International effects of national regulations: external reference pricing and price controls*

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First draft: April 2015
This draft: August 2017

Abstract

Under external reference pricing (ERP) the price that a government permits a firm to charge in its market depends upon the firm's prices in other countries. In a two-country (home and foreign) model where demand is asymmetric across countries, we show that home's unilaterally optimal ERP policy permits the home firm to engage in a threshold level of international price discrimination above which it is (just) willing to export. If the firm faces a price control abroad or bargains over price with the foreign government, an ERP policy can even yield higher home welfare than a direct price control.

Keywords: External reference pricing policies, price controls, patented products, welfare. *JEL Classifications*: F10, F12, D42, L51.

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*For helpful comments and discussions, we thank two anonymous referees, the editor, and seminar audiences at Dartmouth College, Midwest International Economics Spring 2015 Meeting (Ohio State), Oregon State University, the Southern Economics Association 2015 Meeting, Florida International University, University of Akansas-Fayetteville, the 3rd insTED workshop at the University of Indiana at Bloomington, and the 9th Annual Conference of the International Economics and Finance Society at the University of International Business and Economics (Beijing). All errors are our own.

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1 Introduction

Governments across the world rely on a variety of price regulations to combat the market power of firms selling patented pharmaceutical products. Two such commonly used regulations are external reference pricing (ERP) and price controls. Under a typical ERP policy, the price that a country permits a firm to charge in its market for a particular product depends upon the firm's prices for the same product in a well-defined set of foreign countries, commonly called the country's *reference basket*.[1] 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).

While ERP policies affect prices by restricting the degree of international price discrimination practised by firms, governments can also directly control prices via a variety of other measures: for example, governments can control the ex-manufacturer price, the wholesale markup, the pharmacy margin, the retail price, or use some combination of these measures. Though few countries, if any, 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.[2]

This paper addresses several inter-related questions pertaining to ERP policies that have not been tackled by existing literature: What are the underlying economic determinants

[1] Thus the use of an ERP policy by a country can help lower the domestic price of a product only if the price that would have prevailed in its market in the absence of its ERP policy were to exceed prices in the set of reference countries.

[2] 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.

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? Under what circumstances does an ERP policy dominate a direct price control?

We address these questions in a simple model with two countries (home and foreign) where a single home firm produces a patented product, that it potentially sells in both markets. The firm enjoys monopoly status in both markets by virtue of its patent. The home market is assumed to have more consumers and a greater willingness to pay for the product, which in turn creates an incentive for the firm to price discriminate in favor of foreign consumers. Home's ERP policy δ (where $\delta \geq 1$) is defined as the ratio of the firm's domestic price to its foreign price and it is chosen by the home government to maximize national welfare, which equals the sum of the firm's global profit and domestic consumer surplus. Under this formulation, if the firm sells in both markets when facing the ERP policy δ at home then its equilibrium home price is simply δ times its foreign price.

From the firm's perspective, home's ERP policy is a constraint on the degree of international price discrimination that it can practice while from the domestic government's perspective it is a tool for lowering the price at home (while simultaneously raising it abroad).[3] Since the domestic market is more lucrative for the firm, too tight an ERP policy at home creates an incentive on its part to not sell abroad in order to sustain its optimal monopoly price at home. 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 (2012) 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.[4]

[3] In this sense, ERP policies are similar to exhaustion policies that determine whether or not holders of intellectual property rights (IPRs) are subject to competition from parallel imports when they choose to engage in international price discrimination. Unlike ERP policies, the economics of exhaustion policies has been investigated widely in the literature: see Malueg and Schwarz (1994), Maskus (2000), Richardson (2002), Li and Maskus (2006), Valletti (2006), Grossman and Lai (2008), and Roy and Saggi (2012).

[4] Further evidence consistent with launch delay spurred by the presence of price regulations is provided

While the firm only cares about its total global profit, 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 the home country's unilaterally optimal ERP policy permits the firm to engage in the minimum level of price discrimination at which the firm just prefers selling in both markets to selling only at home. An important feature of this nationally optimal ERP policy is that the less lucrative the foreign market, the greater the room that the firm is given to price discriminate internationally. Such an ERP policy is optimal from the perspective of home welfare because of the following trade-off. On the one hand, given that the firm exports, home has an incentive to tighten its ERP policy to lower domestic price. On the other hand, tightening the ERP policy below the threshold level induces the firm to drop the foreign market and home consumers end up facing the firm's optimal monopoly price p_H^m. The outcome under which the firm sells only at home is decidedly worse for the home country than one in which the firm faces no ERP constraint whatsoever (and therefore necessarily sells in both markets) – while domestic consumers pay p_H^m under both scenarios, the firm collects monopoly profits abroad only in the latter scenario.

Though we model home's ERP policy as the extent to which the firm is free to price discriminate in favor of foreign consumers, as we noted earlier, in the real world countries often implement ERP policies by requiring the local price charged by a firm to be no higher than its prices in the set of countries that constitute its reference basket. Thus, the extent to which a firm is constrained by a country's ERP policy is a function of the *composition* of its reference basket. Our simpler two-country formulation allows us to capture the essence of ERP policies in a manner that is not only tractable but also useful for understanding the structure of real-world ERP policies. Casual empiricism suggests that when defining their reference baskets, countries typically tend to include foreign countries with similar market sizes and per capita incomes. For example, 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 is that they choose not to do so because casting too wide a net while setting ERP policies can backfire by causing firms to forsake foreign markets just so that they can sustain monopoly prices in their domestic markets.

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.

We show that under home's unilaterally optimal ERP policy the equilibrium foreign price (p_F^*) ends up *exceeding* the firm's optimal monopoly price p_F^m for that market (i.e. $p_F^* > p_F^m$). Given this outcome, we build on our benchmark ERP model by allowing the foreign government to impose a local price control $\overline{p}_F$ on the firm in order to curtail the international spillover generated by home's ERP policy. When both countries are policy active, home sets its ERP policy taking into account the incentives of not just the firm but also the foreign country. We show that the tighter the home's ERP policy, the looser the foreign price control needs to be for the firm to be willing to sell there. Indeed, home's ERP policy undermines the effectiveness of the foreign price control since the minimum price at which the firm is willing to sell abroad is higher when home has an ERP policy in place relative to when it does not.

An interesting insight delivered by our analysis is that a tightening of the foreign price control $\overline{p}_F$ can raise welfare in both countries (i.e. it can be Pareto-improving). This surprising result arises whenever $\overline{p}_F \in [p_F^m, p_F^*]$ and the intuition for it is as follows. Whenever $\overline{p}_F \geq p_F^m$ a tightening of the foreign 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 market via its ERP policy. However, since the firm's foreign profit is decreasing in $\overline{p}_F$ for all $\overline{p}_F \in [p_F^m, p_F^*]$, only a moderate relaxation of home's ERP policy is required to ensure that the firm continues to export if the foreign price control is tightened. As a result, whenever $\overline{p}_F \in [p_F^m, p_F^*]$ a tightening of the foreign price control $\overline{p}_F$ also lowers home price (which equals $\delta\overline{p}_F$). Thus, the existence of an ERP policy at home not only causes the foreign price control to spill over to the home market, the nature of the spillover is such that a tightening of the foreign price control can make both countries better off.

A central result of the paper is that when both countries are policy active, the equilibrium ERP policy of the home country is Pareto-efficient and it results in the foreign country having to allow the firm to charge its optimal monopoly price p_F^m in its market (which is lower than p_F^* – the price that obtains abroad in the absence of the price control). In addition, we show that the jointly-optimal ERP policy – i.e. the policy that maximizes the sum of home and foreign welfare – is more stringent than the ERP policy implemented by the home government (who does not take into account the adverse effect of its ERP policy on foreign consumers).

In sub-section 4.1, we expand the menu of policies available to the home country by allowing it to choose between a domestic price control and an ERP policy. This analysis shows when and why an ERP policy dominates a price control. The key difference between the two instruments is that, unlike an ERP policy, a domestic price control does *not* affect the foreign price control facing the firm and therefore has no bearing on its decision to export. Therefore, if home uses a price control as opposed to an ERP policy, foreign simply chooses the lowest price at which the firm is willing to sell in its market (i.e. it sets its price control at the firm's marginal cost thereby maximizing local consumer surplus and eliminating the firm's foreign profit). On the other hand, if home institutes an ERP policy, a stricter foreign price control also leads to a lower home price (holding constant home's ERP policy) – something that tends to make exporting less attractive to the firm. Recognizing the link between prices in the two markets created by home's ERP policy and its impact on the firm's incentives, the foreign government is unable to push down its price control all the way to the firm's marginal cost when home's price regulation takes the form of an ERP policy as opposed to a price control. As a result, from the perspective of home welfare, the trade-off between an ERP policy and a local price control boils down to the following: while a price control yields greater domestic surplus (defined as the sum of consumer surplus and firm's home profit), an ERP policy helps the firm earn greater profit abroad. Therefore, an ERP policy dominates a price control when maintaining the monopoly mark-up in the foreign market is important or, equivalently, when the profit earned from the foreign market accounts for a significant component of the firm's total profit – something that happens when demand in the foreign market is relatively similar in magnitude to that at home.

Since firms selling patented products (such as in the pharmaceutical industry) often bargain with governments over prices of their products, in section 4.2 we consider Nash bargaining (both with and without side-payments) between the firm and the foreign government over price. We derive optimal ERP policies under both scenarios and investigate their properties. A major result of this analysis is that the weaker the bargaining position of the firm vis-à-vis the foreign government, the more likely it is that the home country prefers an ERP policy to a price control. This result can be viewed as a generalization of the core model since, after all, a foreign price control simply represents a scenario where all of the bargaining power resides with the foreign government.

By explicitly bringing in international pricing considerations and policy interaction between national governments, our paper makes an important contribution 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. They compare generic and therapeutic reference pricing – with each other and with the complete lack of reference pricing.[5] One of their important findings is that therapeutic reference pricing generates stronger competition and lower prices than generic reference pricing.[6]

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 best 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.

The rest of this paper is structured as follows. We first introduce our two-country

[5]Therapeutic clusters upon which reference pricing is based can be defined in several ways. As per Brekke et. al. (2007), under generic reference pricing the cluster includes products that have the same active chemical ingredients whereas under therapeutic reference pricing the cluster includes products with chemically related active ingredients that are pharmacologically equivalent or have similar therapeutic effects. While the cluster includes only off-patent brand-name drugs and generic substitutes under generic reference pricing, such is not necessarily the case under therapeutic reference pricing under which it may include on-patent drugs.

[6]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.

[7]The Norwegian price cap regulation 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.

framework and analyze home's optimal ERP policy as well as its welfare implications. Next, in section 3, we allow the foreign country to utilize a price control and study its interaction with home's ERP policy. Section 4 extends the main analysis in two important directions. First, we endogenize the home country's choice between an ERP policy and a domestic price control. Next, we study the role of ERP policy when the firm and the foreign government bargain over price. We consider bargaining both with and without side-payments. Section 5 concludes while section 6 constitutes the appendix where we present all of the supporting calculations and undertake two important extensions of our analysis: in sub-section 6.2, we describe equilibrium outcomes when the two countries pick their respective policies simultaneously as well as when the foreign country moves first while in section 6.3 we consider a three-country model to derive one country's optimal ERP policy when it takes the form of a reference basket.

2 A benchmark model of ERP

We consider a world comprised of two countries: home (H) and foreign (F).[8] A single home firm sells a patented product (x) with a quality level s. Each consumer in country i ($i = H, F$) buys at most 1 unit of the good at the 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 from each other in two ways. First, home consumers value quality relatively more, that is, $\mu_H = \mu \geq 1 = \mu_F$. Second, the home market is larger: $n_H = n \geq 1 = n_F$. As one might expect, since $\mu \geq 1$ the firm has an incentive to price discriminate internationally.[9]

The home government sets an external reference pricing (ERP) policy that stipulates

[8] In the appendix, we derive home's optimal reference basket for the case of three countries.

[9] We should note here that ERP policies are typically implemented at the national level and therefore may apply to a wide range of patented products whereas our model is focused on a single product. Furthermore, while the foreign country has no incentive to use an ERP policy in our model, in the real world two countries can simultaneously belong to each other's reference baskets. Such an outcome can be rationalized via a generalized multi-product version of our model if demand elasticities for some products are higher at home than abroad with the opposite being true for other products. Alternatively, an Armington type assumption wherein consumers in both countries place a higher value on home products could also create a potential role for an ERP policy.

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 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 differences in the structure of demand across two countries, the firm has no incentive to discriminate in favor of home consumers so there is no loss of generality in assuming $\delta \geq 1$. Note also that when $\delta = 1$ home's ERP policy leaves the firm no room to price discriminate across markets.

