Patent protection in developing countries and global welfare: WTO obligations versus flexibilities*

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Abstract

This paper develops a North-South model to evaluate the South's incentive for patent protection when a Northern firm's investment in quality-enhancing research and development (R&D) is affected by its patent policy. The model is used to (a) evaluate the impact of requiring the South to fulfill its key WTO *obligation* of instituting patent protection and (b) to address the role of two major *flexibilities* that WTO members enjoy with respect to their patent policies: the freedom to implement exhaustion policies of their choosing and the right to use compulsory licensing (CL) subject to certain stipulations. Two forces drive the model: how much the firm invests in R&D and whether or not selling in the South maximizes its global profit. CL improves consumer access in the South and can even raise innovation and global welfare. Provided the South implements patent protection, innovation and welfare are higher if the North follows national as opposed to international exhaustion. However, the South's incentive for patent protection is not necessarily stronger under national exhaustion. Not only is CL more likely to be used under international exhaustion, the welfare gain resulting from its application is also higher relative to that under national exhaustion.

Keywords: Patented protection, Compulsory Licensing, Exhaustion policies, Imitation, TRIPS, Quality, Welfare, WTO. *JEL Classifications*: O34, O38, F12, F13, F23.

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1 Introduction

The Agreement on Trade Related Aspects of Intellectual Property Rights (TRIPS) *obligates* member countries of the World Trade Organization (WTO) members to offer and enforce certain minimum standards of protection for virtually all major types of intellectual property rights (IPRs). At the same time, TRIPS contains two major *flexibilities* that grant national governments some discretion in the design and enforcement of their respective IPR policies: the right to use compulsory licensing (CL) to ease consumer access to patented products and the freedom to implement exhaustion policies of their choosing. This paper analyzes how these two key flexibilities available under TRIPS interact with its central obligation, both from the viewpoint of developing countries and global welfare.

Before describing our analytical approach in detail, we discuss the economically relevant institutional aspects of the two TRIPS flexibilities motivating this paper. Consider CL first. As per TRIPS rules, when a country is faced with no or limited access to a patented foreign product, it has the right to issue a compulsory license to someone other than the patent-holder to produce the product.[1] Article 31 of TRIPS provides conditions under which WTO members can resort to CL of a patent. In particular, this Article stipulates that "the right holder shall be paid adequate remuneration in the circumstances of each case, taking into account the economic value of the authorization" and that "any such use shall be authorized predominantly for the supply of the domestic market of the Member authorizing such use".[2] Our model incorporates both these key features of Article 31 of TRIPS.

Now consider the policy flexibility available to WTO members with respect to exhaustion of IPRs. Article 6 of TRIPS explicitly states that "nothing in this Agreement shall be used to address the issue of the exhaustion of intellectual property rights". Exhaustion policies determine the legality of *parallel trade* – i.e. the type of trade that occurs when a product protected by an IPR offered for sale by the right holder in one country is re-sold in another country without the right holder's permission. As is clear, the incentive to engage in such trade naturally arises in the presence of significant international price differences. Furthermore, since parallel trade flows from low-price markets to high-price ones, the exhaustion policies of high-price markets are more consequential

[1] The word 'compulsory' reflects the fact that the country issuing the license does not have to obtain the patent-holder's consent (who has no choice but to comply).

[2] The latter requirement was loosened in 2003 to allow a country to import a patented product via CL if it lacks the technological capability to produce it locally and also fails to secure it from the patent-holder directly. Clearly, exports under CL to those markets that are already served by the patent-holder (including its home market) are not permitted under TRIPS.

than those of low-price ones.[3] Accordingly, in our North-South framework we consider the effects of alternative exhaustion policies on the part of the North.[4] We examine *national* and *international* exhaustion: under the former policy, the North prohibits parallel imports into its market whereas under the latter policy, it permits them. A key difference between the two exhaustion policies is that under national exhaustion the firm can charge its optimal price in each market whereas under international exhaustion it faces a trade-off: it can either sell only in the North at its optimal price for that market or sell in both markets at a common international price (so as to eliminate the flow of parallel imports into the more lucrative Northern market). As a result, the firm is less inclined to sell in the South when the North implements international exhaustion.

In practice, the two TRIPS flexibilities studied by our model are of special concern to the pharmaceutical industry. First consider CL. A country's ability to operationalize CL is likely to depend not just on its technological capability, but also on the nature of the product. One would expect that the issuance of a compulsory license is facilitated when the product is protected by a single (or just a few patents), as opposed to a large number of them. In this sense, the pharmaceutical industry is a natural candidate for CL since most patented drugs are typically protected by a single patent, unlike say, the smartphone industry where a single phone can contain literally hundreds of patents.[5] Furthermore, imitation in the pharmaceutical industry is remarkably cheap relative to innovation, thereby making patent protection especially valuable for firms. With regard to exhaustion policy, the cost of shipping patented drugs internationally is often fairly miniscule relative to their value so that the incentive for arbitrage-induced parallel imports is strong in this industry. This implies that both the main TRIPS obligation of providing IPR protection as well as its two key flexibilities – CL and exhaustion policy – are especially relevant to the pharmaceutical industry.

Our stylized North-South model involves two parties: the Southern government and a Northern firm that sells a product that is protected by a patent (that lasts for T periods) in its local market. The timing of decision making is as follows. In the first period, the South decides whether or not to institute patent protection in its market

[3]See Maskus (2000) for a useful but slightly dated discussion of the observed variation in exhaustion policies across countries. For more recent accounts see Ghosh (2013) and Ghosh and Calboli (2018).

[4]In our model, the exhaustion policy of the South is immaterial since equilibrium price is always (weakly) higher in the Northern market.

[5]Beall and Kuhn (2012) report that during 1995-2011 there were 24 cases of CL of patented pharmaceuticals in 17 countries. These 24 episodes collectively involved 22 products and only 40 patents. As noted above, the low number of patents involved surely facilitated CL. Furthermore, the level of CL activity occurring in the least developed and low-income countries was fairly limited (accounting for only a third of the 24 cases). Factors that help explain the low incidence of CL in such countries include the low level of their technological capabilities, legislative difficulties confronting the approval and implementation of CL, and the limited capacity of their healthcare systems (Beall and Kuhn, 2012).

while the firm chooses its investment in quality-enhancing research and development (R&D) and decides whether or not to incur the fixed cost of entry necessary for selling its product in the South. As in related literature, our model assumes that if the South does not implement patent protection then the firm's technology diffuses locally and a competitive local industry producing an imitated version of the firm's product comes into existence. Due to the limited technological capability of the South, the quality of the imitated product is assumed to be (weakly) lower than that of the original.

Our core model assumes that the North follows national exhaustion and it delivers three main results. First, the South chooses to institute patent protection iff such protection is necessary and sufficient to induce entry by the firm and the quality disadvantage suffered by local imitators is sufficiently large. This finding clarifies how a balancing of the competing welfare effects of its patent policy – on local consumers on the one hand and foreign innovation incentives on the other – can induce a developing country to voluntarily institute patent protection even though it itself lacks the ability to innovate. Our second key finding is that the introduction of patent protection in the South increases the firm's R&D investment as well as its incentive to enter the Southern market. The beneficial effect of Southern patent protection on R&D has consequences for not just the firm but also Northern consumers. The third major result delivered by the core model is that even if the firm is willing to sell in the South in the absence of local patent protection, providing such protection increases global welfare since the South's incentive for patent protection is too weak relative to what is jointly optimal. This last result provides a potential rationale for the strengthening of patent protection in developing countries required under TRIPS. However, we also find that if the firm has no incentive to sell in the South even when it's granted patent protection, then forcing the South to offer such protection lowers global welfare. The intuition here is that if the Southern market does not factor into the firm's global profit then the South's patent policy has no affect on the firm's R&D incentive. Under such a situation, denying Southern consumers access to the imitated product inflicts a welfare loss on them without generating *any* gains for the firm or Northern consumers.

As the above discussion clarifies, an important driver of the welfare consequences of Southern patent protection in our model is its effect on the firm's entry decision. How relevant is this channel empirically? A well-developed empirical literature has demonstrated beyond doubt that this channel is very much operative in the real world. For example, using export data at the 3-digit ISIC level from 1962-2000, Ivus (2010) investigates the impact of TRIPS induced IPR reforms in developing countries on the exports of developed countries to their markets and finds that the strengthening of IPR protection undertaken by 18 non-colonies (in her set of 53 developing countries) increased the annual value of developed country exports to their markets in patent-sensitive industries by about $35 million (or about 8.6%). She also shows that the increases in the value of imports was driven largely by changes in quantities as opposed to prices.[6] Using data on launches of 642 new drugs in 76 countries during 1983-2002, Cockburn et al. (2016) estimate that, controlling for a variety of economic and demographic factors, starting from the complete lack of patent protection, the introduction of product patents (lasting 18 years) increases the per-period hazard of drug launch in a country by about 55%. This finding is of vital importance since new drugs are launched only in a handful of rich countries and usually become available in other parts of the world with significant delay. For example, in their entire sample of 642 new drugs, 39% were launched in ten or fewer countries and only 41% were launched in more than 25 countries.[7]

We extend the core model to analyze the role of two key TRIPS flexibilities: the South's right to use CL licensing and the North's right to implement the exhaustion policy of its choosing. Consistent with TRIPS rules, our model incorporates CL as follows: given that the South offers patent protection and the firm chooses not to enter in the first period, for the remaining duration ($T-1$ periods) of the patent the South has the authority to issue a compulsory license to a local producer who is required to set price equal to marginal cost. In the event of CL, the South pays a per-period royalty to the Northern firm. This royalty captures the adequate remuneration requirement of Article 31 of TRIPS. The one-period waiting period before CL can be activated by the South captures the TRIPS requirement that a patent-holder must be granted a "reasonable" amount of time to work its patent in a market before the local government can issue a compulsory license.

Our analysis shows that the effects of CL on innovation incentives are more nuanced than previously understood. In our model, making CL available to the South has an adverse effect on the firm's R&D incentive only when the possibility of CL induces the firm to forsake entry in order to collect royalty payments under CL. On the other hand, when the firm has no intention of selling in the South in the absence of CL, making CL available allows the firm to collect royalties from the Southern market that are proportional to the quality of its product and this tends to increase its R&D investment.[8] We also identify circumstances where CL is preferable to entry from a joint welfare perspective as well as when it is not. When CL encourages R&D, it welfare dominates entry since it also economizes on the fixed cost of entry. A welfare trade-off between the

[6]In a follow up paper, using data at the 10-digit HMS level, Ivus (2015) investigates the effects of stronger IPR protection on US exports to 64 developing countries. She finds that changes in the IPR regimes of developing countries induced by TRIPS increased the annual value of US exports in industries that rely heavily on patent protection (such as pharmaceuticals) by roughly 16% and that almost the entire increase in exports was driven by an expansion in product variety.

[7]Similar findings are reported by Kyle and Qian (2014).

[8]In this context, it is interesting to note that Baten et al. (2017) find that the compulsory licensing of German chemical patents by the United States at the end of World War I was associated with a 30% increase in invention by German firms whose inventions were licensed.

two modes only arises when CL dampens R&D incentives and delivers a lower quality product to consumers. When such is the case, entry is preferable from a global welfare perspective whenever the fixed cost of entry is low and the technological disadvantage under CL is large.

In section 4 of the paper, we examine how the firm and consumers in the two region fare if the North were to implement international exhaustion as opposed to national exhaustion. As in related literature, we find that holding constant the South's patent protection policy, the firm is more willing to sell in the South under national exhaustion. Furthermore, the South is better off under national exhaustion due to two separate reasons: first, holding constant the quality of the product across the two exhaustion regimes, price in the South is lower under national exhaustion. Second, the Northern firm invest more in R&D and therefore delivers a higher quality product under national exhaustion. From the North's viewpoint, these two forces work against each other: price is higher under national exhaustion but quality is also higher. All in all, national exhaustion delivers higher joint welfare than international exhaustion provided the firm sells in both markets. This result fits well with the traditional argument that parallel trade reduces innovation incentives by undermining the ability of IPR holders to profit from their R&D investments.[9]

How do Southern incentives for patent protection depend upon North's exhaustion policy? As in the case of national exhaustion, the South chooses to provide patent protection under international exhaustion only when its imitative ability is low and patent protection is necessary to induce entry by the firm although the relevant thresholds are not the same under the two scenarios. Interestingly, the fact that profits from entry are lower under international exhaustion results in an ambiguous relationship between North's exhaustion policy and Southern patent protection. Relative to national exhaustion, both the maximum level of the fixed entry cost below which the South is willing to offer patent protection *and* the minimum level of fixed entry cost above which patent protection is desirable for the South are lower under international exhaustion. As a result, the relationship between North's exhaustion policy and South's incentive for patent protection is generally ambiguous. This ambiguity implies that Northern R&D could be either higher or lower under national exhaustion once the induced effect of the South's

[9]We should note, however that several papers have shown that the traditional argument against parallel trade need not always hold. See, for example, Li and Maskus (2006), Li and Robles (2007), and Grossman and Lai (2008). In a model similar to us, assuming that the monopolist necessarily serves all markets, Valletti (2006) has shown that whether national exhaustion delivers more R&D than international exhaustion depends upon the underlying reason for international price discrimination on the part of the monopolist. He shows that when such discrimination is demand-based (as is the case in our model) then incentives for quality improvement are lower when parallel trade can occur but the opposite is true when discrimination arises because the monopolist faces different costs of accessing markets. See also Valletti and Szymanksi (2006).

patent policy on R&D is taken into account.[10] Finally, we examine the interaction between CL in the South and the nature of Northern exhaustion policy and show that not only is CL more likely to arise in equilibrium under international exhaustion, it is also more likely to be socially efficient relative to entry.

