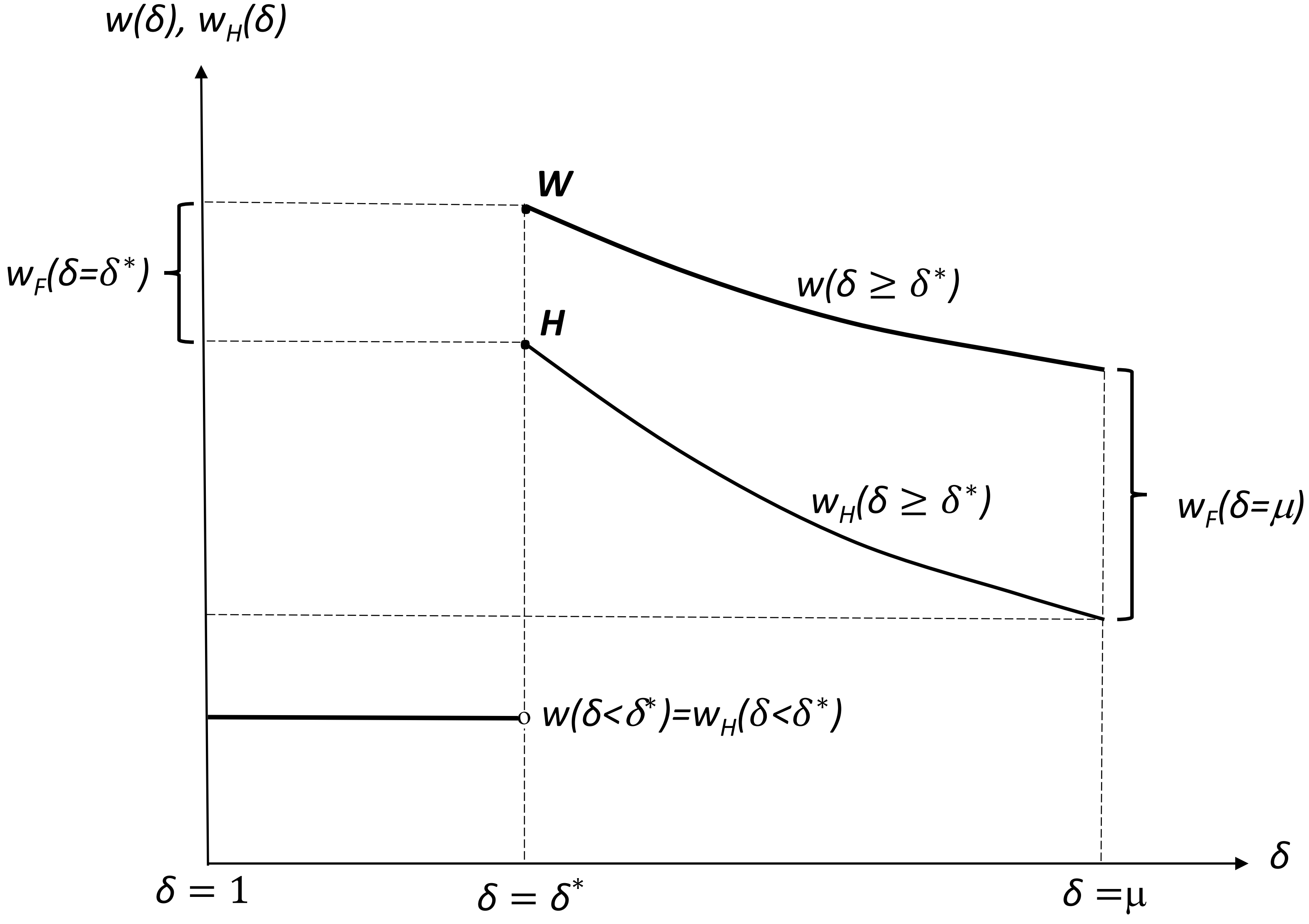

Figure 1: Efficiency of Nash equilibrium