2.1 Pricing under the ERP constraint

If the ERP constraint is absent, 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 choose prices across countries, it sets a market specific price in each country to maximize its global profit as follows

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

It is straightforward to show that the firm's optimal monopoly prices in the two markets are: $p_H^m = \mu/2$ and $p_F^m = 1/2$. The associated sales in each market equal $x_H^m = n/2$ and $x_F^m = 1/2$. Global sales under price discrimination equal $x_G^m = x_H^m + x_F^m = (n+1)/2$. Observe that

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

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 pricing be denoted by $\pi^m \equiv \pi_G(p_H^m, p_F^m)$.

Now consider the firm's pricing problem under 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.[10] Of course, we implicitly assume

[10] 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 $\delta = \mu$.

that the government has the ability to sustain its preferred degree of international price discrimination (i.e. any price differentials that arise cannot be undercut via arbitrage by third parties).

When faced with the ERP constraint, the firm can either choose to sell only at home thereby evading it or sell in both markets at prices that abide by the constraint, in which case it solves:[11]

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

It is straightforward to show that the ERP constraint binds (i.e. $p_H = \delta p_F$) and the firm's optimal prices in the two markets are

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

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

$$x_H^\delta = \frac{n[\delta(n\delta - 1) + 2\mu]}{2(n\delta^2 + \mu)} \text{ and } x_F^\delta = \frac{2n\delta^2 - (n\delta - 1)\mu}{2(n\delta^2 + \mu)}$$

Provided the firm sells in both markets, global sales under the ERP constraint equal $x_G^\delta = x_H^\delta + x_F^\delta$. Using the above formulae, it is straightforward to show the following:

Lemma 1: *Provided the firm sells in both markets, the imposition of an ERP policy by the home country that leaves the firm with some room to price discriminate internationally (i.e. $\delta > 1$) but not complete freedom to do so (i.e. $\delta < \mu$) leads to lower global sales relative to international price discrimination:*

$$x_G^\delta - x_G^m = -\frac{n(\delta - 1)(\mu - \delta)}{2(n\delta^2 + \mu)} \leq 0.$$

Lemma 1 can be seen as a generalization of a central result in the literature on exhaustion of intellectual property rights that compares global sales under two extreme cases – one where the firm is completely free to price discriminate internationally (i.e. $\delta \geq \mu$) and another where it must set a common international price (i.e. $\delta = 1$).[12] This literature has shown that, under the assumptions of our model, global sales under the two types of pricing are the same. Observe from Lemma 1 that this result also holds in our model:

[11] 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 selling only at home since no foreign consumers are willing to buy the good if $p_F \geq 1$.

[12] See Saggi (2016) for an extensive discussion of the relevant literature.

when $\delta = 1$ total sales under the ERP constraint are indeed the same as those under price discrimination, i.e. $x_G^\delta = x_G^m$. However, for any positive level of price discrimination – i.e. for $\delta \in (1, \mu)$ – this result does not hold and the imposition of an ERP policy at home lowers total global sales relative to unconstrained price discrimination.

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

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

As one might expect,

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

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

Of course, the firm 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^m in the home market where

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

Since (i) $\partial \pi_G^\delta / \partial \delta > 0$; (ii) $\pi_G^\delta \big|_{\delta \geq \mu} = \pi^m > \pi_H^m$; and (iii) π_H^m 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:

$$\pi_G^\delta \geq \pi_H^m \Longleftrightarrow \delta \geq \delta^* \text{ where } \delta^* \equiv \frac{1}{2}\left(\mu - \frac{1}{n}\right) \tag{5}$$

We refer to δ^* as the *export inducing* ERP policy. Observe that the export inducing ERP policy δ^* is increasing in the two basic parameters of the model (i.e. μ and n) since an increase in either 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.

The first main result can now be stated:

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

(ii) Given that the firm sells in both markets when facing an ERP policy at home, the following hold:

(a) The use of an ERP policy by home reduces the local price relative to the optimal monopoly price whereas it raises the foreign price: $p_H^\delta \leq p_H^m$ *and* $p_F^\delta \geq p_F^m$ *with the inequalities binding at* $\delta = \mu$.

(b) Home price and the firm's global profit increase in δ *(i.e.* $\partial p_H^\delta / \partial \delta > 0$ *and* $\partial \pi_G^\delta / \partial \delta > 0$*) whereas foreign price decreases in it (i.e.* $\partial p_F^\delta / \partial \delta < 0$*).*

(c) Prices in both markets increase if 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 (*iia*) highlights that the introduction of an ERP policy at home moves prices in the two markets in opposite directions: it lowers the domestic price whereas it raises the foreign price. These price changes obviously imply that home's ERP policy 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^m 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 home 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.[13]

Part (*iib*) also captures the conflicting effects of a tightening of home's ERP policy on the firm and domestic consumers – a trade-off that is at the heart of the welfare analysis that follows in section 2.2. Part (*iic*) highlights the fact that the international price linkage created by home's ERP policy makes prices in *both* markets a function of the two key home demand parameters (i.e. μ and n) that determine the profitability of the domestic market relative to the foreign one.

2.2 Optimal ERP policy

Having understood the firm's pricing and export behavior, we are now in a position to derive home's optimal ERP policy. To do so, we assume that home's objective is to maximize its

[13] In an insightful survey of the relevant empirical literature, Goldberg (2010) notes that the use of ERP policies by developed countries could put developing countries in a situation where they end up facing prices in excess of local monopoly prices – something that emerges sharply in the equilibrium of our model.

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

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

Let $cs_H^\delta = cs_H(p_H^\delta)$. Since the firm exports iff $\delta \geq \delta^*$, domestic welfare as a function of the ERP policy can be written as:

$$w_H(\delta) = \begin{cases} w_H^m = \pi_H^m + cs_H^m \text{ if } \delta < \delta^* \\ \\ w_H^\delta = \pi_G^\delta + cs_H^\delta \text{ if } \delta \geq \delta^* \end{cases}$$

The logic for why home welfare is discontinuous in its ERP policy is straightforward: for $\delta \geq \delta^*$, the firm exports and domestic welfare equals the sum of the firm's global profit π_G^δ and local consumer surplus cs_H^δ whereas for $\delta < \delta^*$ the firm only sells at home at its optimal monopoly price and domestic welfare equals $w_H^m = \pi_H^m + cs_H^m$.

An important feature of our model is that provided the firm exports, the tighter the ERP policy (i.e. the lower is δ), the higher is home welfare: i.e. $\partial w_H^\delta/\partial\delta \leq 0$ if $\delta \geq \delta^*$.[14] Thus, for all $\delta \geq \delta^*$, the home government has an incentive to reduce δ. But once $\delta = \delta^*$, any further reduction in δ leads the firm to eschew exports and home welfare drops from w_H^δ to w_H^m since the downward pressure on domestic price that is exerted by home's ERP policy disappears once the firm decides to sell only at home.[15]

We can directly state the main result:

Proposition 2: *Let $\mu^* \equiv 2 + 1/n$. Home's optimal ERP policy is δ^e where*

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

Observe that for $\mu \leq \mu^*$ home's optimal ERP policy calls for the firm to set a common international price (i.e. $\delta^e = 1$) whereas for $\mu > \mu^*$, it permits some degree of international

[14] An explicit derivation of this welfare result is contained in the appendix.

[15] Indeed, for any ERP policy for which the firm does not export (i.e. for all $\delta < \delta^*$), home is strictly better off not imposing any ERP constraint on the firm at all (i.e. setting a δ higher than μ which allows the firm to charge its optimal monopoly prices in both markets): while the firm charges p_H^m at home both when $\delta < \delta^*$ and when $\delta \geq \mu$, it only exports when under the latter scenario where home's ERP policy is so lax that the firm's pricing behavior is completely unconstrained.

price discrimination (i.e. $\delta^e = \delta^* > 1$) on the part of the firm.[16] The logic behind this result is simple. In terms of home welfare, imposing an ERP policy that makes the firm abandon exporting is even worse than not having an ERP policy whatsoever – in both cases the firm makes monopoly profit π_H^m in the home market but only in the latter case does the firm collect monopoly profit π_F^m in the foreign market. 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.[17] When $\mu \leq \mu^*$, the foreign market is fairly comparable to the domestic one and the firm does not drop it even if it has to charge the same price in both markets (i.e. $\delta^e = 1$) since is global profit under the ERP policy exceeds monopoly profit at home. But when $\mu > \mu^*$, the firm is only willing to export if it can engage in some price discrimination and the larger is μ, the more lax home's ERP policy needs to be to preserve the firm's export incentive. In general, the firm's export incentive is too weak relative to what is domestically optimal since 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 in the sense that any profit increase enjoyed by the firm that comes at the expense of domestic consumers does not increase total domestic welfare.

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:

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

[16]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.

[17]Suppose the home government attaches greater weight to the firm's profit relative to local consumer surplus home so that its ERP policy is chosen to maximize $\alpha\pi_H + cs_H$ where $\alpha \geq 1$. Under such a scenario, we can show that $\frac{\partial^2 w_H(\delta,\alpha)}{\partial\delta\partial\alpha} = \frac{n\mu(\mu-\delta)(n\delta+1)}{2(\mu+n\delta^2)^2} > 0$ – i.e. the marginal return from tightening the ERP policy (i.e. lowering δ) decreases in the weight given to the firm's profit. Alternatively, we can show that $\frac{\partial w_H(\delta)}{\partial\delta}|_{\delta=\delta^*} > 0$ for all $\alpha > \widehat{\alpha} = \frac{3n^2\mu^2+8n\mu-3}{2(n\mu+1)^2}$ where $\widehat{\alpha} > 1$. Thus, if the home country were to put a sufficiently large weight on profits relative to consumer surplus (i.e. $\alpha > \widehat{\alpha}$) it would set a more lax ERP policy than the export inducing policy δ^*. Moreover, the optimal ERP policy is an increasing function of α and it converges to its upper-bound μ when α tends to infinity.

Joint welfare as a function of the home's ERP policy equals[18]

$$w(\delta) = \begin{cases} w_H^m \text{ if } \delta < \delta^* \\ \\ w_H^\delta + cs_F^\delta \text{ if } \delta \geq \delta^* \end{cases}$$

Lemma 1 showed that an interior ERP policy (i.e. $\delta \in (1, \mu)$) lowers global sales relative to international price discrimination so that its imposition has two conflicting effects on world welfare: it reduces the international price differential across markets but also lowers total global sales relative to unrestricted price discrimination. What is the net effect? Lemma 2 provides the answer:

Lemma 2: *Given that the firm sells in both markets when facing an ERP policy at home, joint welfare increases as the home's ERP policy becomes tighter:*

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

The literature on the exhaustion of intellectual property rights in the global economy has shown that the scenario of uniform pricing ($\delta = 1$) yields higher global welfare than international price discrimination ($\delta \geq \mu$) because it fully eliminates the price differential across countries that exists under price discrimination without lowering total global sales. What Lemma 2 shows is that home's ERP policy – regardless of its level – increases global welfare relative to unrestricted price discrimination. In other words, any degree of reduction in the international price discrimination is welfare-improving because it allocates sales away from low valuation (foreign consumers) to high valuation (home consumers).

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 key result and then explain its logic.[19]

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

[18]Note that home welfare jumps from w_H^m to w_H^δ at $\delta = \delta^*$. It is straightforward to show that the size of this welfare jump is increasing in μ:

$$\left.\frac{\partial(w_H^\delta - w_H^m)}{\partial\mu}\right|_{\delta=\delta^*} > 0.$$

[19]We should note here that the result stated in Proposition 3 rests on the assumption that the foreign country is policy inactive. Section 3.4 derives the jointly optimal ERP policy when the foreign country responds to home's ERP policy via a local price control. This jointly optimal ERP policy differs from the one chosen by home in equilibrium (see Proposition 4 and the ensuing discussion).

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 socially 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^m while the firm's profit remains unchanged (i.e. it equals π_H^m). 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 home 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^m). However, we know from Lemma 2 that joint welfare declines in δ for all $\delta > \delta^*$. 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 home's 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 firm 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^*.[20]

At the equilibrium ERP policy δ^* the price in the foreign market equals

$$p_F^* \equiv p_F^\delta(\delta^*) = \frac{n\mu}{1+n\mu} \tag{7}$$

Observe that since $n\mu \geq 1$, we have $p_F^* \geq p_F^m$ – i.e. the price in the foreign market under the equilibrium ERP policy δ^* implemented by home exceeds the price that the firm would have charged abroad in the absence of an ERP policy.