This paper makes several novel contributions to the literature. First, it brings together two important but separate strands of related literature: the rather well-developed literature exploring the economics of alternative exhaustion policies and the emerging literature on the effects of CL.[11] While these two TRIPS flexibilities have been studied separately, there exists no model that analyzes them jointly. Second, we provide a model of CL in which both innovation *and* the South's patent protection policy are endogenous. Although there exist several models of exhaustion that allow for endogenous innovation – such as Valleti (2006) and Grossman and Lai (2008) – these models consider neither CL nor the South's incentive for patent protection. Furthermore, existing models of CL – such as Bond and Saggi (2014, 2017, and 2018) – abstract from innovation and therefore cannot address the effects of CL on innovation incentives.

The model developed in this paper significantly generalizes the analysis of CL developed by Bond and Saggi (2018) in two key dimensions: first, it incorporates endogenous innovation into their model and, second, it sheds light on how the North's exhaustion policy affects the firm's R&D as well as the South's incentive for patent protection. Bond and Saggi (2018) provide a useful starting point for our analysis since, like the model developed here, Southern patent protection policy and the Northern firm's decision to sell in the South are endogenously determined in their model. However, the results reported in the present paper on the linkages between innovation and the two key TRIPS flexibilities are simply beyond the scope of Bond and Saggi (2018) since not only does their model abstract from innovation, it also assumes that the royalty payment under CL is fixed and therefore unresponsive to the quality of the product. While a fixed royalty payment is a reasonable assumption in their model since it does not consider innovation, it nevertheless is limiting in nature since it implies that the return to the

[10] In Grossman and Lai (2008), the South is assumed to provide patent protection but has the ability to impose a price control on patented products whereas we abstract from price controls but allow the South to control its patent policy. Grossman and Lai (2008) argue that there is a presumption that the induced change in the price control due to a switch from national to international exhaustion results in an increase in R&D since the South has an incentive to allow for a higher local price under international exhaustion to ensure that its market is served. By contrast, in our model the South's patent protection policy under international exhaustion is not necessarily more favorable to the firm relative to that under national exhaustion.

[11] Major contributions to the literature on exhaustion of IPRs include Malueg and Schwarz (1994), Scherer and Watal (2002), Li and Maskus (2006), Valetti (2006), Ganslandt and Maskus (2004), Grossman and Lai (2008), Roy and Saggi (2012), and Saggi (2013). By contrast, the formal literature on CL is fairly nascent and recent contributions to it are Bond and Saggi (2014, 2017, and 2018).

firm from licensing its product is unlinked to its economic value – a feature that does not correspond well with existing TRIPS rules on CL.

2 Model

We consider a world economy comprising two regions: North (N) and South (S) denoted by subscript i where $i = N, S$. A single Northern firm sells a patented product (x) with quality level q (endogenously determined). While the firm's technology is protected in the North via the enforcement of intellectual property rights (IPRs), it is potentially subject to imitation in the South.

Our core model is a simple game between the firm and the Southern government. In the first stage, the South chooses whether or not to offer patent protection in its market. Next, the firm invests in R&D that determines the quality of its product while also deciding whether or not to enter the South by incurring the fixed cost φ.[12]

2.1 Demand and payoffs

Each consumer in region i buys at most 1 unit of the good at the local price p_i, where $i = N, S$. The number of consumers in region i equals n_i. If a consumer buys the good, her utility is given by $u_i = q\theta - p_i$, where θ measures the consumer's taste for quality. Utility under no purchase equals zero. For simplicity, θ is assumed to be uniformly distributed over the interval $[0, \mu_i]$ where $\mu_i \geq 1$.

Demand structures in the two regions differ in two ways. First, Northern consumers value quality relatively more, that is, $\mu_N = \mu \geq 1 = \mu_S$. Second, the Northern market is larger: $n_N = n \geq 1 = n_S$. As one might expect, given these differences in demand, the firm has an incentive to price discriminate internationally. We assume that the North practices national exhaustion of IPRs so that the firm is free to set a market specific price in each region to maximize its global profit.[13] Let the firm's marginal cost of production equal zero. The firm's monopoly in the North lasts for the entire life of the product (which equals T periods). In the South, it enjoys monopoly status only if the South offers patent protection.

If the South does not offer patent protection, the firm's technology is imitated locally and imitation leads to the emergence of a competitive industry that produces a lower

[12]It is straightforward to show that, in our model, this two stage game is equivalent to a three stage game where the firm's R&D decision *precedes* its entry decision (see appendix).

[13]In section 4, we consider a scenario where the Northern policy is international exhaustion under which the firm ends up setting a common international price to eliminate possible competition from parallel imports.

quality version of the firm's product. Let the quality of the Southern imitation be denoted by γq where $0 < \gamma \leq 1$.[14] Observe that when $\gamma = 0$, the South is incapable of imitation so that its patent protection policy becomes moot.

2.1.1 Pricing and profits

If the South offers patent protection to the firm and the firm chooses to sell there, it sets its market-specific price in each period to solve:

$$\max_{p_N} \ \pi_N(p_N) \equiv np_N(1 - p_N/\mu q) \text{ and } \max_{p_S} \ \pi_S(p_S) \equiv p_S(1 - p_S/q) \tag{1}$$

It is straightforward to show that the firm's optimal prices in the two markets are: $p_N^*(q) = \mu q/2$ and $p_S^*(q) = q/2$. The associated sales in each market equal $x_N^* = n/2$ and $x_S^* = 1/2$. Denote the firm's maximized profit in region i when the South offers patent protection by $\pi_i^*(p_i^*(q))$, where $\pi_N^* = n\mu q/4$ and $\pi_S^* = q/4$.

In the absence of Southern patent protection, competition within the Southern imitative industry ensures that the imitated good is sold at marginal cost in the local market.[15] Given our assumptions on consumer preferences, when two different qualities are available for purchase at prices p_S (high quality) and 0 (low quality), Southern consumers can be partitioned into two groups: those in the range $[0, \theta(p_S; \gamma)$ buy the low quality whereas those in $[\theta(p_S; \gamma), 1]$ buy the high quality where

$$\theta(p_S; \gamma) = \frac{p_S}{q(1 - \gamma)} \tag{2}$$

When facing competition from imitation in the Southern market, the patent-holder chooses its Southern price p_S to maximize

$$\max_{p_S} \ \pi_S(p_S; \gamma) = p_S[1 - \theta(p_S; \gamma)]$$

The firm's profit maximizing price in the face of imitation equals $p_S^I = q(1 - \gamma)/2 = (1 - \gamma)p_S^*$, where the superscript I indicates the presence of competition between the patent-holder and the imitative industry. Observe that $p_S^I \leq p_S^*$ since $0 < \gamma \leq 1$.

Let $\beta \in [0, 1)$ be the per period discount factor so that the present value of the firm's profits from region i equals

$$(1 + \Omega)\pi_i^*(q) \text{ where } \Omega = \sum_{t=1}^{T} \beta^t \tag{3}$$

[14] In the context of the pharmaceutical industry the imitated product is probably best viewed as a generic that can only be sold in the South.

[15] We assume that due to enforcement of IPRs in the North, the imitated product can only be sold in the South.

Competition from imitation lowers the firm's gross payoff from entering the Southern market to

$$v_S^I(q;\gamma) = (1+\Omega)(1-\gamma)\pi_S^*(q) = (1-\gamma)v_S^*(q) \tag{4}$$

The per-period consumer surplus that accrues to region in i from purchasing the product at price p_i equals

$$cs_i = n_i \int_{p_i/q}^{\mu_i} \frac{(q\theta - p_i)}{\mu_i} d\theta = \frac{n_i(\mu_i q - p_i)^2}{2q\mu_i} \tag{5}$$

2.1.2 R&D and Entry

While conducting its R&D, the firm makes a forward looking decision that takes into account both the fixed cost of selling in the South and the policies of the two governments. We require that the firm's R&D investment be time-consistent with its eventual decision regarding entry into the Southern market. For simplicity, we assume that the cost function for R&D is $c(q) = tq^2/2$ where $t > 0$.

Given patent protection, the firm's optimal R&D investment when it intends to sell in both markets solves

$$\max_q \ (1+\Omega)\sum_i \pi_i^*(q) - c(q)$$

Let the solution to this problem be denoted by q^* and let

$$v^*(q^*) = (1+\Omega)\sum_i \pi_i^*(q^*) - c(q^*)$$

If the firm intends to sell only in the Northern market, it solves

$$\max_q \ (1+\Omega)\pi_N^*(q) - c(q)$$

Denote the firm's optimal R&D investment when it sells only in the North by q^N and let

$$v^N(q^N) = \ (1+\Omega)\pi_N^*(q^N) - c(q^N)$$

It is easy to show that $q^N < q^*$ – i.e. the firm invests more in R&D when it sells in both markets relative to when it sells only at home since the marginal benefit of R&D is strictly higher in the former case.

Given these optimal R&D investments, the firm prefers selling in both markets to selling only at home iff

$$v^*(q^*) - \varphi \geq v^N(q^N)$$

Let

$$\varphi^* \equiv v^*(q^*) - v^N(q^N)$$

define the threshold value of the fixed cost φ below which the firm prefers selling in both markets to selling only at home. We can show that $\partial\varphi^*/\partial n > 0$ and $\partial\varphi^*/\partial\mu > 0$: when there is patent protection in the South, there is a *positive* link between the relative size and profitability of the Northern market (as captured by n and μ) and the incentive to sell in the South since the firm's R&D investment is based on the global market. A larger or more profitable Northern market increases the firm's incentive to invest in R&D which, ex post, also makes it more attractive for it to sell in the South.

The firm's maximized payoff function under patent protection equals

$$\begin{cases} v^*(q^*) - \varphi \text{ if } \varphi \leq \varphi^* \\ \\ v^N(q^N) \text{ if } \varphi > \varphi^* \end{cases}$$

The firm's R&D decision in the absence of patent protection in the South is analogous to above. Let

$$q^I = \arg\max_q \; (1+\Omega)[(1-\gamma)\pi_S^*(q) + \pi_N^*(q)] - c(q)$$

and let

$$v^I(q^I) = (1+\Omega)[(1-\gamma)\pi_S^*(q^I) + \pi_N^*(q^I)] - c(q^I)$$

Since imitated products are not sold in the North, the firm's R&D investment if it sells only in the North continues to equal q^N. Given this, when facing competition from imitated products in the South, the firm prefers selling in both markets to selling only at home iff

$$\varphi \leq \varphi^I \text{ where } \varphi^I \equiv v^I(q^I) - v^N(q^N)$$

We can show that $\partial\varphi^I/\partial n > 0$ and $\partial\varphi^I/\partial\mu > 0$. As before, these comparative statics arise from the fact that increases in n or μ induce the firm to invest more in R&D (i.e. $\partial q^*/\partial n > 0$ and $\partial q^*/\partial\mu > 0$) so that the profit that accrues to the firm from the Southern market increases thereby making it more willing to enter. Furthermore, as one might expect, $\partial\varphi^I/\partial\gamma < 0$; $\partial^2\varphi^I/\partial^2\gamma > 0$; and if $\gamma = 0$ we have $\varphi^I = \varphi^*$. Finally, note that $\varphi^I = 0$ when $\gamma = 1$ – i.e. if Southern imitation suffers from no quality disadvantage relative to the patented product then the firm is unwilling to enter the South even when such entry entails no fixed costs since price competition eliminates all rents in such a situation.

The firm's maximized payoff in the absence of Southern protection equals

$$\begin{cases} v^I(q^I) - \varphi \text{ if } \varphi \leq \varphi^I \\ \\ v^N(q^N) \text{ if } \varphi > \varphi^I \end{cases}$$

We can show the following:

Proposition 1. *The lack of patent protection in the South reduces the firm's R&D investment (i.e.* $q^I \leq q^*$*) as well as its incentive to enter the Southern market (i.e.* $\varphi^I \leq \varphi^*$*). Furthermore, changes in the pattern of Northern demand (such as increases in* μ *or* n*) that increase the firm's R&D investment (*q^**) strengthen its incentive to sell in the South (i.e.* $\partial\varphi^*/\partial n > 0$ *and* $\partial\varphi^*/\partial\mu > 0$*). Finally, the stronger the intensity of imitative competition in the South, the lower the firm's investment in R&D (i.e.* $\partial q^I/\partial\gamma < 0$*) and the weaker its incentive to sell in the South (i.e.* $\partial\varphi^I/\partial\gamma < 0$*).*

2.2 Southern patent protection

The South sets its patent protection policy anticipating the patent-holder's R&D and entry decisions. We assume that the objective of the South is to maximize local consumer welfare over the life of the product. As we explain below, Southern consumer surplus depends upon not just its patent protection policy but also on the R&D and entry decisions of the firm.