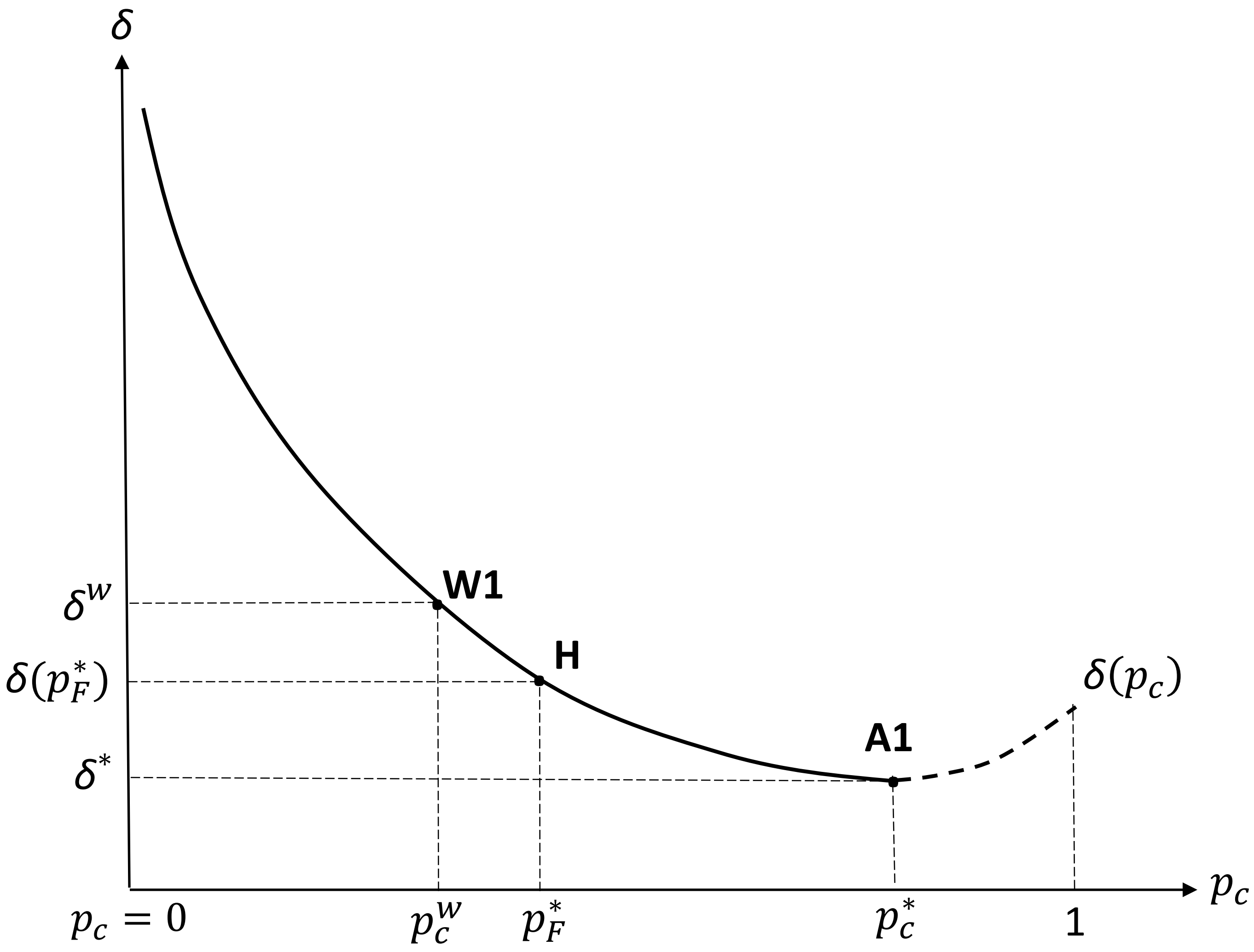

Figure 2: Equilibrium policies

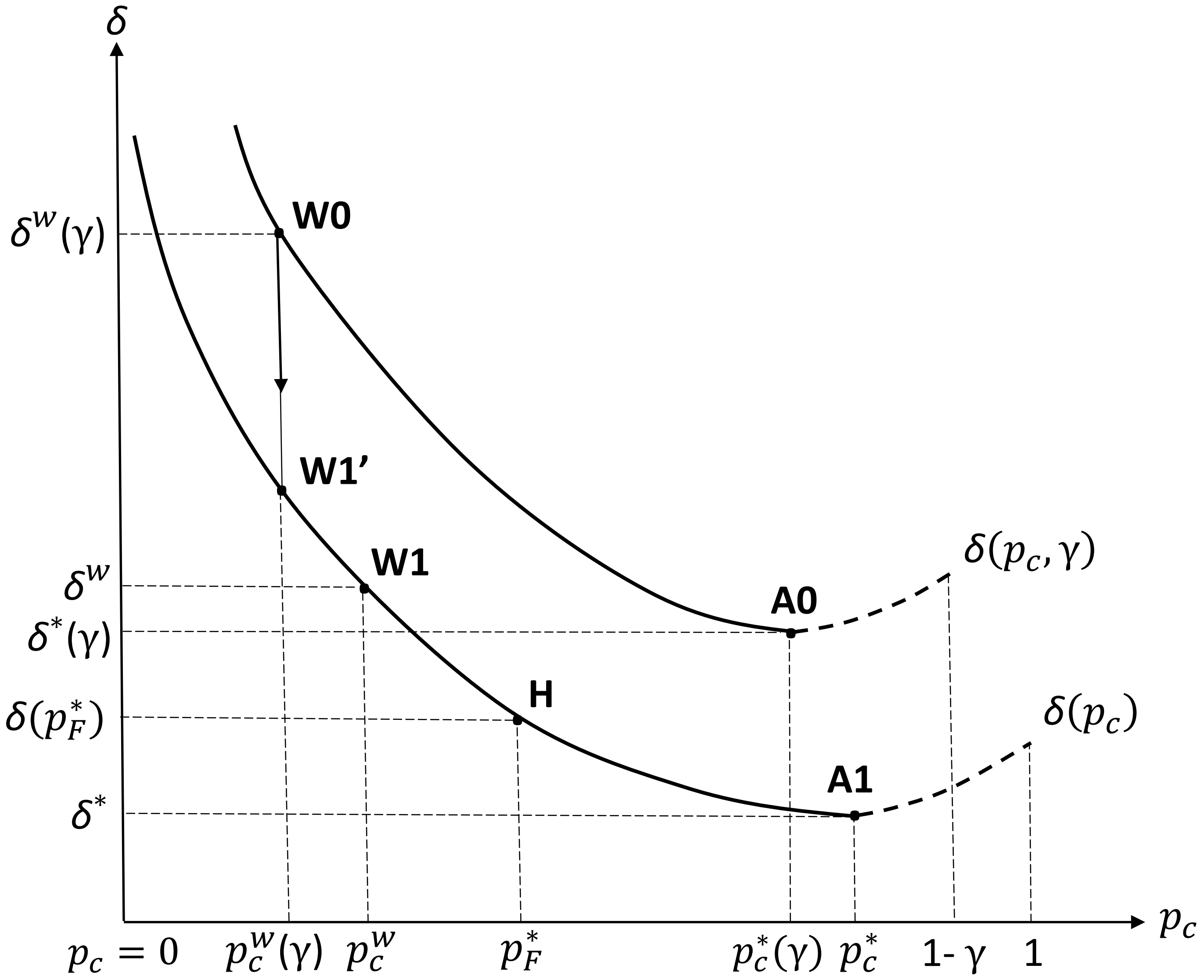