A well-known result in the existing literature is that for price discrimination to welfare dominate uniform pricing, a necessary (but not sufficient) condition is that the total output under discrimination be higher (Varian, 1985). As Lemma 1 notes, the total global output of the firm under price discrimination is indeed higher than that which it produces when facing an ERP constraint – i.e. the reduction in foreign sales caused by the ERP constraint exceeds the increase in home sales. However, it turns out that the positive effect of the ERP constraint on global welfare that arises due to a reduction in the international price differential dominates the negative effect of reduced global sales so that it is jointly optimal to restrain price discrimination to the lowest level that is necessary for ensuring that foreign consumers do not go unserved.[21]

While our benchmark model is useful for clarifying the mechanics of ERP policies, it does not address two important issues. First, it assumes that the foreign country's government is policy inactive. This is a potentially important shortcoming since the use of an ERP policy by home generates a negative price spillover for the foreign country, thereby creating an incentive for it to resort to a price control. Second, the benchmark model is silent on when and why a government would prefer to use an ERP policy over a standard price control. As we will show below, allowing the foreign government to directly control

[20] When $\mu \leq \mu^*$, the firm exports regardless of the ERP policy at home and in this case the discontinuity in Figure 1 disappears: domestic welfare and total welfare both monotonically decline in δ so that it is socially optimal to set $\delta = 1$ (which is what the home country does in equilibrium).

[21] Under alternative assumptions regarding the structure of demand in the two markets, total output could very well be lower under price discrimination. Under such a situation, the ERP constraint is more likely to improve welfare since both effects (i.e. the reduction in the international price differential and the increase in global sales caused by it) would reinforce each other. See Schmalensee (1981).

the price in its market not only allows us to understand the interaction between domestic ERP policy and the foreign price control but it also sheds light on the issue of when and why home prefers to use an ERP policy over a domestic price control.

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 government directly sets the patented product's price ($\overline{p}_F$) in its market. 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. $\overline{p}_F = 0$). 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. 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.

To fully explore the nature of interaction between home's ERP policy and the foreign country's price control, we analyze the following three-stage game:[22] At the first stage, home chooses its ERP policy δ.[23] Next, foreign sets its local price control $\overline{p}_F$.[24] Finally, the firm chooses its domestic price p_H.

3.1 Pricing and export decision

As usual, we solve the game by backward induction. At the last stage, if the firm chooses to export, it sets p_H to maximize aggregate profit while being subject to an ERP policy at

[22] In section 6.1 we discuss the case where countries simultaneously choose their respective policies. As we show below, the simultaneous case is relatively tedious and our main insights emerge more sharply in the sequential policy game described above.

[23] In section 4.1 we analyze a scenario where home chooses between a domestic price control and an ERP policy and describe circumstances under which each of the policies is preferable to the other – see Proposition 6.

[24] The foreign price control can also be thought of as the foreign government purchasing the good from the firm at the price $\overline{p}_F$ on behalf of local consumers. In section 4.2 we extend this analysis to a situation where the firm and the foreign government bargain over price (as opposed to the foreign government having the power to determine it unilaterally).

home and a price control abroad:

$$\max_{p_H \leq \delta\overline{p}_F} \frac{n}{\mu} p_H(\mu - p_H) + \overline{p}_F(1 - \overline{p}_F) \text{ where } \overline{p}_F \in [0, 1] \tag{8}$$

Assuming that the ERP constraint $p_H \leq \delta\overline{p}_F$ binds, the solution to the above problem requires the firm to set $p_H = \delta\overline{p}_F$ so that its total profit equals:[25]

$$\pi^{\delta}(\overline{p}_F) = \frac{n}{\mu}\delta\overline{p}_F(\mu - \delta\overline{p}_F) + \overline{p}_F(1 - \overline{p}_F) \tag{9}$$

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 $\overline{p}_F$ abroad and $\delta\overline{p}_F$ at home. If the firm chooses not to export, it charges its optimal monopoly price at home and earns π_H^m. Thus, when facing a price control abroad and an ERP policy at home, the firm exports iff

$$\pi^{\delta}(\delta, \overline{p}_F) \geq \pi_H^m \tag{10}$$

Substituting the formulae for the two profit functions, this inequality binds at

$$\frac{n}{\mu}\delta\overline{p}_F(\mu - \delta\overline{p}_F) = \frac{n\mu}{4} - \overline{p}_F(1 - \overline{p}_F)$$

This equation can be solved for the *threshold ERP policy* (i.e. the ERP policy above which the firm exports) as a function of the foreign price control:[26]

$$\overline{\delta}(\overline{p}_F) = \frac{\mu}{2\overline{p}_F} - \frac{1}{n\overline{p}_F}\sqrt{n\mu\overline{p}_F(1 - \overline{p}_F)} \tag{11}$$

Note that in the complete absence of policy intervention, the firm would charge its monopoly price p_F^m in the foreign market, which serves as the natural upper bound for $\overline{p}_F$ 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. $p_F^{\delta} \geq p_F^m$). Thus, in the presence of an ERP policy at home, the natural upper bound for the foreign price control is the choke-off price $\overline{p}_F = 1$.

Lemma 3: *The threshold ERP policy $\overline{\delta}(\overline{p}_F)$ has the following properties:*

[25] It will turn out that the ERP constraint necessarily binds in equilibrium.

[26] Observe that the ERP constraint necessarily binds so long as $p_H^m \geq \delta\overline{p}_F$ which is the same as $\delta \leq \delta^b(\overline{p}_F) \equiv p_H^m/\overline{p}_F$. Now observe that the ERP policy that induces the firm to export can be written as $\overline{\delta}(\overline{p}_F) = p_H^m/\overline{p}_F - \gamma(\overline{p}_F)$ where $\gamma(\overline{p}_F) \equiv \sqrt{\mu n\overline{p}_F(1 - \overline{p}_F)}/(2n\overline{p}_F) \geq 0$. Therefore, $\overline{\delta}(\overline{p}_F) \leq \delta^b(\overline{p}_F)$ which implies that the export inducing ERP policy necessarily binds. A detailed derivation of the expression for $\overline{\delta}(\overline{p}_F)$ reported in equation (11) is contained in the appendix.

(i) $\partial\overline{\delta}(\overline{p}_F)/\partial\overline{p}_F \leq 0$ *for* $0 < \overline{p}_F \leq p_F^*$ *with the equality binding at* $\overline{p}_F = p_F^*$.[27]
(ii) $\partial^2\overline{\delta}(\overline{p}_F)/\partial\overline{p}_F^2 > 0$ *for* $0 < \overline{p}_F < 1$.
(iii) $\overline{\delta}(\overline{p}_F = p_F^m) > \delta^*$.
Proof: see appendix.

— [Figure 2 here] —

The first part of Lemma 3 says that if the foreign price control lies in the interval $0 \leq \overline{p}_F < p_F^*$ a tightening of the price control requires a relaxation of home's ERP policy if the firm is to continue to export. When $\overline{p}_F < p_F^*$, the foreign price control is below the firm's optimal price for the foreign market and a tightening of the 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 $0 \leq \overline{p}_F < p_F^*$, the foreign price control generates an international spillover by reducing the range of ERP policies that home can implement without undermining its firm's export incentive. Indeed, $\overline{\delta}(\overline{p}_F)$ tends to infinity as $\overline{p}_F$ falls to zero: an extremely stringent price control ($\overline{p}_F \approx 0$) translates into a zero home price for any finite δ, so that there exists no feasible ERP policy that can provide the firm sufficient incentive to export.

The second part of Lemma 3 says that $\overline{\delta}(\overline{p}_F)$ is convex in $\overline{p}_F$, indicating that the home's ERP policy must adjust to a larger extent as the price control abroad becomes stricter. This property of $\overline{\delta}(\overline{p}_F)$ plays an important role in determining the jointly optimal pair of policies, an issue that we address in section 3.4 below.

Part (*iii*) of Lemma 3 points out that even if the foreign price control is set at the firm's optimal monopoly price (i.e. $\overline{p}_F = p_F^m$) for that market, the export inducing ERP policy $\overline{\delta}(p_F^m)$ is more lax than the policy that is chosen by home in the absence of a price control (δ^*). The intuition for this is that in the absence of a foreign price control, under the export inducing policy δ^* the foreign price actually exceeds the firm's optimal monopoly price abroad (i.e. $p_F^* > p_F^m$) so that a foreign price control set at p_F^m actually binds for the firm.

[27] Note that $\partial\delta(\overline{p}_F)/\partial\overline{p}_F \geq 0$ for $p_F^* \leq \overline{p}_F \leq 1$ but as we will show below, the equilibrium outcome never lies on this region of the $\delta(\overline{p}_F)$ curve.

3.2 Foreign best response

Given the home's ERP policy, the foreign country picks the lowest possible price control that just induces the firm to export. For $\overline{p}_F \in [0, p_F^*]$ since the $\overline{\delta}(\overline{p}_F)$ function is monotonically decreasing in $\overline{p}_F$, its inverse $\overline{p}_F(\delta)$ yields the best response of the foreign country to a given ERP policy of home. For $\overline{p}_F \in [p_F^*, 1]$ the $\overline{\delta}(\overline{p}_F)$ function is increasing in $\overline{p}_F$ and 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 foreign to pick the lower of these two price controls, the best response of foreign can never exceed p_F^*. Thus, foreign's best response curve coincides with the downward sloping part of the $\overline{\delta}(\overline{p}_F)$ curve shown in Figure 2.

3.3 Equilibrium ERP policy

Since home has the first move, it chooses its most preferred point on the downward sloping part of the $\overline{\delta}(\overline{p}_F)$ curve in Figure 2. For any ERP policy below this curve, the firm does not export so home welfare is at its lowest possible level whereas for any policy above the curve, home welfare can be increased by lowering δ: doing so lowers the home price without compromising the firm's export incentive. The following result is useful for understanding the equilibrium ERP policy chosen by home:

Lemma 4: *For all policy pairs that lie on the $\overline{\delta}(\overline{p}_F)$ curve, changes in the foreign price control $\overline{p}_F$ affect the welfare of the two countries in the following manner:*

(i) For all $\overline{p}_F \in (p_F^m, p_F^*]$ a reduction in $\overline{p}_F$ is Pareto-improving (i.e. makes both countries strictly better off).

(ii) For $\overline{p}_F \in (0, p_F^m]$, a reduction in $\overline{p}_F$ makes foreign better off at the expense of home.

Figure 2 is useful for explaining the logic of Lemma 4. The equilibrium policy pair in the absence of a foreign price control is given by point **E** in Figure 2 the coordinates of which are (p_F^*, δ^*). To understand the intuition behind Lemma 4 first consider the case where $\overline{p}_F \in (p_F^m, p_F^*]$. Over this range, a reduction in the foreign price requires home to make its ERP policy less stringent $(\partial\overline{\delta}(\overline{p}_F)/\partial\overline{p}_F < 0)$ to ensure that the firm's export incentive is preserved. But since $\left|\overline{\delta}(\overline{p}_F)/\partial\overline{p}_F\right|$ is relatively small in magnitude in this region, the direct decline in $\overline{p}_F$ dominates the increase in $\overline{\delta}(\overline{p}_F)$ so that $p_H^\delta(\overline{p}_F) = \overline{\delta}(\overline{p}_F)\overline{p}_F$ declines as $\overline{p}_F$ falls. Thus, *both countries gain from a tighter foreign price control* when $\overline{p}_F \in (p_F^m, p_F^*]$. Observe that home will not set an ERP policy tighter than $\delta(p_F^m)$, which we will denote simply by δ^m.

When $\overline{p}_F \in (0, p_F^m]$, 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 price at home (due to the sharp adjustment in its ERP policy) so that home loses while foreign gains from reducing $\overline{p}_F$. The following result is immediate:

Proposition 4: *In equilibrium, home implements the ERP policy δ^m, where*

$$\delta^m = \frac{1}{n}(n\mu - \sqrt{n\mu}).$$

This ERP policy is Pareto-efficient and it induces foreign to set its price control at the firm's optimal monopoly price (p_F^m) for its market.

The equilibrium policy pair (δ^m, p_F^m) is denoted by point **H** on Figure 2. The reason point **H** is home's most preferred policy pair is that home price $p_H^\delta(\overline{p}_F) = \overline{\delta}(\overline{p}_F)\overline{p}_F$ declines in $\overline{p}_F$ when $\overline{p}_F \in (0, p_F^m]$ whereas it increases with it for $\overline{p}_F \in (p_F^m, p_F^*)$ so that, subject to the firm exporting, home price is minimized at point **H**. Intuitively, since the firm has the strongest incentive to export when its foreign price equals the optimal monopoly price p_F^m, by choosing to implement the policy δ^m home can induce foreign to pick the price control p_F^m. In the absence of a foreign price control, point **H** is unattainable for home since if it were to announce the policy δ^m the firm would export and its price abroad would equal $p_F^\delta(\delta = \delta^m) > p_F^m$ and its total profit would exceed π_H^m. But when the foreign price control exists and responds endogenously to home's ERP policy, home can implement δ^m knowing that foreign will impose the lowest price consistent with the firm exporting, which equals p_F^m. Thus, because 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 equilibrium foreign price equals p_F^m, from the viewpoint of foreign consumers the equilibrium outcome coincides with that which obtains when the firm is completely free to price discriminate across markets. Even though the firm charges its optimal monopoly price p_F^m abroad when home implements the policy δ^m, the ability of home to commit to an ERP policy makes foreign consumers *better off* relative to the case where there the foreign price control is absent because the foreign price under δ^* is strictly higher than that under δ^m (i.e. $p_F^* > p_F^m$).