Southern welfare under patent protection equals

$$\begin{cases} w_S^*(q^*) = (1+\Omega)cs_S(p_S^*(q^*)) \text{ if } \varphi \leq \varphi^* \\ \\ 0 \text{ if } \varphi > \varphi^* \end{cases}$$

Note that when $\varphi > \varphi^*$, the firm does not sell in the South even if its patent is protected and Southern consumers have no access to its product so that $w_S = 0$.

If the South permits imitation and the firm sells only in the Northern market, then Southern consumers have access to only the low quality imitated product and per-period consumer surplus equals

$$cs_S^L(\gamma q_N) = \int_0^1 \gamma q_N \theta d\theta \tag{6}$$

whereas if the firm sells in both markets then per-period consumers surplus in the South equals

$$cs_S(p_S^I(q^I);\gamma) = \int_0^{1/2} \gamma q^I \theta d\theta + \int_{1/2}^1 \left[q^I\theta - p_S^I(q^I)\right] d\theta$$

Thus, the Southern welfare function in the absence of patent protection equals

$$\begin{cases} w_S^I(q^I) = (1+\Omega)cs_S(p_S^I(q^I);\gamma) \text{ if } \varphi \leq \varphi^I \\ \\ w_S^L(\gamma q^N) = (1+\Omega)cs_S^L(\gamma q^N) \text{ if } \varphi > \varphi^I \end{cases}$$

When $\varphi > \varphi^I$, the firm does not enter the Southern market and local consumers obtain access (only) to the lower quality imitated good at a price equal to marginal cost (set to zero) and Southern welfare equals $w_S^L(q^N;\gamma)$ where the superscript L indicates that Southern consumers have access to only the low-quality imitated product. However, if the firm enters the Southern market despite imitation (which it does when $\varphi \leq \varphi^I$), Southern welfare equals $w_S^I(q^I;\gamma)$. Observe that since the firm does greater R&D when it sells in both markets, the quality of the product that Southern consumers obtain access to via imitation is lower when the firm sells only in the Northern market (i.e. $q^I \geq q^N$).

It is straightforward to show the following:

Lemma 1. *The following hold: (i)* $w_S^I \geq \max\{w_S^*, w_S^L\}$ *and (ii) there exists* γ^* *such that* $w_S^* \geq w_S^L$ *iff* $\gamma \leq \gamma^*$ *where* $\partial\gamma^*/\partial n < 0$ *and* $\partial\gamma^*/\partial\mu < 0$.

Lemma 1 says that the South's most preferred outcome is one where it allows imitation and the firm enters its market despite the competition it faces from imitators. The reason $w_S^I \geq w_S^L$ is easy to see: not only do local consumers have access to both products when the firm enters despite imitation, the quality of the two products is also higher since the R&D investment of the firm is higher when it sells in both markets ($q^I \geq q^N$).

Given that the firm is willing to sell in the South even without patent protection, Southern consumers value imitation due to two reasons. First, imitation increases variety in the local market and those Southern consumers that are unwilling to pay the price for the high quality patented product gain access to the low quality imitated version that sells at a lower price. Second, competition from the imitated product lowers the price of the high quality patented product. However, these two positive effects of imitation are counterbalanced by the fact that offering patent protection induces the firm to invest more in R&D so that the quality of the patented product is higher under patent protection ($q^* > q^I$). It turns out that, from the South's perspective, the two positive effects of imitation on consumer welfare dominate the negative effect that results from the reduction in the firm's R&D investment. As a result, given that the firm sells in its market, the South is better off without patent protection.

Finally, when the firm sells in the South only if its patent is protected, the South faces the following trade-off: it can either provide local consumers with the high quality patented product at the firm's optimal monopoly price or the low quality imitated product at the competitive price (i.e. at marginal cost). In such a scenario, the South is better off with patent protection only when the quality disadvantage suffered by local imitators is sufficiently large (i.e. $\gamma \leq \gamma^*$). An important point to note here is that the larger or more profitable the Northern market is, the less likely the South is to offer patent protection (i.e. $\partial\gamma^*/\partial n < 0$ and $\partial\gamma^*/\partial\mu < 0$) because Southern protection is relatively less important for incentivizing R&D when n and/or μ are large.

We can now state the following:

Proposition 2. *In equilibrium, the South offers patent protection to the firm iff such protection is necessary and sufficient to induce entry by the firm (i.e. $\varphi \in [\varphi^I, \varphi^*]$) and the quality disadvantage suffered by local imitators is sufficiently large (i.e. $\gamma \leq \gamma^*$).*

The CL model of Bond and Saggi (2018) reports a finding similar to the one above. However, since that model abstracts from innovation, the critical thresholds for the fixed cost parameter φ as well as the technological capability parameter γ differ across the two scenarios. A comparison of the two models provides a confirmation of the intuition that the South has a stronger incentive to institute patent protection in the presence of Northern innovation that responds to its patent policy. Indeed, we can show that $\gamma^* - \gamma_N^* = 1/(4n\mu)$ where γ_N^* is the critical level of technological capability above which the South implements patent protection in the absence of Northern innovation in the CL model of Bond and Saggi (2014). Note also that as either of the two parameters (μ and n) determining the relative profitability of the Northern market increase, the two thresholds converge (i.e. γ^* approaches γ_N^*) since the Southern market becomes a less important driver of Northern innovation.

2.3 Global welfare and TRIPS

Northern welfare when the South implements patent protection equals

$$\begin{cases} w_N^*(q^*) - \varphi \text{ where } w_N^*(q^*) = (1+\Omega)cs_N(p_N^*(q^*)) + v^*(q^*) \text{ if } \varphi \leq \varphi^* \\ w_N^N(q^N) = (1+\Omega)cs_N(p_N^*(q^N)) + v^N(q^N) \text{ if } \varphi > \varphi^* \end{cases}$$

whereas Northern welfare in the absence of patent protection equals

$$\begin{cases} w_N^I(q^I) - \varphi \text{ where } w_N^I(q^I) = (1+\Omega)cs_N(p_N^I(q^I)) \; + v^I(q^I) \text{ if } \varphi \leq \varphi^I \\ w_N^N(q^N) = (1+\Omega)cs_N^N(p_N^*(q^N)) + v^N(q^N) \text{ if } \varphi > \varphi^I \end{cases}$$

It is obvious that the firm is better off when the South offers patent protection relative to when it does not. A slightly more subtle observation is that Southern patent protection is also in the interest of Northern consumers since, given that the firm sells in both markets, the firm invests more in R&D when its patent is protected relative to when it is not – i.e. the quality of the product sold in the North is higher if the South implements patent protection (i.e. $q^* > q^I$) when the firm sells in the South. A related point is that, all else equal, Northern consumers benefit if the firms sells in the South since it invests more in R&D when it serves both markets relative to when it sells only at home (i.e. $q^* > q^N$ and $q^I > q^N$). Of course, both the firm and the Southern government ignore the impact of their respective decisions on Northern consumers.

Global welfare under Southern patent protection equals

$$\begin{cases} w^*(q^*) - \varphi \text{ where } w^*(q^*) = w_N^*(q^*) + w_S^*(q^*) \text{ if } \varphi \leq \varphi^* \\ \\ w^N(q^N) = w_N^N(q^N) \text{ if } \varphi > \varphi^* \end{cases}$$

whereas in the absence of patent protection it equals

$$\begin{cases} w^I(q^I) - \varphi \text{ where } w^I(q^I) = w_S^I(q^I) + w_N(q^I) \text{ if } \varphi \leq \varphi^I \\ \\ w^L(q^N;\gamma) = w_S^L(\gamma q^N) + w_N^N(q^N) \text{ if } \varphi > \varphi^I \end{cases}$$

We have:

Proposition 3. *(i) Even if the firm is willing to sell in the South in the absence of patent protection (i.e. $\varphi \leq \varphi^I$), providing such protection increases world welfare: $w^I(q^I) < w^*(q^*)$.*

(ii) If patent protection is necessary to induce the firm to sell in the South (i.e. $\varphi^I < \varphi < \varphi^*$), it is jointly optimal to provide such protection iff $\varphi < \varphi^w$ where $\varphi^w \equiv w^*(q^*) - w^L(q^N;\gamma)$ where (a) $\partial\varphi^w/\partial\gamma < 0$, $\partial\varphi^w/\partial n > 0$, and $\partial\varphi^w/\partial\mu > 0$, and (b) $\varphi^w \geq \varphi^*$ iff $\gamma \geq \gamma^w$ where (a) $\gamma^w > \gamma^*$, (b) $\partial\gamma^w/\partial n < 0$ and $\partial\gamma^w/\partial\mu < 0$.[16]

(iii) If the firm does not sell in the South even if its granted patent protection (i.e. $\varphi > \varphi^*$), then offering such protection lowers welfare: $w^L(q^N;\gamma) > w^N(q^N)$.

Figure 1 illustrates the South's optimal patent policy as well as the firm's equilibrium decision and it proves useful for assessing the welfare effects of TRIPS.

In this figure, the equilibrium outcome is denoted by pair (X, Y) where $X = P$ or I where P denotes the existence of patent protection in the South and I denotes imitation (or, equivalently, the absence of patent protection) and $Y = E$ or N denotes the firm's equilibrium choice, with E denoting entry and N its decision to stay out of the Southern market. Furthermore, the joint welfare maximizing outcome is denoted by an asterisk. Furthermore, $\varphi^m = w^*(q^*)$ denotes the maximum level of fixed cost below which entry is socially desirable given that the South offers patent protection.

[16] The three statements of Lemma 1 together imply that joint welfare is maximized by having the South offer patent protection whenever $\varphi \leq \min\{\varphi^*, \varphi^w\}$.

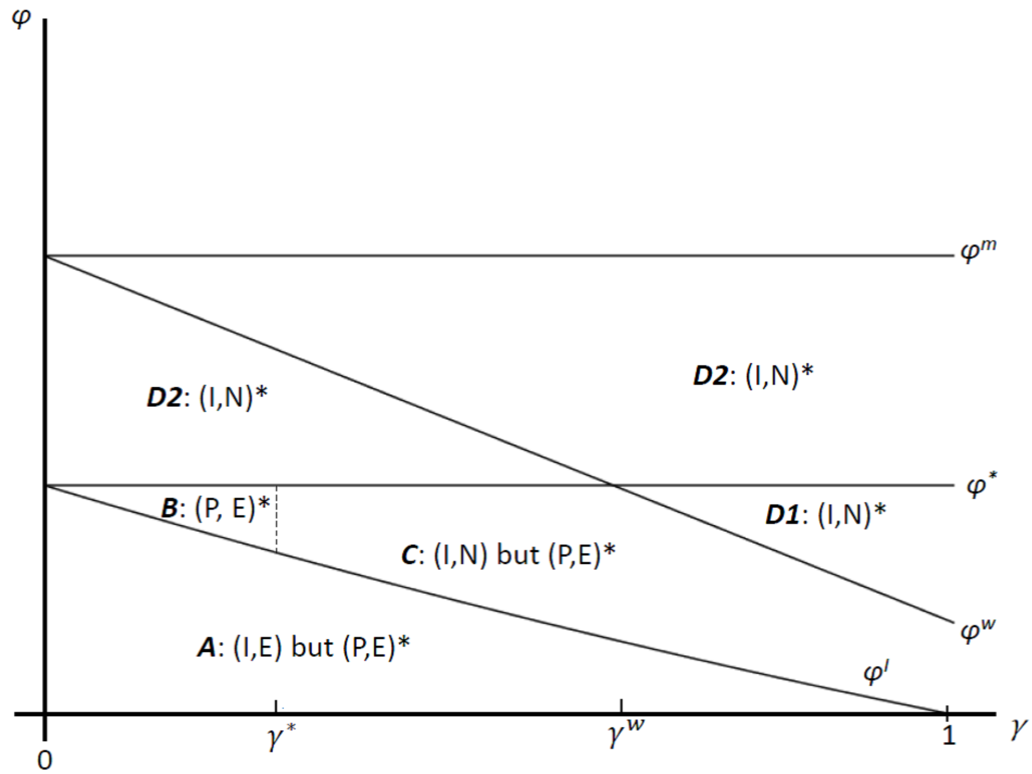

Figure 1: Equilibrium outcomes and efficiency

Figure 1 shows that the South chooses to offer patent protection in only region **B**: over this region, the South's technological disadvantage is large (i.e. $\gamma \leq \gamma^*$) *and* patent protection is necessary to induce the firm to enter its market (i.e. $\varphi^I < \varphi < \varphi^*$). For all other parameter values, the South chooses to deny patent protection to the firm. Whereas South offers patent protection only over region **B** in Figure 1, it is jointly optimal to offer it over regions **A**, **B**, and **C**. While setting its patent policy, though the South accounts for the effects of R&D on local consumers, it ignores not just the profit effects of R&D but also the benefits enjoyed by Northern consumers.