Figure 3: Equilibria with and without foreign patent protection

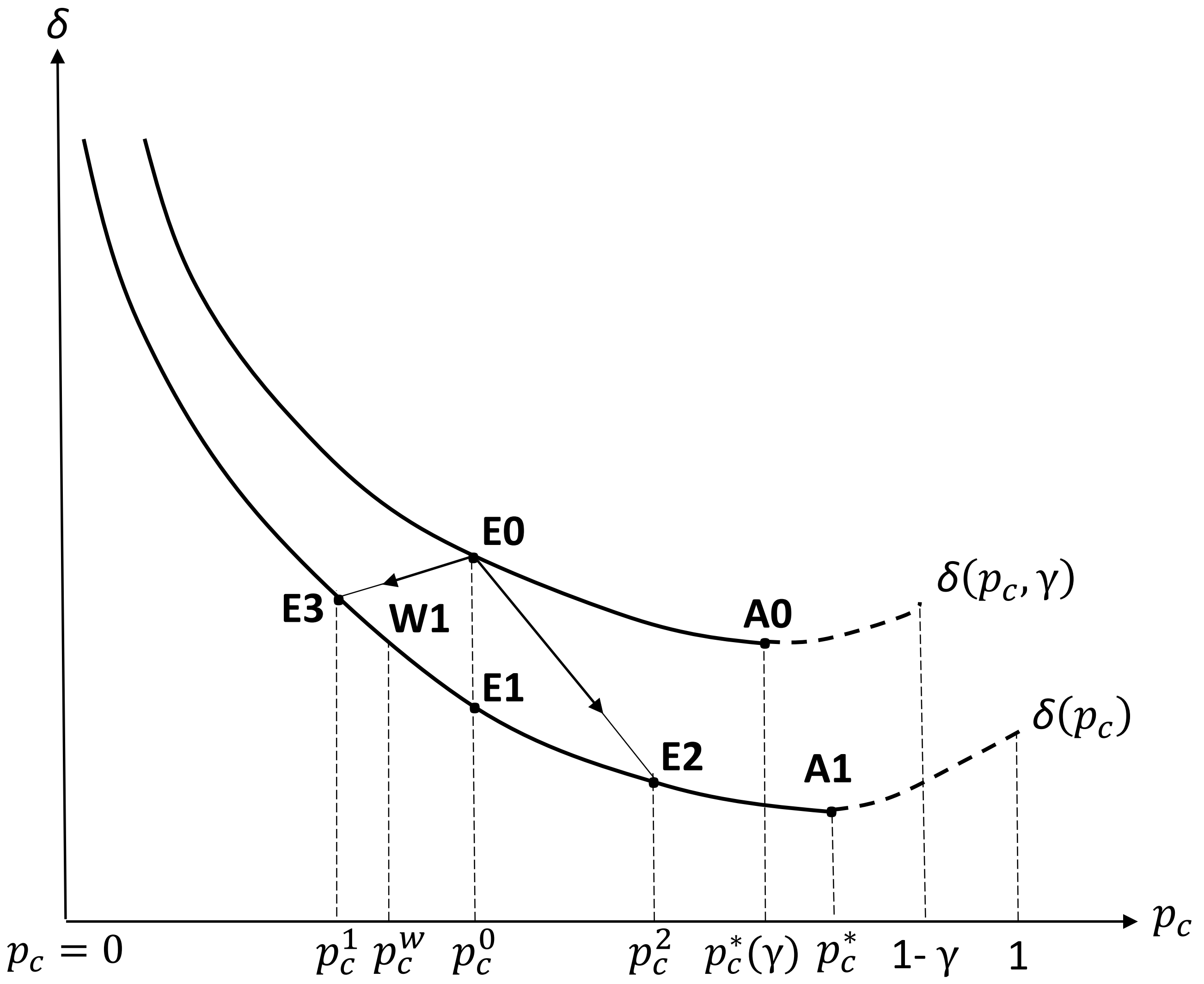

Figure 4: Effects of shutting down foreign imitation