Further note that as Figure 2 shows $\delta^m > \delta^*$: i.e. 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_F^* (which exceeds p_F^m) forcing home to set a stricter ERP policy to keep the domestic price low while preserving the firm's export incentive.

3.4 Welfare: jointly optimal policies

It is clear that a jointly optimal pair of policies must lie on the $\overline{\delta}(\overline{p}_F)$ curve in Figure 2. Any combination of policies above this curve lowers welfare by widening the international price differential while any policy pair below the curve has the same effect by inducing the firm to not export. Furthermore, from Lemma 4 it is also clear that any jointly optimal price control has to lie in the range $(0, p_F^m]$. The jointly optimal pair of policies solves the following problem

$$\max_{\delta,\ \overline{p}_F} w(\delta \overline{p}_F,\ \overline{p}_F) \tag{12}$$

Substituting $\overline{\delta}(\overline{p}_F)$ into (12) and maximizing over $\overline{p}_F$ yields the jointly optimal price control:[28]

$$p_F^w = p_F^m(1 - \theta(n, \mu)) \tag{13}$$

where

$$\theta(n, \mu) = \frac{1}{\sqrt{1 + n\mu}} \tag{14}$$

Observe that

$$\frac{p_F^m - p_F^w}{p_F^m} = \theta(n, \mu) \tag{15}$$

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. $p_F^w < p_F^m$). 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 $\overline{p}_F = p_F^w$ in equation (11). Since $p_F^w < p_F^m$ 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 makes it possible to implement a more lax ERP policy provided the two countries coordinate their policies.

Finally, observe that home's equilibrium ERP policy δ^m is more stringent than the welfare maximizing policy δ^w (i.e. $\delta^w > \delta^m$) because it ignores the effect of its decision on

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

foreign consumers. The welfare maximizing policy pair (p_F^w, δ^w) is denoted as point **W** in Figure 2 and, for reasons explained above, it lies Northwest of the equilibrium point **H**.

4 Further analysis

In this section, we consider two important extensions of the policy game analyzed in section 2. We first expand the menu of policies available to the home country by allowing it to choose between a direct price control and an ERP policy. Next, we extend the policy game to allow for a scenario where the foreign price is determined by bargaining between the firm and the foreign government as opposed to being set unilaterally by one party.

4.1 An ERP policy or a price control?

Thus far, our analysis has ignored the possibility that home might prefer a domestic price control to an ERP policy. We now extend the model to directly address this issue. Suppose at the first stage of the policy game home can choose between setting an ERP policy (δ) or a price control $\overline{p}_H$ with the rest of stages of the game remaining the same as in the three-stage policy game described at the beginning of section 3.

We know from our previous analysis that if home uses an ERP policy then the equilibrium policy pair is (δ^m, p_F^m). Let home welfare under this policy pair be denoted by $w_H^m(\delta^m, p_F^m)$. Now consider the equilibrium outcome if home chooses a domestic price control. Unlike an ERP policy, a domestic price control does *not* affect the firm's foreign price and thus has *no bearing on its decision to export.* Therefore, in the second stage, foreign simply chooses the lowest price at which the firm is willing to sell in its market (i.e. it sets $\overline{p}_F = 0$ to maximize local consumer surplus). At the first stage of the game, home sets its price control to maximize its welfare knowing that the local price does not affect the firm's decision to export. Like foreign, home too finds its optimal to set the price control equal to the marginal cost of production (i.e. it sets $\overline{p}_H = 0$). Thus, when both countries use a price control, price equals marginal cost in each market and the firm makes zero profits. Let home welfare under $\overline{p}_H = 0 = \overline{p}_F$ be denoted by w_H^0 and firm profits in market i by π_i^0, $i = H$ or F.

From the perspective of home welfare, the trade-off between an ERP policy and a local price control boils down to the following: while a price control yields greater domestic surplus (defined as the sum of consumer surplus and firm's home profit), an ERP policy helps the firm earn greater profit abroad since the equilibrium price in the foreign market under the equilibrium ERP policy δ^m ends up being the optimal monopoly price p_F^m.

Let $\Delta\pi_F = \pi_F(\delta^m, p_F^m) - \pi_F^0$. Since $\pi_F^0 = 0$ we have $\Delta\pi_F = \pi_F(\delta^m, p_F^m)$. Similarly, $\Delta\pi_H = \pi_H(\delta^m, p_F^m) - \pi_H^0 = \pi_H(\delta^m, p_F^m)$. Furthermore, let Δcs_H be the amount by which consumer surplus at home under the ERP policy δ^m falls short of that under the price control $\overline{p}_H = 0$:

$$\Delta cs_H = -\frac{n}{\mu}\int_0^{\delta p_F^m}(t - \delta p_F^m)dt$$

Then, home prefers the ERP policy δ^m to the price control $\overline{p}_H = 0$ iff $\Delta w_H = w_H(\delta^m, p_F^m) - w_H^0 \geq 0$ which is the same as

$$\Delta\pi_F + \Delta\pi_H + \Delta cs_H \geq 0$$

where $\Delta\pi_H + \Delta cs_H \leq 0$ (i.e. the higher profit in the home market under its optimal ERP policy δ^m relative to the price control $\overline{p}_H = 0$ is more than offset by the accompanying loss in consumer surplus). Simplifying the the above inequality yields the following:

Proposition 5: *The home country prefers an ERP policy to a domestic price control (i.e. $w_H(\delta^m, p_F^m) \geq w_H^0$) iff $\mu < \overline{\mu}(n)$ where $\overline{\mu}(n) = (2\sqrt{2} + 3)/n$.*

This result sheds useful light on when and why a country might prefer an ERP policy to a domestic price control. If an ERP policy is in place at home, for all $p_F^\delta \leq p_F^m$ a stricter foreign price control translates into a lower home price (holding constant the ERP policy) and lower global profit for the home firm, something that tends to make exporting less attractive to the firm. Recognizing this link between prices in the two markets created by home's ERP policy, foreign is willing to push down its own price control only so far when home's price regulation takes the form of an ERP policy as opposed to a price control. In contrast, when home implements a price control rather than an ERP policy, there is no link between prices in the two markets and the foreign government is free to set its price control at marginal cost without affecting the firm's decision to export. While this outcome is desirable from the viewpoint of foreign consumers, it is not in the interest of the firm since it makes zero profits abroad when the foreign price control equals its marginal cost. An ERP policy can dominate a price control from the perspective of home welfare when the foreign market is not too different in size from the home own market so that the higher foreign profit ($\Delta\pi_F$) under an ERP policy dominates the loss in domestic surplus ($\Delta\pi_H + \Delta cs_H$) created by it relative to a price control. When $\mu > \overline{\mu}(n)$ the home market is significantly more lucrative for the firm than the foreign market and home's incentive to extract profit from foreign consumers is trumped by the loss in domestic surplus it suffers under an ERP policy relative to a local price control.[29]

It is worth noting that from home's perspective an ERP policy is dominated by a domestic price control when the firm does not face a price control abroad, i.e., $w_H(\delta^*, p_F^*) < w_H^0$. The logic for why the presence of a foreign price control makes it more attractive for home to use an ERP policy is as follows. First, recall that the firm is willing to export for all foreign price controls and ERP policy combinations that lie on the $\overline{\delta}(\overline{p}_F)$ curve. Second, in the presence of a foreign price control ($\overline{p}_F$), home can take advantage of the fact that the foreign government will set its price control $\overline{p}_F$ so as to ensure that the firm sells in its market. By contrast, in the absence of a foreign price control, home has to preserve the firm's export incentive entirely on its own. As a result, in the absence of the foreign price control, the only point on the $\overline{\delta}(\overline{p}_F)$ that is accessible to home is the pair (δ^*, p_F^*) whereas in the presence of an endogenously determined foreign price control, home can obtain any pair of policies on the $\overline{\delta}(\overline{p}_F)$ curve as an equilibrium outcome. This wider choice set allows home to pick its most preferred point on the $\overline{\delta}(\overline{p}_F)$ curve. Furthermore, we know from Lemma 3(i) that home welfare strictly increases as we move along the $\overline{\delta}(\overline{p}_F)$ curve from point **E** towards point **H** (where it reaches its maximum value): as we move up the $\overline{\delta}(\overline{p}_F)$ curve from point **E** towards point **H**, the total profit of the home firm remains unchanged (equals π_H^m) whereas home price (p_H^δ) falls so that total domestic welfare increases.

4.2 Price bargaining

We now discuss the case where the foreign government and the firm bargain over price. The timing of moves is as follows. First, home chooses its ERP policy (δ). Next, the firm and the foreign government bargain over the firm's foreign price (p_F). We utilize the Nash bargaining solution as the outcome of the bargaining subgame. We first examine bargaining in the absence of side-payments and then consider the case where side-payments are possible between the two parties so that the price in the foreign market is chosen to maximize their joint surplus. We show that, from the perspective of home, an ERP policy can dominate a domestic price control under both scenarios.

[29] Observe that $\overline{\mu}(n)$ is decreasing in n. This makes intuitive sense: as the home market becomes larger relative to the foreign market (i.e. as n increases) , the ERP policy becomes less attractive relative to a price control because domestic consumer surplus is proportional to n.

4.2.1 Nash bargaining

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 $[\overline{p}_F(\delta), p_F^{\delta}(\delta)]$ where the $\overline{p}_F(\delta)$ 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 $\pi_G(p_F;\delta)$ where

$$\begin{aligned}\pi_G(p_F;\delta) &= \pi_H(p_F;\delta)+\pi_F(p_F;\delta)\\ &= \frac{n}{\mu}\delta p_F(\mu-\delta p_F)+p_F(1-p_F)\end{aligned}$$

The price under Nash bargaining solves

$$\max_{p_F} \beta\ln[cs_F(p_F)]+(1-\beta)\ln[\pi_G(p_F;\delta)-\pi_H^m] \tag{16}$$

subject to $\pi_G(p_F;\delta)\geq\pi_H^m$. The parameter $\beta\in[0,1]$ can be interpreted as the bargaining power of the foreign government relative to the firm. The first order condition for this problem is

$$\frac{\beta}{cs_F(p_F)}\frac{dcs_F(p_F)}{dp_F}+\frac{1-\beta}{\pi_G(p_F;\delta)-\pi_H^m}\frac{d\pi_G(p_F;\delta)}{dp_F}=0$$

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

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

where

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

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

Now consider home's ERP policy decision. Home sets its ERP policy taking into account the price $p_F(\delta,\beta)$ that emerges from the bargaining that follows its decision. When $\beta=1$, the home's ERP policy is given by point **H** in Figure 2. In this case, the firm has zero bargaining power and the foreign government effectively controls the price. As a result, home's most preferred policy ensures that the firm ends up charging its optimal monopoly price p_F^m abroad and therefore has the strongest incentive to export. When $\beta=0$, the firm is free to pick any price abroad and home sets a much more stringent ERP policy with the equilibrium policy outcome being given by point **E** in Figure 2. When bargaining power is split between the two parties, the firm earns strictly positive rents in the bargaining subgame and $p_F(\delta, \beta) > p_F^*$. At the first stage, home simply chooses its most preferred point on the $\overline{\delta}(\overline{p}_F)$ curve which will generally lie Northwest of point **E**.

Consider now the impact of bargaining on home's choice between an ERP policy and a local price control. We know from previous analysis that when $\beta = 0$ (i.e. when the home firm is free to set its foreign price) a domestic price control dominates an ERP policy whereas when $\beta = 1$ (i.e. foreign has all the bargaining power) an ERP policy dominates a price control if the countries are sufficiently alike (see Proposition 5). This suggests that the case for an ERP policy relative to a price control is likely to be stronger when the bargaining power of the domestic firm is lower. While analytical derivations are cumbersome, we have numerically confirmed this insight and illustrate in Table 1 below.[30] The last column of this table shows home's welfare gain (in percentage terms) from replacing the optimally chosen price control by the optimal ERP policy. The table illustrates that as the foreign government's bargaining power increases, the foreign price decreases and even though the home country relaxes its ERP policy, the price at home also falls. Furthermore, the higher the bargaining power of the foreign government, the smaller the amount by which domestic surplus under an ERP surplus falls short of he domestic surplus under a local price control and the higher the amount by which the firm's foreign profit under an ERP policy at home exceeds its foreign profit when it faces a price control at home. Perhaps most importantly, home prefers an ERP policy to a price control (i.e. $\Delta w_H > 0$) when its firm's bargaining position is weak relative to the foreign government (i.e. when β is higher).