Figure 1 shows that once the effects of Southern patent policy on all parties are accounted for, it is generally optimal to institute patent protection in the South whenever the firm is willing to enter given protection (i.e. $\varphi \leq \varphi^*$) except for when γ is high and φ is close to or exceeds φ^* (i.e. in region **D1**). In region **D1**, $\varphi \simeq \varphi^*$, the Southern market yields very little to the firm in the way of rents and is therefore not particularly consequential for incentivizing innovation on its part and the negative spillover on Northern consumers caused by the lack of patent protection in the South is rather small. Furthermore, since γ is near 1 in region **D1**, the imitative capacity of the South is high (and the local product is fairly close in quality to the Northern product). Under such circumstances, offering patent protection to induce entry by the firm is especially damaging to Southern consumers since the patented product is sold at monopoly price whereas the local imitated product is available at price equal to marginal cost. When $\varphi > \varphi^*$ (i.e. in region **D2**) the Southern market has absolutely no effect on innovation since the firm has no interest in selling there even if its patent is protected. As a result, in region **D2**, Southern imitation does not affect the firm (or Northern consumers) while offering large welfare gains to Southern consumers, thereby making the lack of patent protection in the South socially optimal.

What are the implications of shutting down Southern imitation (i.e. TRIPS)? As Figure 1 shows, such a policy change raises welfare in regions **A** and **C** whereas it lowers it in region **D1** and **D2**. In region **A**, although the firm sells the South even in the absence of patent protection, TRIPS raises welfare by increasing the firm's R&D investment. In region **C**, patent protection in the South is also socially optimal since the loss to the South from eliminating the imitated product is trumped by the gains enjoyed by the firm and consumers worldwide due to an increase in R&D. For $\varphi > \varphi^*$ (i.e. region **D2**), the firm continues to stay out of the South even when its granted patent protection. As a result, its R&D incentive is unchanged due to TRIPS, and shutting down imitation makes the South lose access to the imitated product without conferring any welfare gain on the North. Thus, for all $\varphi > \varphi^*$, enforcing patent protection in the South reduces welfare. Finally, as explained above, over region **D1**, while the North loses from lack of patent protection, its loss is dominated by South's gain due to its strong ability to imitate.

To better understand the consequences of requiring the South to offer patent protection, it is useful to consider the globally optimal level of R&D investment. Assuming the South implements patent protection and the firm sells in both markets, the globally optimal R&D is given by

$$q_w \equiv \arg\max w_N^*(q) + w_S^*(q)$$

where we can show that $q_w > q^*$ – i.e. the firm under-invests in R&D since it does not take into account the additional consumer surplus generated by its R&D investment. Similarly, the optimal R&D investment for when the firm sells only in the North is defined by $q_w^N \equiv \arg\max w_N^*(q)$ where $q_w^N > q^N$.[17] Thus, in our model, patent protection is attractive whenever it helps nudge the firm's R&D investment in the right direction.

[17]Note that we could also discuss the socially optimal entry thresholds if R&D is done at the socially optimal level.

3 Compulsory licensing and exhaustion policy

We first extend our model to allow for the possibility of compulsory licensing and then examine the robustness of our key conclusions for the case where the North practices international exhaustion of IPRs.

3.1 Incorporating compulsory licensing

As noted above, forcing the South to offer patent protection can lead to a situation where the imitated product is eliminated from its market but the firm still does not enter. If this happens, patent enforcement hurts the South without offering any benefit to the North. In such a situation, we now allow the South the option of issuing a compulsory license to a local producer who is granted the authority to produce the patented product for the local market.

Consistent with WTO rules, we assume that the South can issue a compulsory license to a local firm *only if* the patented product is not sold in the South in the first period. The length of the first period captures the time-period that is available under TRIPS to a patent-holder to work its patent in a country before the local government is authorized to issue a compulsory license. Under the Berne Convention, this "reasonable" time period is interpreted to be three years long.

As per Article 31 of TRIPS, we require that in the event of CL the South provide remuneration to the firm for utilizing its patent locally. According to recommendations of the World Health Organization (WHO), royalty rates under a compulsory license should be specified as a percentage of the wholesale price. We model this by assuming that the per-period royalty rate r under CL is a fraction $\alpha \in (0, 1)$ of the price that the licensee would charge as a monopoly supplier, i.e., we set $r = \alpha p^L$ where $p^L = \gamma^R q/2$, where $\gamma^R q$ denotes the quality of the product under CL. Since, the firm may provide some technical assistance to the local licensee under CL, we assume that the technological capability of the licensee is at least as high as that of an imitator: i.e. $\gamma^R \geq \gamma$. However, since the firm's incentive for sharing knowledge with the licensee is limited (because it can only extract part of the surplus earned by the licensee), we assume $\gamma^R < 1$ so that we have $\gamma \leq \gamma^R < 1$.

Given that the objective of CL is to improve consumer access, we posit that the Southern government requires the licensee to sell the licensed product locally at price equal to marginal cost (inclusive of the royalty payment r). This implies that the price in the South under CL equals $r = \alpha p^L = \alpha \gamma^R q/2$ with the associated sales of $x^{CL} = 1 - p^L = 1 - \alpha/2$.

3.2 CL versus entry: the firm's perspective

The per-period royalty payment $R(q)$ collected by the firm under CL for the remaining duration of the patent ($T-1$ periods) equals

$$R(q) = rx^{CL} = \frac{(2-\alpha)\alpha\gamma^R q}{4} \tag{7}$$

Observe that an increase in the technological capability of the licensee (γ^R) increases the royalty payment $R(q)$ while lowering the quality adjusted price faced by Southern consumers.

Given that consumers in the South pay a price of $r = \alpha p^L$ in the event of CL, Southern welfare under CL equals:

$$w_S^{CL}(q) = \Omega\left[\frac{(\gamma^R q - r)^2}{2\gamma^R q}\right] = \Omega\left[\frac{\gamma^R(2-\alpha)^2 q}{8}\right] \tag{8}$$

The $w_S^{CL}(q)$ function is decreasing in α and increasing in $\gamma^R q$. A larger value of α reduces Southern welfare because it raises the royalty payment made to the firm, while an increase in the quality of the licensee's product raises consumer surplus. Since Southern welfare in the absence any local sales equals zero, the South issues a compulsory license if the firm does not enter in the first period and the licensee has at least some technological capability to produce the product (i.e. $\gamma^R \neq 0$). Thus, for all $\gamma^R > 0$, CL is a credible threat for the South.

The firm takes the possibility of CL into account when making its R&D decision. The firm foresees two options for selling in the South: (a) incur the fixed cost φ and enter or (b) stay out of the South in the first period and wait for CL in the next period. If a compulsory license is issued, the firm's profits over the life of the patent equal the discounted value of its profits in the Northern market and the stream of royalty payments collected the South, i.e.

$$v^{CL}(q) = (1+\Omega)\pi_N^*(q) + \Omega R(q) - c(q). \tag{9}$$

The firm's optimal quality under CL maximizes $v^{CL}(q)$ and it is given by

$$q^{CL} = q^N + \frac{\Omega\alpha\gamma^R(2-\alpha)}{4t} < q^* \quad \text{where} \quad q^* = q^N + \frac{1+\Omega}{4t} \tag{10}$$

Observe that $q^{CL} > q^N$: this is because the royalty payments under CL provide the firm with a stronger incentive to improve product quality relative to a scenario where it only sells in the North. Furthermore, q^{CL} is increasing in α and γ^R, since each of these parameters increases the marginal return to quality from royalty payments collected under CL. However, $q^{CL} < q^*$ since the firm's incentive for R&D under CL is less than that under entry due to the lower return per unit sold ($\gamma^R < 1$ and $\alpha \leq 1$) and the one-period delay involved under CL.

Although the firm earns higher product market profits under entry relative to CL, entry also incurs the fixed cost φ. Thus, the firm prefers entry to CL iff

$$v^*(q^*) - \varphi \geq v^{CL}(q^{CL}) \Leftrightarrow \varphi \leq \varphi^{CL}(\alpha, \gamma^R) \equiv v^*(q^*) - v^{CL}(q^{CL}) \tag{11}$$

Since the per-period royalty payment under CL is increasing in α for $\alpha \in [0, 1)$, we have $\partial\varphi^{CL}/\partial\alpha < 0$. Similarly, $\partial\varphi^{CL}/\partial\gamma^R < 0$ because a greater ability on the part of the licensee raises the royalties under CL. Observe that since $v^{CL}(q^{CL}) \geq v^N(q^N)$, we have $\varphi^{CL} \leq \varphi^*$. In other words, the possibility of CL makes the firm *less willing to enter* the South because it can earn a positive return from royalty payments under CL (which necessarily occurs in the second period if the firm stays out), so that the preceding two inequalities are strict provided $\alpha > 0$ and $\gamma^R > 0$.

The impact of CL on R&D thus depends on how the firm's entry decision is affected by the possibility of CL. For $\varphi > \varphi^*$, there are no sales in the South if CL is not an option, so the availability of CL raises the equilibrium quality of the firm's product. On the other hand, for $\varphi \in [\varphi^*_{CL}, \varphi^*)$, the existence of CL undermines the firm's R&D incentive because the firm would have entered had CL not been possible. Finally, for $\varphi < \varphi^{CL}(\alpha, \gamma^R)$ there is no effect on product quality because the firm enters with or without the CL option. We can now state:

Proposition 4. *When the South can avail of CL, the firm enters if its fixed cost φ is less than the threshold level $\varphi^{CL}(\alpha, \gamma^R)$, which is decreasing in α and γ^R . Furthermore, the following hold:*

(i) For $\varphi > \varphi^*$, the option of CL gives the South a product of quality $\gamma^R q^{CL}$ whereas no product would have been available in the South in its absence.

(ii) For $\varphi \in [\varphi^{CL}(\alpha, \gamma^R), \varphi^*)$, which is a non-empty interval if $\alpha, \gamma^R > 0$, the option of CL causes the firm to switch from entry in the first period to waiting for CL in the second period.

(iii) For $\varphi < \varphi^{CL}$, the firm enters whether or not the South can utilize CL.

How does the option of CL affect Southern welfare? We now address this key question.

3.3 CL versus entry from South's perspective

From Proposition 4 it follows that for $\varphi > \varphi^*$ the South is better off due to the CL option since it obtains access to the locally produced version of the patented product under CL whereas it is unaffected for $\varphi < \varphi^{CL}$ since the firm enters whether or not CL is permissible. For $\varphi \in (\varphi^{CL}, \varphi^*]$ the comparison is ambiguous because the possibility of CL induces the firm to switch from entry in the first period to CL in the second. Relative to entry, the price paid by Southern consumers is lower under CL ($\alpha\gamma^R q^{CL}/2 < q^*/2$) but the quality of the product is also lower ($\gamma^R q^{CL} < q^*$) and the product becomes available after a delay of one-period.

Evaluating (8) at q^{CL} yields welfare of the South under CL:

$$w_S^{CL}(\alpha, \gamma^R) = \Omega \left[\frac{\gamma^R (2-\alpha)^2 q^{CL}(\alpha, \gamma^R)}{8} \right] \tag{12}$$

Lemma 2. *Southern welfare $w_S^{CL}(\alpha, \gamma^R)$ under CL has the following properties:*

(i) w_S^{CL} is convex and increasing in γ^R.

(ii) A sufficient condition for w_S^{CL} to be decreasing in α is $\frac{1+\Omega}{\Omega}\mu n > 2\gamma^R$.

(iii) If $\gamma^R > \gamma_m^R \equiv \frac{(1+\mu n)(1+\Omega)}{4\mu n \Omega}$, the South prefers CL to entry for $\varphi \in [\varphi^{CL}, \varphi^*)$ and for α sufficiently low.

The royalty parameters α and γ^R have a direct effect on Southern consumer surplus (for a given q) and an indirect effect through their impact on the quality of the product created by the firm (q^{CL}). For an increase in γ^R both of these effects work in the same direction. An increase in γ^R increases the quality of licensee's product (for a given q) and it increases the firm's R&D investment in quality improvement since its payoff from CL increases with γ^R. For an increase in α, on the other hand, the direct and indirect effect work in opposite directions. A higher α reduces Southern consumer surplus by raising the royalty paid to the firm, but it also simultaneously increases the firm's R&D investment in quality improvement. A sufficient condition for an increase in α to harm the South is that the Northern market be sufficiently large relative to the South, since in such a situation the Southern market has a limited impact on the firm's R&D incentive. Similarly, the South must lose in the neighborhood of $\alpha = 1$ since an increase in α has minimal impact on the firm's R&D.

Part (*iii*) of Lemma 2 shows that the South prefers CL to entry at $\alpha = 0$ provided the the licensee's technological capability γ^R is sufficiently high (i.e. $\gamma^R > \gamma_m^R$). The critical threshold γ_m^R is decreasing in Ω since a longer duration of the patent implies that the one-period delay involved in CL is a relatively minor concern for the South. The threshold γ_m^R is also decreasing in n and μ, since a larger or more lucrative Northern market reduces the relative importance of the Southern market in determining the firm's overall R&D incentive.

For the North, welfare under CL is simply the sum of firm's total payoff under CL and consumer surplus:

$$w_N^{CL}(\alpha, \gamma^R) = v^{CL}(q^{CL}) + (1 + \Omega) cs_N^N(p_N^*(q^{CL}))$$

The impact of CL on Northern welfare depends on the firm's choices regarding entry as well as R&D. For $\varphi > \varphi^*$, the option of CL creates royalties for the firm and increases product quality, so both the firm and North consumers benefit from it. For $\varphi \in (\varphi^{CL}, \varphi^*]$, the option of CL increases the firm's profits but it reduces product quality relative to entry. The North necessarily prefers entry to CL at $\varphi = \varphi^{CL}$, since at that point the firm is indifferent between entry and CL but Northern consumers lose from the lower quality product under CL. Whether the North prefers entry to CL at φ^* depends on the values of the two key parameters under CL: α and γ^R. The North is more likely to prefer CL to entry when royalty payments are sufficiently high and the negative impact of CL on product quality is small. For $\varphi < \varphi^{CL}$, the firm enters regardless of the availability of the CL, so Northern welfare is unaffected.

3.4 CL and global welfare

From a global welfare perspective, entry is preferable to CL iff

$$w_S^*(q^*) + w_N^*(q^*) - \varphi \geq w_S^{CL}(\alpha, \gamma^R) + w_N^{CL}$$

For $\varphi > \varphi^*$, world welfare must necessarily increase from the option of CL since, as noted above, welfare in both regions is higher if CL is available. It is also clear that the CL option has no effect on world welfare for $\varphi < \varphi^{CL}$ since, over this region, the firm chooses to enter whether or not CL is possible.

For $\varphi \in (\varphi^{CL}, \varphi^*]$, there are two conflicting effects that together determine whether or not the option to use CL is welfare-improving. Over this parameter range, the firm switches from entry to CL and although this switch economizes on the fixed entry cost φ, it also reduces consumer surplus due to the the reduction in R&D (recall $q^* > q^{CL}$). Entry yields higher joint welfare than CL iff $\varphi \leq \varphi_W^{CL}$ where

$$\varphi_W^{CL} \equiv w_S^*(q^*) + w_N^*(q^*) - w_S^{CL}(\alpha, \gamma^R) - w_N^{CL} \tag{13}$$

We can establish the following properties of the threshold value of fixed cost φ_W^{CL} at which world welfare under CL equals that under entry:

Lemma 3. *The threshold level of the fixed entry cost $\varphi_W^{CL}(\alpha, \gamma^R)$ below which entry in the first period yields higher global welfare than CL in the second has the following properties:*

(i) $\varphi^* < \varphi_W^{CL}(\alpha, 0)$.

(ii) $\frac{\partial \varphi_W^{CL}}{\partial \gamma^R} < \frac{\partial \varphi^*}{\partial \gamma^R} < 0$.

(iii) If $\Omega > 1$*, then* $\varphi_W^{CL}(\alpha, 1) - \varphi^*$ *is decreasing in* μ and n.

(iv) $\varphi^{CL}(1,1) < \varphi_W^{CL}(1,1)$.

When $\gamma^R = 0$, the product is unavailable in the South and it incurs no royalty payments. Part (i) of Lemma 3 reflects the fact that the firm ignores the gains in consumer surplus in *both* regions that result from its entry into the South, so its threshold for entering the Southern market is lower than the socially optimal threshold $\varphi_W^{CL}(\alpha, 0)$ because the welfare gains to the world from the firm's entry into the South exceed those to the firm. The firm's failure to internalize the consumer surplus effects of the innovation induced by entering the South also explain part (ii). Increases in γ^R raise firm profits and consumer surplus in both markets under CL, so the threshold for entry for the firm declines more slowly with γ^R because the firm does not consider the effect of its decisions on consumer surplus.

When $\gamma^R = 1$ the licensee is able to produce the same quality product as the firm. Lemma 3 (iii) shows that the differential between $\varphi_W^{CL}(\alpha, 1)$ and φ^* declines more rapidly the larger is the Northern market relative to the South. This indicates that if the delay involved under CL is not too long, increased effective market size in the North causes world welfare under CL to increase more rapidly relative to the firm's profits under CL. Part (iv) establishes that when the royalty rate is set to capture the entire monopoly profit (i.e. $\alpha = 1$) and the licensee is as efficient as the patent holder (i.e. $\gamma^R = 1$), the firm is too willing to wait for CL relative to the social optimum.

Figure 2 uses the results of Lemma 3 to illustrate how the option of CL affects world welfare for the case where the royalty rate is sufficiently low that $\varphi_W^{CL} < \varphi^{CL}$ at $\gamma^R = 1$. In regions **A** and **B** the firm has no incentive to enter the South (since $\varphi > \varphi^*$) so the option of CL provides South consumers access to the product while simultaneously providing the firm with royalty payments which in turn increase its incentive to produce a higher quality product. Therefore, the option of CL increases world welfare in regions **A** and **B**. Note, however, that in region **A**, the quality of the product under CL is sufficiently low that world welfare would be higher if the firm could be induced to choose entry.

In regions **C** and **D**, where $\varphi \in (\varphi^{CL}, \varphi^*)$, the option of CL results in a switch from entry to CL. In region **D**, which lies below the φ_W^{CL} locus, this switch reduces world welfare due to the lower quality of the product produced by the licensee. In region **C**, the quality of the licensee's product is sufficiently high that world welfare rises from the switch from entry to CL. In regions **E** and **F**, which lie below the φ^{CL} locus, the existence of the CL has no effect on the equilibrium outcome. However, the ability of

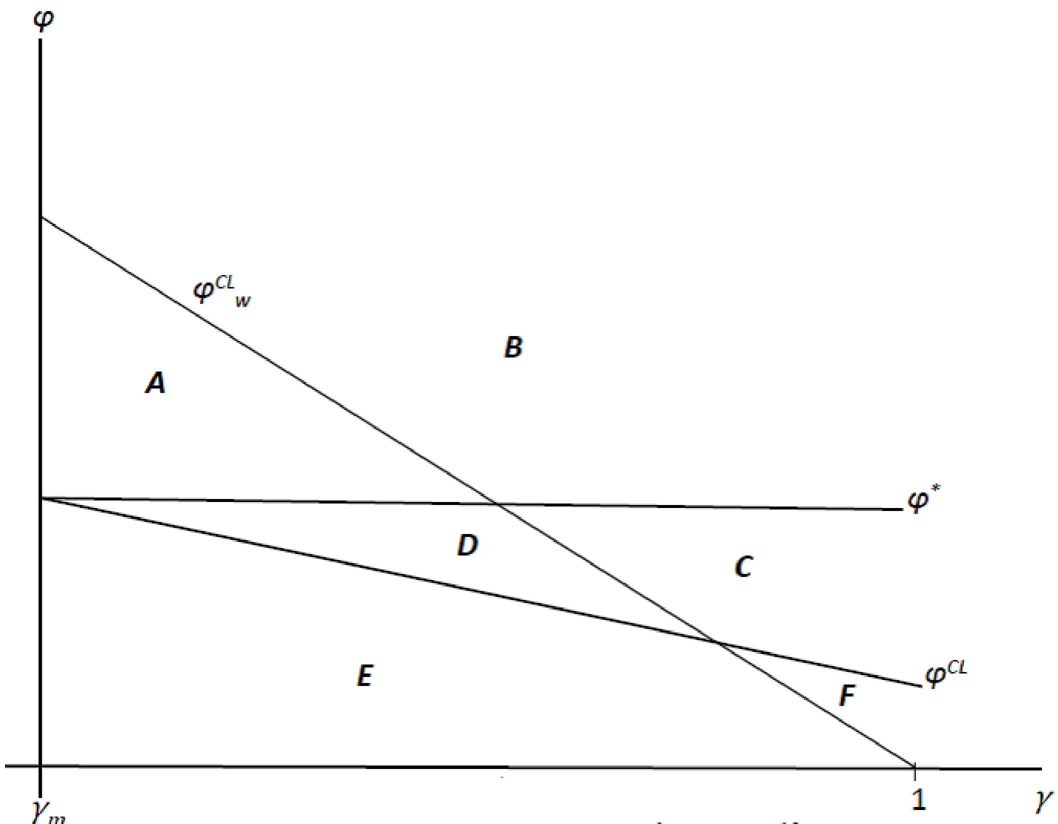

Figure 2: CL versus Entry and joint welfare

the licensee is sufficiently high in Region **F** that world welfare would be higher if CL were to occur as opposed to entry.[18]

Finally, we note that world welfare is increasing in α at $\alpha = 0$ whereas it is decreasing in α at $\alpha = 1$. In the neighborhood of $\alpha = 0$, an increase in the royalty rate raises welfare

[18]Two other cases are possible. If $\varphi^* > \varphi_W^{CL} > \varphi^{CL}$ at $\gamma = 1$, region **F** does not exist. If $\varphi_W^{CL} > \varphi^*$ at $\gamma = 1$, neither region **C** nor region **F** exist.

by encouraging additional R&D on the part of the firm. In the neighborhood of $\alpha = 1$, on the other hand, the increase in product quality obtained by raising the royalty rate is sufficiently small that it is dominated by the loss in consumer surplus in the South. Therefore, world welfare is optimized by setting a royalty rate that is positive but less than the monopoly price for the licensee's product.

Next, we analyze our model for the case where the North practices international exhaustion of IPRs as opposed to national exhaustion.

4 International exhaustion of IPRs

We begin by describing product market outcomes under international exhaustion.

4.1 Product market

When the North implements international exhaustion of IPRs, when selling in both markets it is optimal for the firm to set a common global price to eliminate any possible competition from parallel imports. This global price p solves:

$$\max_{p} \pi(p) \equiv np(1 - p/\mu q) + p(1 - p/q)$$

which yields the optimal global price

$$p^G = \frac{\mu q}{2} \frac{n+1}{n+\mu} \tag{14}$$

It is straightforward to show that $p_S^* < p^G < p_N^*$ – i.e. the firm's common international price under international exhaustion is bound by its optimal discriminatory prices for the two markets. Let the firm's maximized per-period profit under international exhaustion be denoted by $\pi^G = \pi(p^G) = p^G(n+1)/2$.

If the firm faces competition from imitators in the South then its optimal price under international exhaustion equals

$$p^{IG} = \frac{\mu q}{2} \frac{(n+1)(1-\gamma)}{n(1-\gamma)+\mu} \tag{15}$$

which can be rewritten as

$$p^{IG} = \sigma(\gamma) p_N^*$$

where $0 \leq \sigma(\gamma) < 1$. Furthermore, p^{IG} is increasing in m and n whereas it is decreasing in γ – i.e. competition from imitation partly spills over to the Northern market under international exhaustion. Furthermore, as one might expect, we have $p^{IG} > p_S^*$. It is worth noting that $p^{IG} > (1-\gamma)p^G$. In other words, since the firm sets a common international price under international exhaustion, the price reduction that the South enjoys due to imitation is relatively smaller when the firm sets a common international price relative to when the firm price discriminates internationally (as it does when North practices national exhaustion of IPRs). We have $\pi^{IG}(q) = p^{IG}(n+1)/2$.

4.2 R&D under international exhaustion

Let $q^G = \arg\max\ (1+\Omega)\pi^G(q) - c(q)$ be the optimal R&D investment of the firm in the presence of patent protection in the South. Similarly, let $q^{IG} = \arg\max\ (1+\Omega)\pi^{IG}(q) - c(q)$ be its R&D investment in the absence of patent protection. As before, let $v^G = (1+\Omega)\pi^G(q^G) - c(q^G)$ and $v^{IG} = (1+\Omega)\pi^{IG}(q^{IG}) - c(q^G)$.

The firm's maximized payoff under international exhaustion when its patent is protected in the South equals

$$\begin{cases} v^G - \varphi \text{ if } \varphi \le \varphi^G = v^G - v_N^* \\ \\ v_N^* \text{ if } \varphi > \varphi^G \end{cases}$$

Similarly, the firm's payoff under international exhaustion in the absence of patent protection equals

$$\begin{cases} v^{IG} - \varphi \text{ if } \varphi \le \varphi^{IG} = v^{IG} - v_N^* \\ \\ v_N^* \text{ if } \varphi > \varphi^{IG} \end{cases}$$

We can use these conditions to obtain the following result on the threshold values at which the firm will enter the South market under international exhaustion.

Lemma 4.
(i) $\varphi^G \ge 0$ *iff* $\mu \le \mu^* \equiv 2 + 1/n$.

(ii) $\partial\varphi^G/\partial\mu\big|_{\mu=1} > 0$ *whereas* $\partial\varphi^G/\partial\mu\big|_{\mu=\mu^*} < 0$.

(iii) $\varphi^{IG} \ge 0$ *iff* $\mu \le (1-\gamma)\mu^*$.

Part (i) of Lemma 4 says that when $\mu > \mu^*$, the firm prefers to sell only in the North even when the fixed cost of selling in the South equals zero and its patent is protected there. Part (iii) establishes a similar (and more stringent) condition for the firm to be willing to sell in the South in the absence of patent protection. These conditions show that when the willingness to pay is sufficiently higher in the North market, preserving profit in the Northern market is so important that the firm is willing to forsake the Southern market to charge its optimal price in the North. The condition is more stringent without patent protection because the firm faces competition from imitators. In contrast, the firm is willing to enter the South when fixed costs are zero under national exhaustion for all values of μ because there is no negative spillover from its price in the Southern market on its profits in the North.