Table 1: ERP versus price control: the role of foreign bargaining power

Foreign bargaining power (β)	δ^*	$\overline{p}_F(\delta^*)$	$p_H(\delta^*)$	$\Delta cs_H + \Delta\pi_H$	$\Delta\pi_F$	Δw_H	$\Delta w_H\%$
$\beta = 0.5$	1.867	0.652	1.218	-0.185	0.039	-0.146	-6.7%
$\beta = 0.6$	1.912	0.619	1.183	-0.175	0.076	-0.099	-4.6%
$\beta = 0.7$	1.948	0.586	1.142	-0.163	0.115	-0.048	-2.3%
$\beta = 0.8$	1.976	0.556	1.098	-0.151	0.157	0.006	0.3%
$\beta = 0.9$	1.993	0.527	1.050	-0.137	0.201	0.064	3.1%
$\beta = 1.0$	2.000	0.500	1.000	-0.125	0.250	0.125	6.3%

Additional insight into the home country's choice between an ERP policy can be obtained by examining how this choice is affected by changes in μ – the key demand parameter that nails down the domestic monopoly price and therefore the relative profitability of the

[30] For the calculations presented in Table 1, we set $n = 1$ and $\mu = 4$.

two markets from the firm's perspective. Table 2 shows that as μ increases, the loss in domestic surplus caused by an ERP policy relative to a price control increases whereas the gain in foreign profit experienced by the firm decreases.[31] As a result, the home country's welfare under an ERP policy exceeds that under a price control only when μ is not too large (i.e. foreign demand is relatively similar to domestic demand).

Table 2: ERP versus price control: the role of demand asymmetry

Home demand	δ^*	$\overline{p}_F(\delta^*)$	$p_H(\delta^*)$	$\Delta cs_H + \Delta\pi_H$	$\Delta\pi_F$	Δw_H	$\Delta w_H\%$
$\mu = 3.0$	1.295	0.541	0.700	−0.081	0.158	0.077	4.8%
$\mu = 3.5$	1.634	0.548	0.897	−0.115	0.158	0.042	2.3%
$\mu = 4.0$	1.976	0.556	1.098	−0.151	0.157	0.006	0.3%
$\mu = 4.5$	2.318	0.562	1.302	−0.188	0.156	−0.032	−1.4%
$\mu = 5.0$	2.660	0.568	1.510	−0.228	0.155	−0.072	−2.8%
$\mu = 5.5$	3.001	0.573	1.721	−0.269	0.155	−0.115	−4.0%

4.2.2 If side-payments are possible

Now consider the case where side payments are possible between the two parties so that the foreign price p_F is chosen to maximize their joint welfare.[32] In other words, given home's ERP policy δ, the foreign price is chosen to maximize the sum of the firm's global profit and consumer surplus in the foreign market:

$$\max_{p_F} S(p_F; \delta) \equiv \pi_G(p_F; \delta) + cs_F(p_F; \delta) \tag{17}$$

The solution to the above problem is described in the following lemma:

Lemma 5: *(i) Given home's ERP policy, the joint surplus $S(p_F; \delta)$ of the foreign government and the firm is maximized by setting $p_F = p_F^b(\delta)$ where*

$$p_F^b(\delta) = \frac{n\mu\delta}{\mu + 2n\delta^2} \tag{18}$$

(ii) $\partial p_F^b(\delta)/\partial n > 0$; $\partial p_F^b(\delta)/\partial \mu > 0$; and $\partial p_F^b(\delta)/\partial \delta > 0$ iff $\delta < \delta_B \equiv \sqrt{\mu/2n}$.

The jointly optimal price $p_F^b(\delta)$ has intuitive properties. As the home market becomes more lucrative for the firm (either due to an increase in n or μ), the two parties agree to set a higher price in the foreign market. The non-monotonicity of $p_F^b(\delta)$ in δ described in part *(ii)* of Lemma 5 can be understood as follows: when δ is small (i.e. near 1), the

[31] For the calculations presented in Table 2, we set $n = 1$ and $\beta = 0.8$.

[32] This would be the case if the two parties can make side-payments to each other to ensure that the jointly optimal price is charged in the foreign market. Of course, this does not maximize global welfare since neither party cares about consumer surplus at home.

price in the home market is quite far from the firm's optimal home price p_H^m so that its global profit is well below its maximum value. Starting at $\delta \simeq 1$, the jointly optimal foreign price $p_F^b(\delta)$ 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_B, 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. Note that $p_F^b(\delta)$ 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 since doing so maximizes their joint surplus.

The firm's price at home equals $p_H^b(\delta) = \delta p_F^b(\delta)$. It is straightforward to show that

$$\frac{dp_H^b(\delta)}{d\delta} > 0$$

i.e. the price in home increases as home's ERP policy becomes more lax. Thus, a relaxation of the home's ERP policy makes domestic consumers worse off even when the foreign price maximizes the joint welfare of the firm and the foreign government. Furthermore, we have

$$\frac{dS^b(\delta)}{d\delta} > 0$$

Since π_H^m is independent of δ, this implies that the joint surplus available to the firm and the foreign government from reaching agreement over the price $p_F^b(\delta)$ is higher when the home's ERP policy is looser. The intuition is straightforward: the firm's global profit as well as consumer surplus abroad increase when it has greater freedom to price discriminate internationally.

We assume that the bargaining process is such that the two parties agree to allocate the joint surplus created abroad at price $p_F^b(\delta)$ in the following manner: they first give each party a share of the total surplus that equals its payoff under disagreement and then share the remaining surplus between themselves with $\beta \in [0, 1]$ denoting the share of the foreign government. Since the firm's profit under no agreement equals π_H^m, its payoff from reaching agreement with the foreign government under which it sells in the foreign market at price $p_F^b(\delta)$ equals

$$v^b(\delta) = \pi_H^m + (1 - \beta)[S(p_F^b(\delta)) - \pi_H^m] \tag{19}$$

while that of the foreign government equals

$$w_F^b(\delta) = \beta[S(p_F^b(\delta)) - \pi_H^m]$$

Observe that for foreign sales to raise the total surplus available to the two parties and for the firm to prefer selling in both markets at price $p_F^b(\delta)$ to selling only at home at its optimal monopoly price p_H^m, we must have $S(p_F^b(\delta)) \geq \pi_H^m$. This inequality binds at $\delta = \delta^b$ i.e. we have:

$$S(p_F^b(\delta)) \geq \pi_H^m \Leftrightarrow \delta \geq \delta^b = \frac{\sqrt{n\mu(n\mu - 2)}}{2n} \tag{20}$$

i.e. if home's ERP policy is any tighter than δ^b then the firm is unwilling to sell abroad.[33]

The home government chooses its ERP policy δ to maximize local welfare taking into account the effect of its policy on the outcome of the bargaining process. It solves:

$$\max_{\delta} w_H^b(\delta) = \begin{cases} \pi_H^m + cs_H^m \text{ if } \delta < \delta^b \\ v^b(\delta) + cs_H^b(\delta) \text{ if } \delta \geq \delta^b \end{cases}$$

where $cs_H^b(\delta) = cs_H(p_F^b(\delta))$. Since $v^b(\delta^b) > \pi_H^m$ and because $cs_H^b(\delta^b) > cs_H^m$ it follows that home will never set δ below δ^b. Furthermore, it is straightforward to show that

$$\frac{d(v^b(\delta) + cs_H^b(\delta))}{d\delta} < 0$$

i.e. given that the firm sells abroad at $p_F^b(\delta)$, home welfare declines in its ERP policy δ. Thus, in equilibrium, home sets its ERP policy at δ^b. We have:

Proposition 6: *Suppose the firm and the foreign government choose the foreign price p_F to maximize their joint welfare $S(p_F;\delta)$. Then, regardless of how the total surplus is split between the two parties, home's optimal ERP policy is δ^b at which the firm is indifferent between selling only at home (at its optimal monopoly price p_H^m) and selling in both markets while charging the price $p_F^b(\delta)$ abroad and $p_H^b(\delta) = \delta p_F^b(\delta)$ at home. Furthermore, the equilibrium ERP policy δ^b has the following properties: (i) $\partial\delta^b/\partial\mu > 0$; (ii) $\partial\delta^b/\partial n > 0$; and (iii) $\delta^b < \delta^m$.*

Several points are worth noting about the above result. First, since home moves first, it is able to extract all of the surplus created by bargaining between its firm and the foreign government by setting an ERP policy at which the total surplus available to the two parties at their jointly optimal price $p_F^b(\delta)$ equals the firm's profit from not exporting (i.e. $S(p^b(\delta)) = \pi_H^m$). Second, home is able to implement a tighter ERP policy when negotiations between the firm and the foreign country yield the jointly efficient price $p_F^b(\delta)$ as opposed to the profit-maximizing price p_F^m (i.e. $\delta^b < \delta^m$). Since total welfare is decreasing in δ (conditional on the firm exporting), price negotiations increase global welfare by resulting

[33] Note that $\delta^b \geq 1$ only when $\mu \geq \mu^{**} = (1 + \sqrt{4n^2 + 1})/n$, where $\mu^{**} > \mu^*$. In what follows, we focus on the case where $\mu \geq \mu^{**}$ is satisfied. When $\mu < \mu^{**}$, the efficient ERP policy is a corner solution (i.e. $\delta^b = 1$). We can show that even when $\delta^b = 1$ there exist parameter values for which home prefers an ERP policy to a local price control.

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, home 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 $[(\overline{p}_F(\delta), p_F^{\delta}(\delta)]$ over the $\overline{\delta}(\overline{p}_F)$ curve.

Finally, consider the comparison between an ERP policy and a domestic price control $\overline{p}_H$ when the firm and the foreign government choose the price to maximize their joint surplus. Given $\overline{p}_H$, the firm and the foreign government choose p_F to solve:

$$\max_{p_F} S_F(p_F) \equiv \pi_G(\overline{p}_H, p_F) + cs_F(p_F) \tag{21}$$

where

$$\pi_G(\overline{p}_H, p_F) = \pi_H(\overline{p}_H) + \pi_F(p_F)$$

Given that the firm's home profit $\pi_H(\overline{p}_H)$ is independent of the foreign price p_F, the solution to the problem in (21) is to set $p_F = 0$, i.e., when prices in the two markets are not linked – as is the case in the absence of an ERP policy at home – total surplus available to the two parties from the foreign market is maximized by setting price equal to marginal cost.

In the absence of an ERP policy, there is no link between prices in the two markets. As a result, when home uses a price control $\overline{p}_H$, the firm's payoff equals:

$$v^b(\overline{p}_H, p_F) = \pi_H(\overline{p}_H) + (1-\beta)[S_F(p_F) - \pi_H(\overline{p}_H)]$$

where $\pi_H(\overline{p}_H) = \overline{p}_H(n/\mu)(\mu - \overline{p}_H)$ is independent of p_F while $S_F(p_F)$ is independent of $\overline{p}_H$.

Let

$$S_F(0) \equiv S_F(p_F)|_{p_F=0}$$

and

$$v^b(\overline{p}_H, 0) = \pi_H(\overline{p}_H) + (1-\beta)[S_F(0) - \pi_H(\overline{p}_H)]$$

We are now ready to consider home's price control decision at the first stage of the game. It chooses its price control $\overline{p}_H$ to maximize

$$\max_{\overline{p}_H} \quad w_H(\overline{p}_H) \equiv cs_H(\overline{p}_H) + v^b(\overline{p}_H, 0)$$

Since $S_F(0)$ is independent of $\overline{p}_H$, the above problem is the same as

$$\max_{\overline{p}_H} cs_H(\overline{p}_H) + \beta\pi_H(\overline{p}_H)$$

the solution to which is again $\overline{p}_H = 0$. Even though $\pi_H(\overline{p}_H)$ increases in $\overline{p}_H$ when $\overline{p}_H \leq p^m_H$, we know that $\beta \leq 1$ and welfare in the domestic market (i.e. $cs_H(\overline{p}_H) + \pi_H(\overline{p}_H)$) is maximized by setting domestic price equal to marginal cost.

Now we can compare home's equilibrium welfare under an ERP policy with that under a price control. It can be shown that[34]

$$w_H(\delta^b, p(\delta^b)) - w_H(\overline{p}_H)|_{\overline{p}_H=0} > 0 \text{ iff } \mu < \mu^b \text{ where } \mu^b = \frac{2}{n}(\beta + \sqrt{\beta^2 + 1}). \tag{22}$$

In other words, once again, an ERP policy dominates price control when countries are similar enough, i.e. $\mu < \mu^b$. Note that μ^b is increasing in β, meaning that, once again, an ERP policy is more likely to dominate a price control when the foreign government's bargaining power is high.

5 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, home 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 home. 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.

Almost by design, home's ERP policy generates a negative price spillover for foreign consumers in our model. However, quite surprisingly, we find that home's optimal ERP

[34] This welfare comparison applies for the case where the parameter values are such that the ERP policy δ^b is not at a corner solution (i.e. $\delta^b > 1$). As we noted earlier, this requires that $\mu \geq \mu^{**}$. Even when this condition fails (i.e. $\mu < \mu^{**}$ so that $\delta^b = 1$) we can show that home can still prefer the ERP policy δ^b to a domestic price control set at the firm's marginal cost ($\overline{p}_H = 0$).

policy maximizes aggregate welfare even though it 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 home is willing to provide in the absence of a price control abroad.

While our model delivers several important insights, it does make certain specific assumptions (such as linear demand) in order to make sufficient analytical progress on key questions of interest. Nevertheless, we believe that the key driving force of the model – i.e. each country wants to secure access to the patented product at the lowest possible price taking the firm's incentives into account – is fairly general. Similarly, the insight that an ERP policy can be preferable to a local price control when the firm is subject to a foreign price control or is in a weak bargaining position abroad rests on a key aspect of an ERP policy that should continue to hold in a more general setting – i.e. unlike a local price control, an ERP policy links prices internationally and this can help the firm secure a more attractive price and therefore greater profit abroad.

6 Appendix

6.1 Derivation of $\overline{\delta}(\overline{p}_F)$

Here we show that $\overline{\delta}(\overline{p}_F) = \frac{\mu}{2\overline{p}_F} - \frac{1}{n\overline{p}_F}\sqrt{\mu n \overline{p}_F(1-\overline{p}_F)}$. To simplify exposition, let $x = \overline{p}_F$ and $y = \delta$. The firm is indifferent between exporting and selling only at home whenever:

$$\frac{n}{\mu}xy(\mu - xy) + x(1-x) = \frac{n\mu}{4}$$

which can be rewritten as

$$\frac{nx^2y^2}{\mu} - nxy = x(1-x) - \frac{n\mu}{4}$$

Dividing both sides by nx^2/μ gives:

$$y^2 - \frac{\mu y}{x} = \frac{\mu(1-x)}{nx} - \frac{\mu^2}{4x^2}$$

This is a quadratic equation in y and the relevant solution is given by

$$y = \frac{1}{2x}\left(\mu - 2x\sqrt{\frac{\mu\,(1-x)}{nx}}\right)$$

which is the same as

$$y = \frac{\mu}{2x} - \sqrt{\frac{\mu\,(1-x)}{nx}}$$

which can be rewritten as

$$y = \frac{\mu}{2x} - \frac{1}{nx}\sqrt{\mu nx\,(1-x)}$$

which implies

$$\overline{\delta}(\overline{p}_F) = \frac{\mu}{2\overline{p}_F} - \frac{1}{n\overline{p}_F}\sqrt{\mu n\overline{p}_F(1-\overline{p}_F)}.$$

6.2 Alternative timing assumptions

Suppose the two countries set their respective policies simultaneously: home sets its ERP policy δ while foreign sets its price control $\overline{p}_F$. It is clear that given $\overline{p}_F$ the optimal ERP for home is the threshold policy $\overline{\delta}(\overline{p}_F)$. We now characterize foreign's optimal price control given home's ERP policy. If the firm does not export, foreign has no access to the good and its welfare equals zero. Moreover, conditional on the firm exporting, a more lax price control is counter-productive as it simply raises the local price. Hence, for a given ERP policy, foreign picks the lowest possible price control that just induces the firm to export. For $\overline{p}_F \in [0, p_F^*]$ since the $\overline{\delta}(\overline{p}_F)$ function is monotonically decreasing in $\overline{p}_F$, its inverse $\overline{p}_F(\delta)$ yields foreign's best response to a given ERP policy of home. For $\overline{p}_F \in [p_F^*, 1]$ since the $\overline{\delta}(\overline{p}_F)$ function is increasing in $\overline{p}_F$, it is optimal for foreign to pick the lowest price at which the firm is willing to export. Thus, foreign's best response curve coincides with the downward sloping part of the $\overline{\delta}(\overline{p}_F)$ curve. This implies that any point to left of p_F^* on the $\overline{\delta}(\overline{p}_F)$ curve (plotted in Figure 2) is a Nash equilibrium. We can state the following:

Proposition 7: *Any pair of export inducing policies* $(\overline{p}_F, \delta)$ *where* $\overline{p}_F \leq p_F^*$ *and* $\delta \geq \delta^*$ *constitutes a Nash equilibrium of the simultaneous move policy game. In all Nash equilibria, the firm's global profit equals* π_H^m. *For Nash equilibria in which* $\overline{p}_F \in [0, p_F^*]$, *the home price declines in the foreign price control (i.e.* $\partial p_H^\delta(\overline{p}_F)/\partial \overline{p}_F = \partial[\overline{\delta}(\overline{p}_F)\overline{p}_F]/\partial \overline{p}_F < 0$) *whereas for Nash equilibria in which* $\overline{p}_F \in [p_F^m, p_F^*]$, *it increases with it (i.e.* $\partial p_H^\delta(\overline{p}_F)/\partial \overline{p}_F \geq 0$). *Furthermore,* $p_H^\delta(\overline{p}_F \to 0) = p_H^m$.

Proposition 7 says that when the foreign price control is lax (i.e. $p_F^m < \overline{p}_F \leq p_F^*$), a tightening of the foreign price control (i.e. a reduction in $\overline{p}_F$) lowers the home price through the adjustment of home's ERP policy whereas when the price control is relatively stringent ($\overline{p}_F \leq p_F^m$), a further reduction in $\overline{p}_F$ raises the home price. The response of home's ERP policy to changes in the foreign price control (described in Lemma 3) is crucial to understanding the non-monotonicity of $p_H^\delta(\overline{p}_F)$. To see why, note that

$$\frac{\partial p_H^\delta(\overline{p}_F)}{\partial \overline{p}_F} = \overline{\delta}(\overline{p}_F) + \overline{p}_F \frac{\partial \overline{\delta}(\overline{p}_F)}{\partial \overline{p}_F} \tag{23}$$

so that if $\partial \overline{\delta}(\overline{p}_F)/\partial \overline{p}_F \geq 0$ then the home price would necessarily increase with the foreign price control since $\overline{\delta}(\overline{p}_F) > 0$. However, as Lemma 3 notes $\partial \overline{\delta}(\overline{p}_F)/\partial \overline{p}_F < 0$ whenever $0 < \overline{p}_F < p_F^*$, i.e., for this range of the foreign price control, home 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 $\partial^2 \overline{\delta}(\overline{p}_F)/\partial \overline{p}_F^2 \geq 0$, 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

$$\varepsilon_\delta \equiv -\frac{\partial \overline{\delta}}{\partial \overline{p}_F} \frac{\overline{p}_F}{\overline{\delta}}$$

Observe that

$$\frac{\partial p_H^\delta(\overline{p}_F)}{\partial \overline{p}_F} \leq 0 \Longleftrightarrow \varepsilon_\delta \geq 1 \tag{24}$$

It is straightforward to show that

$$\varepsilon_\delta \geq 1 \text{ iff } \overline{p}_F \leq p_F^m \tag{25}$$

As a result, the home price declines in $\overline{p}_F$ for all $\overline{p}_F \in (0, p_F^m]$ whereas it increases with it for $\overline{p}_F \in (p_F^m, p_F^*)$.

The last statement of Proposition 7 says that as $\overline{p}_F \to 0$ the home price converges to the monopoly price p_H^m. This is because home has to completely drop its ERP policy (i.e. $\delta^*(\overline{p}_F)$ tends to $+\infty$) when $\overline{p}_F \to 0$ in order to maintain the firm's export incentive.

We have shown that when the two countries set their policies simultaneously there exist a continuum of Nash equilibria that constitute the downward sloping part of the $\overline{\delta}(\overline{p}_F)$ curve. Of course, as is clear from our analysis in section 3, these equilibria have rather different welfare properties.[35] Furthermore, the firm's total profit does not play a role in determining the relative welfare ranking of these equilibria since in all Nash equilibria the firm's profit equals its monopoly profit under no exporting (π_H^m), i.e., the firm is indifferent between selling only at home and selling in both markets. From Lemma 4 we know that all Nash equilibria for which $\overline{p}_F \in (p_F^m, p_F^*]$ are *Pareto-dominated* by point **H** on the curve in Figure 2 where home sets the policy δ^m and $\overline{p}_F = p_F^m$.

What if foreign selects its 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. $\overline{p}_F \simeq 0$) 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^m. 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.

6.3 Optimal reference basket in a three-country scenario

Suppose there are three countries: A, B and C and let $\mu_A \geq \mu_B \geq \mu_C = 1$. In what follows, we derive the optimal *reference basket* of country A. When setting its ERP policy, country A has four options: it can include only country B, only country C, both countries B and C, or none of them in its reference basket. We denote the alternative reference baskets by R where $R = \{B\}$, $\{C\}, \{B, C\}$, or $\{\Phi\}$. Country A's ERP policy requires that the firm's price in its local market be no higher than the lowest price it charges among all countries

[35] In particular, note that there 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.

included in its reference basket. As will be shown below, country A's optimal reference basket depends on the firm's exporting decision, which in turn is affected by the degree of symmetry across the three markets as captured by μ_i.

When country A does not use any ERP policy (i.e. its policy is $\{\Phi\}$) the firm can charge a monopoly price in each country. We can write the firm's global profit in this case as the sum of its monopoly profits across countries: $\pi_G^m = \sum_i \pi_i^m$, $i = A$, B, or C. Each country's consumer surplus can be written as cs_i^m where $i = A$, B, C. Moreover, country A's welfare equals the sum of its consumer surplus and the firm's global profit: $w_A^m = cs_A^m + \pi_G^m$. World welfare is simply the sum of each country's welfare: $ww^m = \sum_i w_i^m$.

It is helpful to study country A's choice of its reference basket by analyzing three cases depending on the relationship between μ_A and μ_B. First, given that country A's reference basket is $\{B\}$, it can be shown that the firm exports to country B subject to the ERP iff $\mu_A \leq 3\mu_B$ and it only sells in country A if $\mu_A > 3\mu_B$. Second, when facing the ERP policy $\{C\}$, the firm exports to country C iff $\mu_A \leq 3$ and prefers to forego country C if $\mu_A > 3$. Thus the three cases we need to examine can be summarized as: (1) $\mu_A > 3\mu_B$; (2) $3 < \mu_A \leq 3\mu_B$ and (3) $\mu_A \leq 3$, where we have $\mu_A \geq \mu_B \geq \mu_C = 1$.

Also important to our analysis is the case where A's reference basket is $\{B, C\}$. In this case the firm can apply different pricing strategies depending on the relationship between the common price in countries A and C when it sells in both markets (denoted by $p(AC)$) and the monopoly price in country B (p_B^m). To see this, note that if $p(AC) \leq p_B^m$, then conditional on exporting, the firm can charge $p(AC)$ in country A and C and p_B^m in country B, which does not violate the ERP policy constraint of country A. Doing so gives the firm a higher global profit than charging a common price $p(ABC)$ in all countries. In contrast, if $p(AC) > p_B^m$ then the firm in principle has three options: (i) it can charge $p(ABC)$ in all countries or (ii) charge $p(AC)$ in country A and C while foregoing country B or (iii) charge $p(AB)$ in country A and B and forego country C. It can be shown that the second option is never chosen since it is less profitable for the firm than the first one. We can further calculate that $p(AC) \leq p_B^m$ iff (a) $\mu_B > 2$ or (b) $1 < \mu_B \leq 2$ and $\mu_A \leq \widehat{\mu}_A \equiv \frac{\mu_B}{2-\mu_B}$ implying that $p(AC) > p_B^m$ iff $1 < \mu_B \leq 2$ and $\mu_A > \widehat{\mu}_A$.

We are now ready to derive country A's optimal reference basket.

Case 1: $\mu_A > 3\mu_B$.

In this case, $\{B\}$ is dominated by $\{\Phi\}$. To see why, simply note that under $R = \{B\}$ the firm foregoes country B and charges monopoly prices in countries A and C, while under

$\{\Phi\}$ it charges monopoly prices in all countries. Thus the firm's global profit is higher under $\{\Phi\}$, which also leads to higher welfare for country A. Analogously, it is easy to see that $\{C\}$ is also dominated by $\{\Phi\}$. Therefore, country A has to effectively choose between $\{\Phi\}$ and $\{B, C\}$. There are two sub-cases to be considered:

Sub-case 1.1: $p(AC) \leq p_B^m$.

Under $\{\Phi\}$, country A's welfare is w_A^m. Now consider the case where country A's reference basket is $\{B, C\}$. In this case, the firm has three options: (i) export to both foreign countries charging $p(AC)$ in countries A and C and p_B^m in country B or (ii) export to country B at price $p(AB)$ and forego country C or (iii) sell only at home at its optimal monopoly price. Since $\mu_A > 3\mu_B$, option (ii) is dominated by option (iii) from the firm's perspective. Moreover, it turns out that option (iii) also dominates option (i) when $\mu_A > 3\mu_B$. Therefore, $\mu_A > 3\mu_B$, the firm does not export to either market if country A sets its reference basket as $\{B, C\}$. It follows then that country A prefers $\{\Phi\}$ to $\{B, C\}$.

Sub-case 1.2: $p(AC) > p_B^m$.