Part (*ii*) of Lemma 4 highlights the fact that the fixed cost threshold φ^G below which the firm is willing to sell in the South is a non-linear function of μ. When $\mu \approx 1$, consumer preferences in the two regions are very similar and an increase in the willingness to pay on the part of Northern consumers makes the firm more willing to sell in the North whereas the opposite is true $\mu \approx \mu^*$. This result reflects two conflicting effects. As μ increases, the firm's R&D investment q^G goes up and this makes selling in the South more profitable. On the other hand, the larger is μ the greater the loss the firm suffers in terms of reduced profitability in the Northern market from having to set a common international price under international exhaustion. For μ small, the R&D effect dominates whereas for μ large, the loss in Northern profits implied by uniform pricing drives the firm's entry decision. We can show the following:

Proposition 5.

(i) Even when the North practices international exhaustion,, the lack of patent protection in the South reduces the firm's R&D investment (i.e. $q^{IG} \leq q^G$*) as well as its incentive to enter the Southern market (i.e.* $\varphi^{IG} \leq \varphi^G$*). Furthermore, the stronger the intensity of imitative competition in the South, the lower the firm's investment in R&D (i.e.* $\partial q^{IG}/\partial \gamma < 0$*) and the weaker its incentive to sell in the South (i.e.* $\partial \varphi^{IG}/\partial \gamma < 0$*).*

(ii) For a given South patent policy, the firm is more willing to sell in the South under national exhaustion ($\varphi^G < \varphi^*$ *and* $\varphi^{IG} < \varphi^I$*) and chooses a higher level of R&D under national exhaustion (*$q^G \leq q^*$ *and* $q^{IG} \leq q^I$*).*

(iii) There exists $\gamma^f \geq 0$ *such that* $\varphi^I > \varphi^G$ *iff* $\gamma \leq \gamma^f$ *where (a)* $\partial \gamma^f/\partial n > 0$*; (b)* $\partial \gamma^f/\partial \mu > 0$*; and (c) at* $\mu = \mu^*$, $\gamma^f = 1$.

(iv) $q^I \geq q^G$ *iff* $\gamma \leq \gamma^f$.

Part (*i*) of this Proposition establishes that the threshold level of fixed costs for entry with international exhaustion is lower when the South does not provide patent protection, which is similar to the result obtained in Proposition 1 for the case of national exhaustion. Part (*ii*) is easy to understand: having to set a common international price under international exhaustion makes the firm more reluctant to sell in the South because of the resulting loss in profits in the North market. Furthermore, the fact that profits from entering the South market are higher with national exhaustion means that there is a greater incentive to improve the quality of the product by investing in R&D.

Parts (iii) addresses the relative impact of the loss of patent protection and the inability to price discriminate on the profitability of entry in the South. The profit from entry without patent protection is decreasing in the South's imitative ability, so there is a critical value γ^f at which the firm earns the same level of profits with price discrimination and no patent protection as it does with no price discrimination and patent protection. This threshold level of the South's imitative ability is increasing in μ and n because the inability to price discriminate is more damaging to firm profits when the North market is more profitable. Interestingly, part (iv) shows that the marginal profit from improving product quality is also equalized between the cases of national exhaustion without patent protection and international exhaustion with patent protection when $\gamma = \gamma^f$ so $q^I(\gamma^f) = q^G$. Since q^I is decreasing in the imitative ability in the South, $q^I(\gamma) > q^G$ for $\gamma > \gamma^f$ if the firm enters under both regimes.

4.3 South's patent protection policy

Having derived the firm's payoffs, we are now ready to derive the South's equilibrium patent policy. Southern welfare under patent protection equals

$$\begin{cases} w_S^G = (1+\Omega)cs_S(p^G(q^G)) \text{ if } \varphi \le \varphi^G \\ \\ 0 \text{ if } \varphi > \varphi^G \end{cases}$$

whereas that in the absence of patent protection equals

$$\begin{cases} w_S^{IG} = (1+\Omega)cs_S(p^{IG}(q^{IG});\gamma) \text{ if } \varphi \le \varphi^{IG} \\ \\ w_S^L = (1+\Omega)cs_S^L(\gamma q^N) \text{ if } \varphi > \varphi^{IG} \end{cases}$$

We are now ready to state the following:

Lemma 5. *The following hold regarding Southern welfare under various outcomes:*
(i) $w_S^{IG} \ge \max\{w_S^G, w_S^L\}$ *for* $\mu \le (1-\gamma)\mu^*$.
(ii) There exists γ^G *such that* $w_S^G \ge w_S^L$ *iff* $\gamma \le \gamma^G$ *where* $\partial\gamma^G/\partial n < 0$ *and* $\partial\gamma^G/\partial\mu < 0$.
(iii) $\gamma^G < \gamma^*$.
(iv) $w_S^G \le w_S^*$ *for* $\mu < \mu^*$.

Part (i) establishes that the best outcome for the South occurs if the firm's entry costs are sufficiently low that it enters without patent protection. The fact that entry is desirable when there is no patent protection is immediate, since it increases product variety and leads to a higher quality level. Compared to entry with patent protection, the South gets lower prices and greater variety without protection but a lower product quality. As in the case of national exhaustion, the former effects dominate and the South is better off if the firm enters without patent protection. Part (*ii*) shows that Southern consumers are better-off having access to (only) the patented product relative to consuming when the South's imitative ability is below a threshold level. Part (*iii*) says that the maximum level of imitative ability for preferring patent protection is lower under international exhaustion than under national exhaustion because the price of the patented product is higher under international exhaustion.

Parts (*iv*) of Lemma 5 says that, given that it implements patent protection, the South is better off under national exhaustion. This is due to two reasons. First, holding constant the quality of the product across the two exhaustion regimes, price in the Southern market is lower under national exhaustion (i.e. $p_S^* < p^G$). Second, the firm invest more in R&D and therefore delivers a higher quality product under national exhaustion. From the South's viewpoint, both forces reinforce each other thereby making national exhaustion clearly preferable to international exhaustion.[19] Using Lemma 3, we can now state the South's optimal patent protection policy when the North implements international exhaustion:

Proposition 6. *Suppose the Northern policy is international exhaustion and compulsory licensing is not an option. Then, the South's equilibrium patent protection policy is as follows: (i) If* $\mu < (1-\gamma)\mu^*$*, the South offers patent protection to the firm iff* $\varphi \in [\varphi^{IG}, \varphi^G]$ *and* $\gamma \leq \gamma^G$*; (ii) If* $\mu \in [(1-\gamma)\mu^*, \mu^*]$ *the South offers patent protection iff* $\varphi \in [0, \varphi^G]$ *and* $\gamma \leq \gamma^G$*; and (iii) if* $\mu > \mu^*$ *the South does not offer patent protection regardless of its local technological capability (*γ*) or the fixed costs of entry (*φ*).*

The basic message of Proposition 6 is that the South only provides patent protection in cases where the level of φ is such that the firm is willing to enter only if it receives patent protection and the level of γ is sufficiently low. This result is is analogous to Proposition 2, which established the corresponding range of parameter values for which the South provides patent protection when North pursues a policy of national exhaustion. The important point to note is that North's exhaustion policy alters the parameter values for which the South is willing to provide patent protection. For parameter values at which the South chooses to provide patent protection under national exhaustion, patent protection may no longer be sufficient to induce entry under international exhaustion because entry in the South is less attractive to the firm since it has to charge a common international price. For these parameter values, imitation becomes relatively more attractive to the South. Observe, however, that for parameter values at which the firm enters without patent protection under national exhaustion, the firm may no longer

[19]From the North's viewpoint, the two effects work in opposite directions because $p_N^* > p^G$ whereas $q^G < q^*$ – i.e. international exhaustion helps lower the price in the North but it also lowers the firm's incentive to invest in R&D.

be willing to enter without patent protection under international exhaustion. Thus, for $\varphi \in [\varphi^{IG}, \varphi^{I})$, providing patent protection for the South becomes relatively more attractive under international exhaustion when imitators are of relatively low quality because it can be used to induce entry by the firm.

The impact of the North's exhaustion policy on the South's patent decision is illustrated in Figure 3, which compares the entry thresholds under international exhaustion, φ^{G} and φ^{IG}, with those under national exhaustion, φ^{*} and φ^{I} for a case where $\mu < \mu^{*}$. For the values of μ and n used in Figure 3, the horizontal intercept of the φ^{IG} line occurs at $\gamma = 1 - \mu/\mu^{*} > \gamma^{G}$.

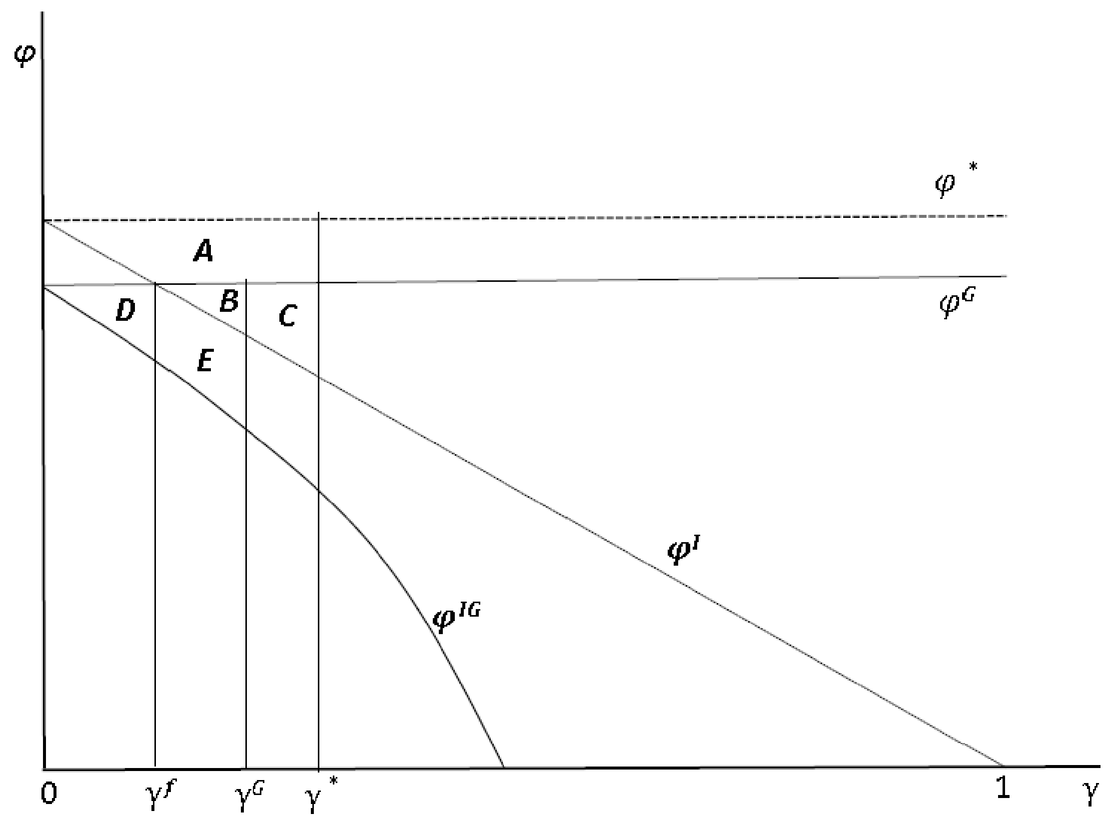

Figure 3: Equilibrium outcomes with International Exhaustion

The set of values of $\{\varphi,\gamma\}$ for which the South offers patent protection under international exhaustion is illustrated by the triangular area made up of regions **B**, **D**, and **E** in Figure 3, as that area satisfies part (i) of Proposition 6. This area can be compared with the triangular area made up of regions **A**, **B**, and **C**, which is the set of values of $\{\varphi,\gamma\}$ for which the South offered patent protection under national exhaustion. The fact that the price the South faces when the firm enters under international exhaustion is higher than that under national exhaustion means that the threshold quality at which the South prefers imitated goods is lower under international exhaustion, as established in Lemma 3(*iii*). Furthermore, the fact that the firm earns less profit from the South market under international exhaustion means that the threshold levels of fixed costs for entry, φ^G and φ^{IG}, are lower than their corresponding values under national exhaustion as established in Proposition 5.[20]

When $\mu > \mu^*$, the firm does not sell in the South even when its patent is protected and the fixed cost of entry equals zero since it wants to preserve its profit in the Northern market. When such is the case, the South has no incentive to offer patent protection under international exhaustion since doing so eliminates the low quality imitated product from the local market without eliciting entry by the firm. By contrast, under national exhaustion, even when $\mu > \mu^*$ the South is willing to offer patent protection so long as it is necessary and sufficient to induce entry by the firm and $\gamma \leq \gamma^*$.