In this case, if country A chooses $\{B, C\}$ the firm again has three options as in sub-case 1.1, except that its option (i) now becomes charging the price $p(ABC)$ in all countries. Given that option (ii) is dominated, we only need to compare the firm's global profit under options (i) and (iii). It is straightforward to show that the firm prefers option (i) to option (iii) iff $\mu_A < \widetilde{\mu}_A \equiv 8\mu_B/(\mu_B + 1)$. Also note that country A's welfare is higher if the firm exports to country B and C since this helps lowers the price at home. Therefore, country A chooses the reference basket $\{B, C\}$ over $\{\Phi\}$ iff $\mu_A \leq \widetilde{\mu}_A$.

Case 2: $3 < \mu_A \leq 3\mu_B$.

In this case, the firm exports to country B if country A's reference basket is $\{B\}$. Moreover, it is easy to see that from A's perspective $\{B\}$ always dominates $\{\Phi\}$ because it lowers price and improves consumer surplus at home. Thus, country A only has to decide between $\{B\}$ and $\{B, C\}$. To compare these choices, we need to consider two sub-cases.

Sub-case 2.1: $p(AC) \leq p_B^m$.

Under $\{B\}$ the firm charges the common price $p(AB)$ in countries A and B while charging its monopoly price p_C^m in country C. On the other hand, under $\{B, C\}$ the firm has three options: it can (i) export to both countries B and C charging $p(AC)$ in country A and C and p_B^m in country B or (ii) export to country B at price $p(AB)$ and forego country C or (iii) sell only at home at p_A^m. Since $\mu_A < 3\mu_B$ we know option (ii) dominates option (iii). Moreover, it can be shown that the firm prefers option (ii) to option (i) iff $\mu_A > \overline{\mu}_A \equiv (\mu_B(\mu_B + 1 + \sqrt{\mu_B^2 + 14\mu_B - 15}))/2(3\mu_B - 4)$. Furthermore, if $\mu_A > \overline{\mu}_A$ then country A is better off under the reference basket $\{B\}$ since the firm still charges $p(AB)$ in country A and B but also exports to country C, hence making greater global profit.

Now consider the case where $\mu_A \leq \overline{\mu}_A$ so that the firm necessarily chooses option (i) under $\{B, C\}$. Comparing $\{B\}$ with $\{B, C\}$, it turns out that country A's welfare is higher under $\{B, C\}$. Hence country A prefers $\{B, C\}$ to $\{B\}$.

Sub-case 2.2: $p(AC) > p_B^m$.

When $p(AC) > p_B^m$, the option (i) under $\{B, C\}$ is to charge the common price $p(ABC)$ in all countries. Moreover, it can be shown that the firm always prefers option (i) to option (ii) under $\{B, C\}$. Comparing reference baskets $\{B\}$ and $\{B, C\}$, it is easy to show that country A's welfare is higher under the latter.

Case 3: $1 \leq \mu_A \leq 3$.

In this case, it can be shown that country A prefers $\{C\}$ to $\{B\}$. The reason is that by referencing country C (as compared to B) an ERP policy can lead to a lower domestic price and thus higher consumer surplus in country A. To determine the optimal reference basket, country A needs to compare $\{C\}$ and $\{B, C\}$. As before, there are two sub-cases to consider.

Sub-case 3.1: $p(AC) \leq p_B^m$.

As above under $\{B, C\}$ the firm can (i) export to both foreign countries charging $p(AC)$ in country A and C and p_B^m in country B or (ii) export to country B at price $p(AB)$ and forego country C or (iii) sell only at home (i.e. country A) at p_B^m. Given the set of permissible parameters for sub-case 3.1, the firm chooses option (i). Hence the reference baskets $\{C\}$ and $\{B, C\}$ are equivalent in the sense that they induce the same pricing strategy by the firm. As a result, country A is indifferent between $\{C\}$ and $\{B, C\}$.

Sub-case 3.2: $p(AC) > p_B^m$.

When $p(AC) > p_B^m$, under option (i) firm charges $p(ABC)$ in all countries under $\{B, C\}$ given it exports to both countries. Again, option (i) yields higher global profit to the firm than options (ii) and (iii). Moreover, country A's welfare is higher under $\{B, C\}$ than $\{C\}$.

We can now state our main result:

Proposition 8: *Under an ERP policy set by country A that requires the firm's price in its market to be no higher than the lowest price it charges in the other markets in which it sells its product, country A's optimal reference basket is characterized as follows:*

(i) When $\mu_A > 3\mu_B$ and $\mu_A > \widetilde{\mu}_A$, country A's reference basket is empty (i.e. it is $\{\Phi\}$) and the firm is free to price discriminate internationally.

(ii) When $\mu_A \leq 3\mu_B$ and $\mu_A > \overline{\mu}_A$, country A includes only country B in its reference basket and the firm is free to set its optimal monopoly price in country C.

(iii) When $\mu_A \leq \widetilde{\mu}_A$ and $\mu_A \leq \overline{\mu}_A$, there are two possible outcomes: (a) if $\mu_A \leq \widehat{\mu}_A$ and $\mu_A \leq 3$ country A is indifferent between including only country C and including both countries B and C in its reference basket and (b) for all other parameter values, it prefers to include both countries B and C in its reference basket.

Proposition 8 is illustrated in Figure 3. As this figure shows, when μ_A is large relative to both μ_B and μ_C it is optimal for country A to not impose any ERP policy on its firm (i.e. its optimal reference basket is $\{\Phi\}$). When country μ_A and μ_B are similar in magnitude and both are large relative to μ_C, it is optimal for country A to include only country B in its reference basket. Finally, when both μ_B and μ_C are similar in magnitude to μ_A, it is optimal for country A to include both of them in its reference basket. Thus, the key insight of our two country model – i.e. the optimal ERP policy of the home country is more stringent when the markets of the two countries are relatively similar to each other – continues to hold in a three-country setting.

6.4 Proof of Proposition 1

(ii) It is straightforward to show that $p_H^\delta - p_H^m = \frac{\mu(\delta-\mu)}{2(n\delta^2+\mu)} \leq 0$ iff $\delta \leq \mu$. Also, we have $p_F^\delta - p_F^m = \frac{n\delta(\mu-\delta)}{2(n\delta^2+\mu)} \geq 0$ iff $\delta \leq \mu$.

(iii) We have $\frac{\partial p_H^\delta}{\partial \delta} = \frac{\mu(2\mu n\delta - n\delta^2+\mu)}{2(n\delta^2+\mu)^2}$. Observe that the sign of $\frac{\partial p_H^\delta}{\partial \delta}$ depends on the term $2\mu n\delta - n\delta^2 + \mu$, which is always positive when $\delta \geq \delta^*$. This implies $\frac{\partial p_H^\delta}{\partial \delta} > 0$.

We have

$$\frac{\partial p_F^\delta}{\partial \delta} = -\frac{\mu n(n\delta^2 + 2\delta - \mu)}{2(n\delta^2 + \mu)^2}$$

It follows from above that $\frac{\partial p_F^\delta}{\partial \delta} < 0$ whenever $\widehat{\delta} < \delta \leq \mu$ where $\widehat{\delta} \equiv \frac{\sqrt{1+\mu n}-1}{n}$. Next, note that $\widehat{\delta} < 1$ whenever $\mu < n+2$. But since we require $\delta \geq 1$, it follows immediately that whenever $\widehat{\delta} < 1$ we must have $\frac{\partial p_F^\delta}{\partial \delta} < 0$ for all permissible δ.

Now consider the case $\widehat{\delta} \geq 1$ (which holds whenever $\mu \geq n+2$). In this case we also must have $\delta^* \geq 1$. This is because $\delta^* = \frac{1}{2}(\mu - \frac{1}{n})$ is strictly increasing in μ and $\delta^*|_{\mu=n+2} \geq 1$ because $n \geq 1$. Furthermore, we have

$$\delta^* - \widehat{\delta} = \frac{(\sqrt{n\mu+1}-1)^2 - 1}{2n}.$$

from which it follows that $\delta^* \geq \widehat{\delta}$ if $\sqrt{n\mu+1} \geq 2$, which requires $n\mu \geq 3$. But since $n \geq 1$ this condition necessarily holds whenever $\mu \geq n+2$. Thus, whenever $\widehat{\delta} \geq 1$ we must have $\delta^* \geq \widehat{\delta}$. Since $\frac{\partial p_F^\delta}{\partial \delta} < 0$ for all $\widehat{\delta} < \delta$, it follows that $\frac{\partial p_F^\delta}{\partial \delta} < 0$ for all $\delta^* < \delta$.

Thus, we have shown that $\frac{\partial p_F^\delta}{\partial \delta} < 0$ for all $\delta^* < \delta \leq \mu$.

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

6.5 Effects of ERP on domestic welfare

Straightforward calculations yield

$$\frac{\partial w_H^\delta}{\partial \delta} = -\frac{n\mu\delta(n^2\delta^3 + 3n\delta^2 - 3n\mu\delta + 2n\mu^2 + \mu)}{4(n\delta^2 + \mu)^3}.$$

Since $n\mu\delta > 0$ and $4(n\delta^2 + \mu)^3 > 0$, the sign of $\frac{\partial w_H^\delta}{\partial \delta}$ is determined by the term $g(\delta) \equiv n^2\delta^3 + 3n\delta^2 - 3n\mu\delta + 2n\mu^2 + \mu$. It suffices to show that $g(\delta) > 0$ for $\delta^* < \delta \leq \mu$. Now consider two cases depending on the value of μ.

First consider the case where $\mu > \mu^* = 2 + \frac{1}{n}$ (so that $\delta^* > 1$).

In this case, we have $g(\delta = \delta^*) = \frac{(n\mu+5)(n\mu+1)^2}{8n} > 0$. To show $g(\delta) > 0$ for $\delta^* < \delta \leq \mu$ it is sufficient to show $g(\delta)$ is increasing in δ over $\delta^* < \delta \leq \mu$. To see this, note that $\frac{\partial g}{\partial \delta} = 3n(n\delta^2 + 2\delta - \mu)$ so that $\frac{\partial g}{\partial \delta}|_{\delta=\delta^*} = \frac{3}{4}(n\mu+1)(n\mu-3) > 0$ whenever $\mu > 2 + \frac{1}{n}$. Moreover, we have $\frac{\partial^2 g}{\partial \delta^2} = 6n(n\delta+1) > 0$. This implies that $\frac{\partial g}{\partial \delta} > 0$ for all $\delta^* < \delta \leq \mu$. It follows that $g(\delta)$ is increasing in δ so that $g(\delta) > 0$ for all $\delta^* < \delta \leq \mu$.

Next consider the case where $\mu \leq \mu^* = 2 + \frac{1}{n}$ so that the firm sells abroad even when $\delta = 1$. In this case we need to show that $\frac{\partial w_H^\delta}{\partial \delta} < 0$ for all $1 < \delta \leq \mu$. Using similar logic above, it can be shown that $g(\delta = 1) = 2n\mu^2 + n^2 - 3n\mu + 3n + \mu > 0$ given $\mu \leq 2 + \frac{1}{n}$. Moreover, we have $\frac{\partial g}{\partial \delta} = 3n(n\delta^2 + 2\delta - \mu)$ and $\frac{\partial g}{\partial \delta}|_{\delta=1} = 3n(n - \mu + 2) > 0$ given $\mu \leq 2 + \frac{1}{n}$. Since $\frac{\partial^2 g}{\partial \delta^2} > 0$ it must be that $\frac{\partial g}{\partial \delta} > 0$ for all $1 < \delta \leq \mu$. It follows that $g(\delta)$ is increasing in δ and $g(\delta) > 0$ for all $1 < \delta \leq \mu$.

6.6 Proof of Lemma 3

(i) We have $\frac{\partial \overline{\delta}(\overline{p}_F)}{\partial \overline{p}_F} = \frac{\mu(\overline{p}_F - h(\overline{p}_F))}{2h(\overline{p}_F)\overline{p}_F^2}$, where $h(\overline{p}_F) \equiv \sqrt{n\mu\overline{p}_F(1-\overline{p}_F)}$. Observe that the sign of $\frac{\partial \overline{\delta}(\overline{p}_F)}{\partial \overline{p}_F}$ depends on the term $\overline{p}_F - h(\overline{p}_F)$. Solving $\overline{p}_F - h(\overline{p}_F) = 0$ for positive $\overline{p}_F$ we see it holds only when $\overline{p}_F = p_F^*$. It is also easy to check that $\overline{p}_F - h(\overline{p}_F) < 0$ when $0 < \overline{p}_F < p_F^*$. Therefore $\frac{\partial \overline{\delta}(\overline{p}_F)}{\partial \overline{p}_F} \leq 0$ for $0 < \overline{p}_F \leq p_F^*$ with the equality binding at $\overline{p}_F = p_F^*$.

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

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

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

(iii) We have $\overline{\delta}(\overline{p}_F = p_F^m) - \delta^* = \frac{n\mu - 2\sqrt{n\mu} + 1}{2n} = \frac{(\sqrt{n\mu} - 1)^2}{2n} > 0$ given $\mu > 1$ or $n > 1$. ■

6.7 Further discussion of Proposition 4

(i) First consider the scenario where $\delta^m > 1$ which requires that $\mu > \mu_1(n) \equiv (2n + 1 + \sqrt{4n+1})/2n$. Recall from Proposition 4 that in this case ERP dominates PC if $\mu < \overline{\mu}(n) \equiv (2\sqrt{2} + 3)/n$. Thus, when $\mu > \mu_1(n)$, for the ERP policy to dominate a domestic price control we need $\mu_1(n) < \mu < \overline{\mu}(n)$ where $\overline{\mu}(n) > \mu_1(n)$ iff $n < \overline{n} \equiv 2 + \sqrt{2}$. As a result, when home's ERP policy is not a corner solution (i.e. $\delta^m > 1$) the ERP policy dominates a price control iff $\mu_1(n) < \mu < \overline{\mu}(n)$ and $n < \overline{n}$.

(ii) Now suppose $\delta^m = 1$ which happens whenever $\mu \leq \mu_1(n)$. In this case, it can be shown that from home's perspective an ERP policy dominates a price control iff $\mu <$

$\widetilde{\mu}(n) \equiv \sqrt{2} - n/2 + 2$. Combining the condition $\mu \leq \mu_1(n)$, we have that an ERP policy dominates a price control if $\mu \leq \mu_1(n)$ and $n < \overline{n}$ or $\mu < \widetilde{\mu}(n)$ and $n > \overline{n}$.

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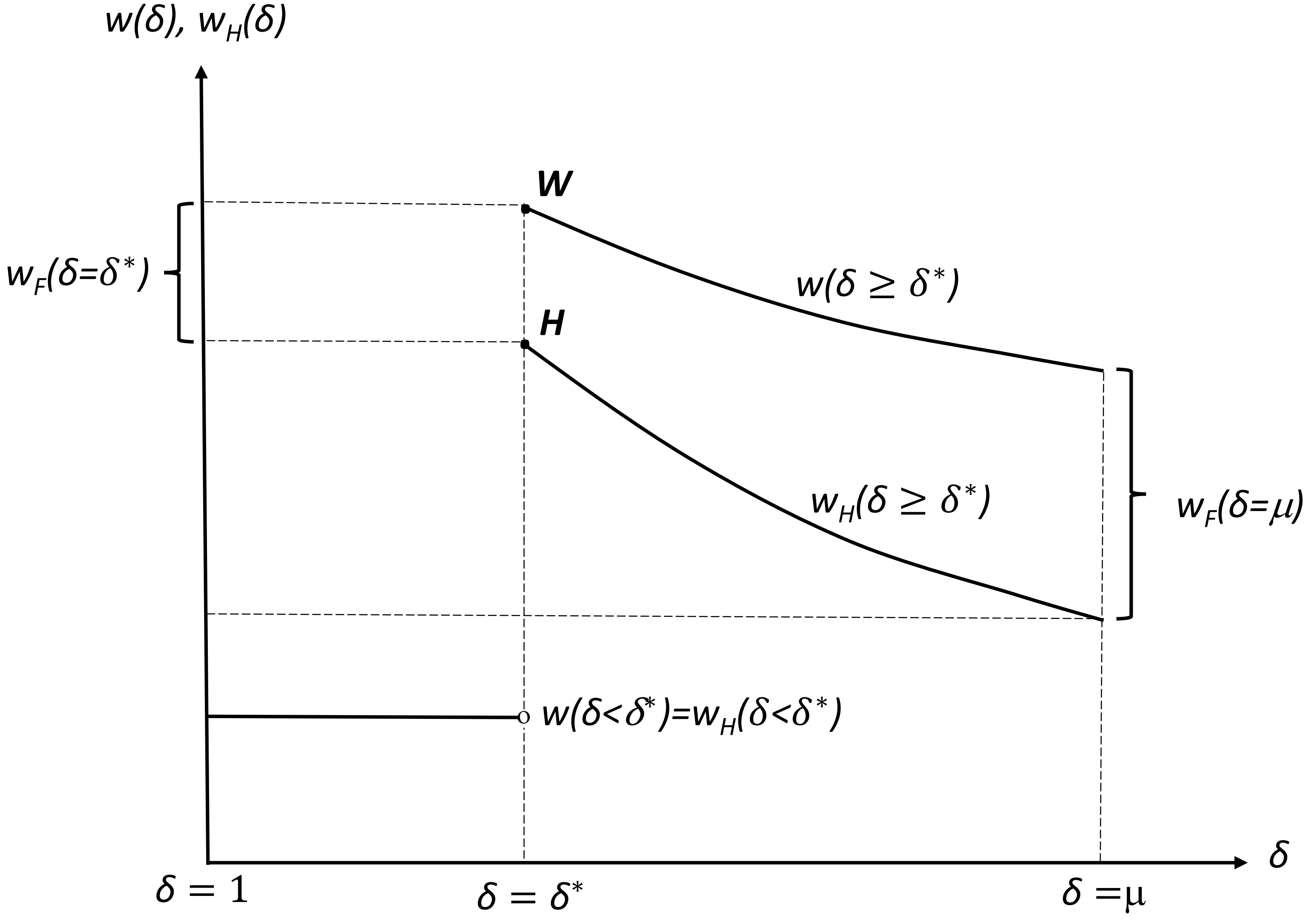

Figure 1: Optimal ERP policy and joint welfare

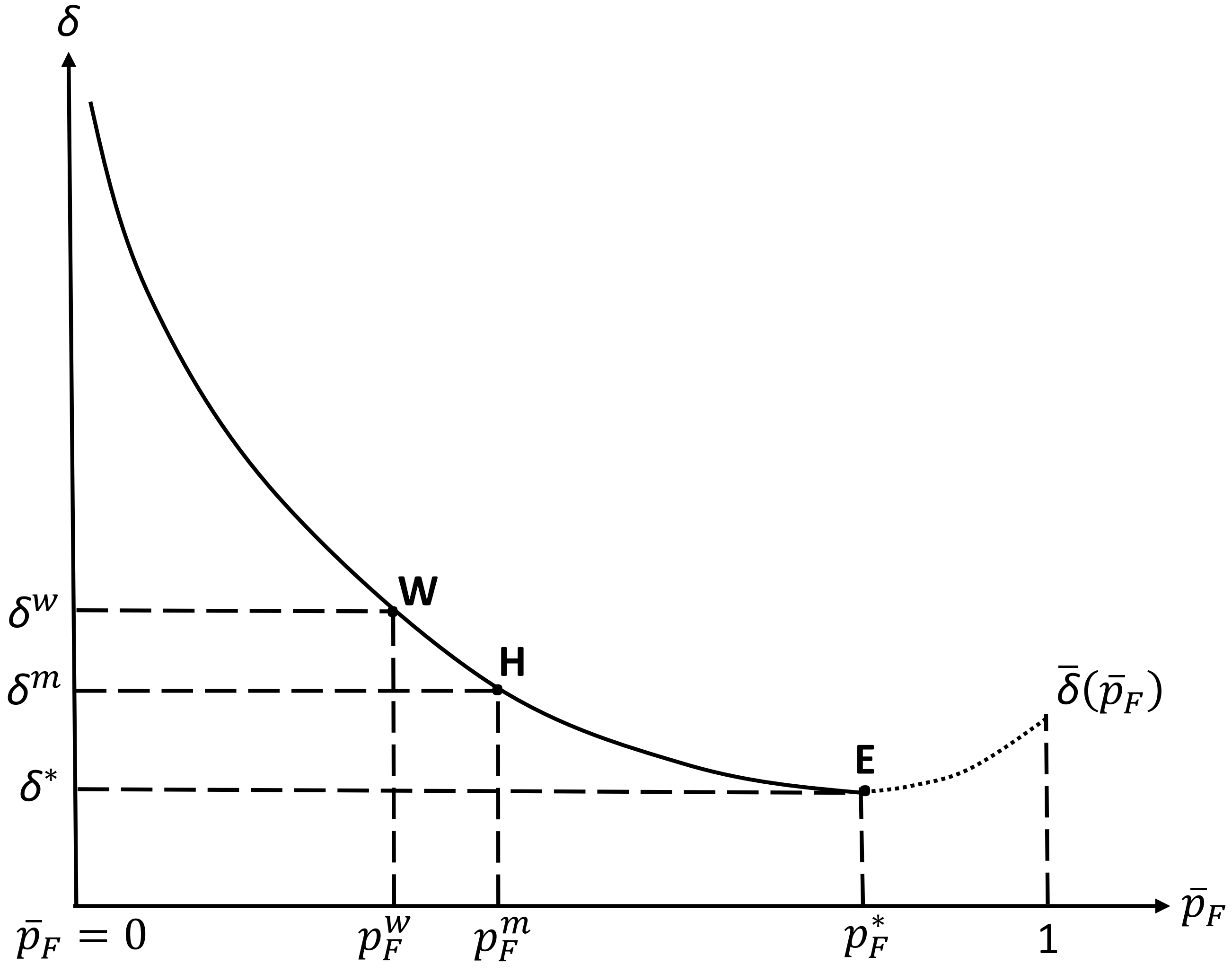

Figure 2: Equilibrium policies

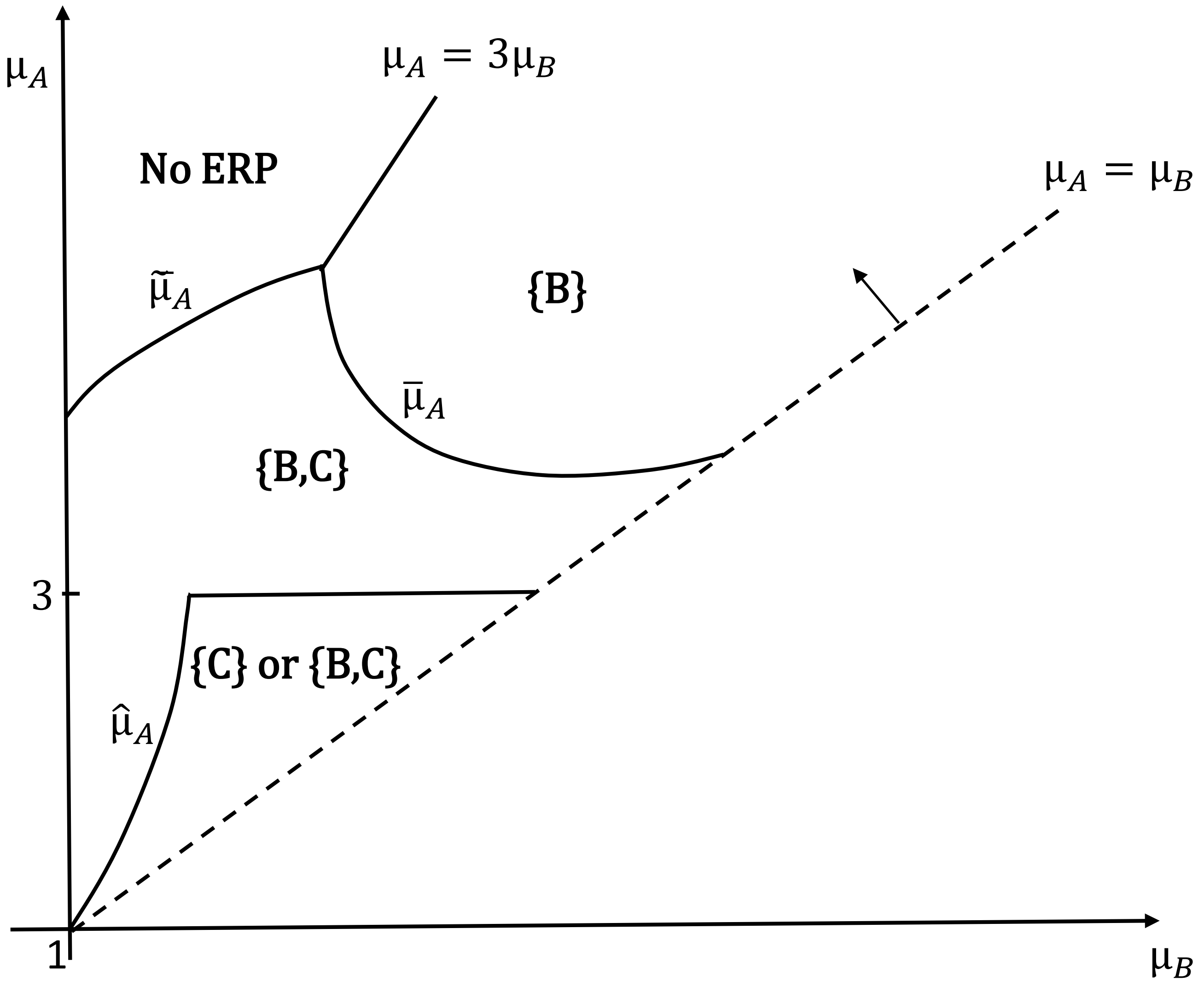

Figure 3: Optimal reference basket of country A