For a given patent policy in the South, international exhaustion results in lower innovation that national exhaustion. The negative effect of international exhaustion on R&D is reinforced if the South has a weaker incentive to offer patent protection under international exhaustion. On the other hand, a more stringent patent policy in the South under international exhaustion has a conflicting effect on firm R&D. Figure 3 can also be used to illustrate how the policy reaction of the South affects R&D incentives under national exhaustion relative to international exhaustion.

In regions **A** and **C**, a switch from national to international exhaustion causes the South to drop its patent protection. The elimination of patent protection in the South further reduces the incentive of the firm to do R&D, so a switch to international exhaustion must unambiguously reduce the quality of the product in regions **A** and **C**. In regions **D** and **E**, the switch from national to international exhaustion causes the South to introduce patent protection. In these two areas, the change in South patent policy tends to raise the firm's innovation incentive while the North's policy change to international exhaustion tends to reduce it. Applying Proposition 5(*iv*), the firm's innovation is lower under international exhaustion in region **D** (since $\gamma < \gamma^f$) while it is greater under international exhaustion in Region **E**.

In summary, innovation is higher under international exhaustion relative to national exhaustion only in cases where the Southern market is sufficiently profitable relative to the Northern one ($\gamma^f < \gamma^G$) and only for entry costs satisfying $\varphi \in [\varphi^{IG}, \varphi^I]$. For all other areas of the parameter space where the firm would enter with national exhaustion,

[20]If $1 - \mu/\mu^* < \gamma^G$, the horizontal intersection of the φ^{IG} locus occurs to the left of γ^G. In that case part (*i*) of the proposition applies for $\gamma \in [0, 1 - \mu/\mu^*]$ and part (*ii*) applies for $\gamma \in (1 - \mu/\mu^*, \gamma^G]$.

innovation is lower under international exhaustion. Our results on the effect of international exhaustion on R&D can be compared with those of Grossman and Lai (2008), who consider the case where the South provides patent protection but also imposes price controls on the Northern producers. In their model, the South chooses a more liberal price control under international exhaustion, leading to a presumption that Northern firms engage in more R&D under international exhaustion. In contrast, we find that when the South's only policy instrument is patent protection, the induced policy change in the South under international exhaustion may either increase or decrease R&D incentives. The South has an incentive to drop patent protection under international exhaustion in cases where such protection is needed to induce entry under national exhaustion. However, the South may choose to adopt patent protection to induce entry under international exhaustion in cases where the firm is willing to enter without patent protection under national exhaustion.

4.4 Welfare under international exhaustion

Let global welfare under international exhaustion when the firm sells in both markets under patent protection be given by w^G where

$$w^G = w_S^G + w_N^G - \varphi$$

and $w_N^G \equiv (1+\Omega)cs_N(p^G(q^G)) + v^G$. Similarly define

$$w^{IG} = w_S^{IG} + w_N^{IG} - \varphi$$

where $w_N^{IG} \equiv (1+\Omega)cs_N(p^{IG}(q^{IG})) + v^{IG}$. We can show the following:

Proposition 7. *The following inequalities hold regarding global welfare (gross of fixed costs of entry) under different policy regimes:*
(i) $w^{IG} \leq w^G$ *and* $w^I \leq w^*$.
(ii) $w^G \leq w^*$ *and* $w^{IG} \leq w^I$.
(iii) $w^I \leq w^G$ *iff* $\gamma > \gamma^f$

Part (*i*) of Proposition 7 says that, provided the firm sells in both markets regardless of the global policy environment faced by it, total welfare is higher if the South offers patent protection relative to when it does not. In other words, the introduction of patent protection in the South raises global welfare under both national and international exhaustion provided the firm sells in both markets under all possible policy configurations. Part (*ii*) of Proposition 7 informs us that, provided the firm sells in both markets, national exhaustion delivers higher joint welfare than international exhaustion when the South's patent protection policy is held constant across the two regimes.

It is well known that in a model with linear demands in both regions and no innovation, international exhaustion is preferable to national exhaustion provided there is patent protection in the South and the firm sells in both markets. When quality is fixed, the firm's total output turns out to be equal under national and international exhaustion, but it is more efficiently allocated globally under international exhaustion because price is equalized across markets. Our result shows that when quality is endogenously determined by the firm's R&D investment and the South's patent policy is held constant, the welfare gain arising from a higher level of innovation under national exhaustion dominates the efficiency gains from price equalization across markets that obtains under international exhaustion.

Part (*iii*) of Proposition 7 shows that world welfare could be higher under international exhaustion if it leads the South to adopt patent protection. If $\gamma = \gamma^f$, the switch from national exhaustion in the North coupled with no patent protection in the South to international exhaustion with patent protection leaves world welfare unaffected because firm profits and consumer surplus are unaffected. For $\gamma > \gamma^f$, however, the increased innovation resulting from a switch to international exhaustion in the North together with patent protection in the South results in higher world welfare. Thus, for parameter values in region **E** in Figure 3, world welfare is higher under international exhaustion than under national exhaustion since the South's patent protection policy is not the same under the two regimes. For the other parameter values at which the firm is willing to enter with national exhaustion, world welfare is lower under international exhaustion.

Finally, we discuss the role of CL under international exhaustion.

4.5 CL and exhaustion policy

Finally, we consider the effect of allowing CL under international exhaustion. Observe that under a compulsory license, the licensee is prevented from exporting the product to the North.[21] This constraint effectively segments the two markets, so the firm is able to charge its monopoly price in the North when CL occurs in the South. We maintain the assumption that the royalty rate under CL is a fraction α of the monopoly price $p^L = \gamma^R q/2$ that would be charged by the licensee, i.e. $r = \alpha p^L = \alpha \gamma^R q/2$, so that the global profit of the firm under CL under international exhaustion is the same as that under national exhaustion which equals $v^{CL}(q) = (1 + \Omega)\pi_N^*(q) + \Omega R(q) - c(q)$.

As in the case of national exhaustion, the South enjoys a positive surplus under CL for all $\gamma^R > 0$, so that the imposition of CL is a credible threat if the firm does not enter

[21]Indeed, as noted earlier, TRIPS rules and the 2003 waiver decision of the WTO explicitly state that production under CL should be sold predominantly in the domestic market or exported to a third country that itself lacks the technological capability to produce the product and cannot obtain it from the patent-holder.

in the first period. The fact that prices and firm profits under CL are unaffected by the exhaustion regime means the welfare of the two regions and the firm's payoff does not depend on the exhaustion policy of the North. However, the North's exhaustion policy does affect the desirability of CL relative to entry from the perspective of both regions.

First consider the firm's incentives. Given that the Northern policy is international exhaustion, the firm prefers entry to CL iff $v^G(q^G) - \varphi \geq v^{CL}(q^{CL}) \Leftrightarrow \varphi \leq \varphi^G_{CL} \equiv v^G(q^G) - v^{CL}(q^{CL})$. It immediately follows from the properties of $v^{CL}(q^{CL})$ that $\varphi^G_{CL} \leq \varphi^G$ with strict inequality for $\alpha, \gamma > 0$. If $\varphi > \varphi^G$, the option of CL increases the firm's R&D incentive since its royalty payments from CL increase with R&D. For $\varphi \in (\varphi^G_{CL}, \varphi^G]$, the option of CL results in the firm switching from entry in the first period to waiting for CL in the second. In contrast to the case of national exhaustion, the possibility of CL has an ambiguous effect on product quality under international exhaustion. This ambiguity arises due to the lower level of profits (and hence R&D) under international exhaustion.

Since $\varphi^G_{CL} < \varphi^{CL}$, the region of the parameter space where CL is used is larger under international exhaustion than under international exhaustion. For $\varphi > \varphi^G$, the option of CL provides the South with access to the patented product, while also benefiting Northern consumers and the firm (i.e. it is Pareto-improving). For $\varphi \in (\varphi^G_{CL}, \varphi^G]$, the option of CL raises firm profits but, as noted above, has an ambiguous effect on product quality. Since world welfare is higher under national exhaustion than under international exhaustion and world welfare under CL is independent of the exhaustion regime, CL provides a larger welfare gain under international exhaustion.

We can now state the following:

Proposition 8. *Not only is compulsory licensing more likely to arise in equilibrium under international exhaustion compared to national exhaustion, its usage also generates a relatively larger welfare gain.*

5 Conclusion

The TRIPS agreement of the WTO forced many developing countries to strengthen their IPR regimes. However, at the same time it left WTO members unconstrained in two key respects: they could avail of compulsory licensing to provide local consumers greater access to patented products and were free to implement exhaustion policies of their choice. This paper provides a unified analysis of the key TRIPS obligation calling for harmonized patent protection across all member states and the two main policy flexibilities it granted them. In so doing, the paper integrates several strands of existing literature that explore various aspects of the multi-faceted relationship between IPR protection and international trade.

Our analysis is couched in a simple North-South model where the two regions differ in terms of their demand structure as well as their innovative capacity (with all of the R&D being done by a Northern firm). We show that the South's unilateral incentive for patent protection is too weak relative to what is jointly optimal. However, this does not imply that forcing the South to offer patent protection is *always* welfare improving. The welfare effects of TRIPS in our model are driven by two forces: how much the firm invests in research and development (R&D) and whether or not it finds it profit-maximizing to sell in the South.

We show that if the Northern firm is unwilling to sell in the South even when it is granted patent protection, forcing the South to implement patent protection makes it worse off without making the North better off. Luckily, however, by including the possibility of CL the TRIPS agreement provides developing countries with an important flexibility that allows them to secure access to foreign patented products when local patent protection fails to induce patent-holders to sell their products in their markets. We show that CL has the potential to make both regions better off and can even increase the firm's R&D investment when it finds it unprofitable to enter the Southern market – in such a situation, CL provides Southern consumers access to its product while allowing the firm to benefit from royalty payments that increase with the quality of its product. However, if the firm chooses to forsake entry in order to take advantage of CL (since its relative payoff under entry is lower), its R&D investment as well as global welfare can decline due to CL.

Finally, we examine how the exhaustion policy of the North affects the two regions as well as the likelihood of CL arising in equilibrium. We show that, provided the South offers patent protection to the firm, global welfare and innovation are higher if the North follows national exhaustion as opposed to international exhaustion. However, there are circumstances where the South is more willing to offer patent protection under international exhaustion and when this is the case, international exhaustion yields greater welfare. Finally, we examine the interplay between the two flexibilities and show that CL is more likely to arise in equilibrium under international exhaustion because the firm is less willing to sell in both markets when it has to set a common international price. Furthermore, the incidence of CL is more likely to be welfare-improving socially under international exhaustion relative to national exhaustion.

6 Appendix

Here we provide supporting calculations for results reported in the paper.

6.1 If quality is chosen before entry

Suppose that the firm choose the quality q of its product before making its entry decision. Then, given q, the maximum value of the fixed cost φ below which the firm is willing to enter is

$$\varphi^M(q) = v^{CL}(q) - v^*(q) = \frac{q}{4}(1 + \Omega(1 - 2\alpha\gamma + \alpha^2\gamma)) \tag{16}$$

Evaluating φ^M at the respective qualities yields

$$\varphi^M(q^{CL}) < \varphi^{CL} < \varphi^M(q^*) \tag{17}$$

Suppose $\varphi < \varphi^{CL}$ and the firm has chosen to produce a product of quality q^*. Then, as inequality (17) notes, at the time of the entry decision the firm's fixed cost is below the threshold for entry, $\varphi < \varphi^M(q^*)$, so that it is indeed optimal for the firm to enter. Similarly, suppose $\varphi > \varphi^{CL}$ and the firm has chosen to produce a product of quality q^{CL}. Again, inequality (17) implies that at the time of the entry decision, the fixed cost facing the firm is above the threshold for entry, $\varphi > \varphi^M(q^{CL})$ so that staying out is optimal for the firm. Thus, the cutoff rule used by the firm in our two-stage game – i.e. if $\varphi < \varphi^{CL}$ do R&D that yields quality q^* and enter in the first period; otherwise, do R&D that delivers quality q^{CL} and wait for CL in the second period – is subgame perfect.

Proof of Proposition 1

It is straightforward to show that

$$q^I = \frac{(1 + \Omega)(n\mu + 1 - \gamma)}{4t} \tag{18}$$

where

$$q^* = q^I\big|_{\gamma=0} \tag{19}$$

Observe that $\partial q^I/\partial\gamma < 0$. It follows then that $q^* > q^I$ for all $\gamma \in [0, 1)$.

Next, note that

$$\varphi^* = \frac{(1 + \Omega)^2(2n\mu + 1)}{32t} \tag{20}$$

It is obvious that φ^* is increasing in n and μ.

We have

$$\varphi^I = \frac{(1 + \Omega)^2(1 - \gamma)(2n\mu + 1 - \gamma)}{32t} \tag{21}$$

so that

$$\frac{\partial\varphi^I}{\partial\gamma} = -\frac{(1 + \Omega)^2(n\mu + 1 - \gamma)}{16t} < 0$$

Proof of Lemma 1

Direct calculations show that

$$w_S^* - w_S^L = \frac{(1+\Omega)^2(n\mu + 1 - 4\gamma n\mu)}{32t}$$

from which it immediately follows that

$$w_S^* \geq w_S^L \text{ iff } \gamma \leq \gamma^* \equiv \frac{n\mu + 1}{4n\mu} \tag{22}$$

It is obvious that γ^* is decreasing in n and μ.

Proof of Proposition 3

(i) We have

$$w^* - w^I = \frac{(1+\Omega)^2\gamma^2}{16t} \geq 0 \tag{23}$$

(ii) Direct calculations show that

$$\varphi^w = w^* - w^L = \frac{(1+\Omega)^2(2n\mu(1-\gamma)+1)}{16t} \tag{24}$$

from which it directly follows that $\partial\varphi^w/\partial\gamma < 0$; $\partial\varphi^w/\partial\mu < 0$; and $\partial\varphi^w/\partial n < 0$. Also, we have

$$\varphi^w - \varphi^* = \frac{(1+\Omega)^2}{32}\frac{2n\mu + 1 - 4n\gamma\mu}{t}$$

From this expression, it immediately follows that $\varphi^w \geq \varphi^*$ iff $\gamma \geq \gamma^w$ where

$$\gamma^w = \frac{2n\mu + 1}{4n\mu} \tag{25}$$

Note that $\partial\gamma^w/\partial\mu < 0$ and $\partial\gamma^w/\partial n < 0$.

Proof of Proposition 4

(i) Evaluating (11) yields $\varphi^{CL}(\alpha, \gamma^R) = \frac{A^2 + A2\mu n(1+\Omega)}{32t}$, where $A = 1 + \Omega - (2-\alpha)\alpha\gamma^R\Omega$ is decreasing in α and γ^R. Using (20),

$$\varphi^* - \varphi^{CL} = \frac{(2-\alpha)\alpha\gamma^R\Omega((2-\alpha)\alpha\gamma^R\Omega + 2\mu n(1+\Omega))}{32t} \geq 0 \tag{26}$$

The above expression is strictly positive for $\gamma^R > 0$ and $\alpha > 0$, and is increasing in γ^R and α.

Proof of Lemma 2

Evaluating (8) using (10) yields the equilibrium payoff to the South under CL:

$$W_S^{CL}(\alpha, \gamma^R) = \frac{(2-\alpha)^2 \Omega \gamma^R \left((1+\Omega)\mu n + \Omega \alpha \gamma^R (2-\alpha)\right)}{32t} \tag{27}$$

Differentiating with respect to γ^R yields

$$\frac{\partial W_S^{CL}}{\partial \gamma^R} = \frac{(2-\alpha)^2 \Omega \left[(1+\Omega)\mu n + (5\alpha - 2(2-\alpha))\alpha \Omega \gamma^R\right]}{32t} > 0, \tag{28}$$

so W_S^{CL} is convex and increasing in γ^R.

Differentiating $W_S^{CL}(\alpha, \gamma^R)$ with respect to α yields

$$\frac{\partial W_S^{CL}}{\partial \alpha} = \frac{-(2-\alpha)\Omega \gamma^R \left[(1+\Omega)\mu n + (5\alpha - 2(1+\alpha^2))\Omega \gamma^R\right]}{16t} \tag{29}$$

Since $5\alpha - 2(1+\alpha^2)$ is increasing in α, a sufficient condition for $\frac{\partial W_S^{CL}}{\partial \alpha} < 0$ is that the bracketed expression be positive at $\alpha = 0$. Evaluating at $\alpha = 0$ yields the condition in the Lemma.

Evaluating the difference between Southern welfare under entry with that under CL at $\alpha = 0$, we have

$$W_S^* - W_S^{CL}(0, \gamma^R) = \frac{(1+\mu n)(1+\Omega)^2 - 4\mu n \gamma^R \Omega (1+\Omega)}{32t} \tag{30}$$

The welfare gain from entry over CL is decreasing in γ^R, so solving for the value of γ^R such that (30) equals zero yields the threshold γ_m^R. Since W_S^{CL} is continuous in α, CL is preferable to entry for α sufficiently close to 0 if $\gamma^R > \gamma_m^R$.

Proof of Lemma 3

Solving (13) yields

$$\varphi_W^{CL}(\alpha, \gamma^R) = \frac{(2\mu n + 1)(1+\Omega)^2 - \alpha((2-\alpha)\Omega\gamma^R)^2 - (2+\alpha-\alpha^2)\Omega(1+\Omega)\mu n \gamma^R)}{16t} \tag{31}$$

Evaluating this expression yields $\varphi_W^{CL}(\alpha,0) = \frac{(1+\Omega)^2(1+2\mu n)}{16t} = 2\varphi^*$ and $\frac{\partial \varphi_W^{CL}}{\partial \gamma^R} < 0$. We also have

$$\varphi_W^{CL}(\alpha,\gamma^R) - \varphi^{CL}(\alpha,\gamma^R) = \frac{(2\mu n+1)(1+\Omega)^2 - 2(2-\alpha)\Omega(1+\Omega)\mu n\gamma^R - \alpha(2-\alpha)^3(\Omega\gamma^R)^2}{32t} \tag{32}$$

Evaluating the above difference in the two cost thresholds at $\alpha = 1$ and $\gamma^R = 1$ yields $\varphi_W^{CL}(1,1) - \varphi^{CL}(1,1) = \frac{2\mu n(1+\Omega)+1+2\Omega}{32t} > 0$.

Proof of Lemma 4

(i) We have

$$\varphi^G = \frac{\mu^2(2n^2+2n+1+n\mu)(2n+1-n\mu)(1+\Omega)^2}{32t(n+\mu)^2} \tag{33}$$

from which it directly follows that $\varphi^G \geq 0$ iff $\mu \leq \mu^* = 2 + 1/n$.

(ii) We have

$$\partial\varphi^G/\partial\mu\Big|_{\mu=1} = \frac{(1+\Omega)^2}{16}\frac{n}{t} > 0$$

and

$$\partial\varphi^G/\partial\mu\Big|_{\mu=\mu^*} = -\frac{n(1+\Omega)^2}{16}\frac{(2n+1)^2}{t(n+1)^2} < 0$$

(iii) We have

$$\varphi^{IG} = \frac{(1+\Omega)^2\mu^2[(2n^2+2n+1)(1-\gamma)+n\mu)][(2n+1)(1-\gamma)-n\mu]}{32t(n(1-\gamma)+\mu)^2} \tag{34}$$

Observe that $\varphi^{IG} \geq 0$ iff $(2n+1)(1-\gamma) - n\mu \geq 0$ or $\mu \leq (1-\gamma)\mu^*$. Also note that

$$\frac{\partial\varphi^{IG}}{\partial\gamma} = -\frac{(1+\Omega)^2\mu^3(n+1)^4(1-\gamma)}{16t(n(1-\gamma)+\mu)^3} \leq 0$$

Proof of Proposition 5

(i) We have

$$q^{IG} = \frac{(1-\gamma)(1+\Omega)\mu(n+1)^2}{4t(n(1-\gamma)+\mu)} \tag{35}$$

where

$$q^G = q^{IG}\big|_{\gamma=0} = \frac{(1+\Omega)\mu(n+1)^2}{4t(n+\mu)} \tag{36}$$

We have

$$\partial q^I/\partial\gamma = -\frac{(1+\Omega)\mu^2(n+1)^2}{4t(n(1-\gamma)+\mu)^2} < 0$$

It follows then that $q^G > q^{IG}$ for all $\gamma \in [0,1)$.

(ii) We have

$$\varphi^I - \varphi^{IG} = \frac{(1+\Omega)^2 n^2(\gamma+\mu-1)^2(2\mu n^2(1-\gamma)+n(\mu+1-\gamma)^2-\gamma\mu)}{32t(n(1-\gamma)+\mu)^2} \geq 0$$

This implies $\varphi^* - \varphi^G \geq 0$. Similarly,

$$q^I - q^{IG} = \frac{(1+\Omega)n(\gamma+\mu-1)^2}{4t(n(1-\gamma)+\mu)} \geq 0,$$

which implies $q^* - q^G \geq 0$.

(iii) Using the definitions of φ^I and φ^G we have:

$$\varphi^I \geq \varphi^G \text{ iff } \gamma \leq \ \gamma^f = \frac{n(\mu-1)^2}{n+\mu} \tag{37}$$

using which the stated properties of γ^f can be established immediately.

(iv) If follows from (18) and (36) that $q^I - q^G$ is decreasing in γ, and is equal to 0 at γ^f.

Proof of Lemma 4

(i) $w_S^{IG} > w_S^L$ follows immediately from the fact that $q^{IG} \geq q^N$ and that consumers have an additional option to purchased the imitated product when the firm enters without patent protection. To establish that the South's payoff under entry without patent protection exceeds that from entry with patent protection, we can write the difference in payoffs as:

$$w_S^{IG} - w_S^G = A(\mu,n,\gamma)B(\mu,n,\gamma), \tag{38}$$

where

$$A(\mu,n,\gamma) = \frac{\gamma\left(\Gamma\mu(1+n)\right)^2}{32(\mu+n)^3 t(\mu+n(1-\gamma))^3} \geq 0$$

and

$$\begin{aligned} B(\mu,n,\gamma) &= (1-\gamma)^2(\mu n^5+(10\mu-4)n^4)-(2(2-\gamma)\mu^4+(5-13\gamma+4\gamma^2)\mu^3)n \\ &\quad -(3(1-\gamma)\mu^3+-12(2-3\gamma+\gamma^2)\mu^2+7(1-\gamma)\mu)n^3 \\ &\quad -((2-\gamma)\mu^4-2(9-9\gamma+2\gamma^2)\mu^3+4\gamma(3-2\gamma)\mu^2)n^2 \end{aligned}$$

The differential (38) is non-negative if $B(m,n,\gamma)$ is non-negative on the region of the parameter space where the firm would enter without patent protection, which is the set $F=\{(\mu,n,\gamma)|\mu\in[1,\mu^*(1-\gamma)],n\geq 1,\gamma\in[0,1-\frac{1}{\mu^*}]\}$.

The proof (available online) shows that for given (m,n),the function B is (a) strictly convex in γ for $,\gamma\in[0,1-\frac{1}{\mu^*}]$, (b) positive and decreasing in γ at $\gamma=0$, and (c) positive and decreasing in γ at $\gamma=\frac{1}{\mu^*}$. As a result, $B>0$ for $\gamma\in[0,1-\frac{1}{\mu^*}]\}$.

(ii) The critical value of γ at which welfare under patented entry is equal to that under imitation without entry is the solution to $w_S^G=w_S^L$,which yields

$$\gamma^G\equiv\ \frac{1}{4}\frac{(n+1)^2[n(\mu-2)-\mu]^2}{n(n+\mu)^3}. \tag{39}$$

The fact that γ^G is decreasing in n and μ follows by differentiation of (39).

(iii) From the definitions of the two thresholds, we have $\gamma^*-\gamma^G=(\mu-1)[\mu^2(\mu+1)+(5\mu+1)\mu n+(7\mu-1)n^2+(3-\mu)\mu n^3]/(4\mu(\mu+n)^3)$, which must be non-negative for $\mu\leq\mu^*\leq 3$.

(iv) With patent protection, the quality of the good is higher under national exhaustion,

$$q^*-q^G=\frac{(1+\Omega)n(\mu-1)^2}{4t(n+\mu)}\geq 0$$

and the price per unit quality in the South is lower

$$\frac{p^*}{q^*}=\frac{1}{2}\leq\frac{p^G}{q^G}=\frac{\mu(n+1)}{2(\mu+n)}$$

Therefore, welfare in the South is higher with patent protection when the North follows a policy of national exhaustion.

Proof of Proposition 7

(i) We have

$$w^* - w^I = \frac{(1+\Omega)^2\gamma^2}{16t} \geq 0$$

Furthermore, we have

$$\frac{\partial w^G}{\partial \gamma} = -\frac{(1+\Omega)^2(n+1)^2\mu^2 F(m,n,\gamma)}{8t(n(1-\gamma)+m)^3}$$

where

$$F(m,n,\gamma) = \gamma(2mn+m-n) + n(m-1)^2$$

Observe that $\frac{\partial w^G}{\partial \gamma} \leq 0$ iff $F(m,n,\gamma) \geq 0$.

Next, note that

$$\frac{\partial F(.)}{\partial \gamma} = (2m-1)n + m > 0$$

and that $F(m,n,\gamma)|_{\gamma=0} = n(m-1)^2 > 0$. This means that $F(m,n,\gamma) > 0$ for all γ. Thus, we must have

$$\frac{\partial w^G}{\partial \gamma} < 0$$

which implies that $w^G > w^{IG}$ since $w^G = w^{IG}\big|_{\gamma=0}$.

(ii) We can show that

$$w^* - w^G = \frac{(1+\Omega)^2 n^2(\mu-1)^4}{16t(n+\mu)^2} \geq 0 \tag{40}$$

Next note that

$$w^I - w^{IG} = \frac{(1+\Omega)^2 n^2(\mu+\gamma-1)^2 G(m,n,\gamma)}{16t(n(1-\gamma)+\mu)^2}$$

where

$$G(m,n,\gamma) = 2m\gamma(n+1) + n(m-1)^2 - \gamma^2 n$$

Observe that $w^I - w^{IG} \geq 0$ iff $G(m,n,\gamma) \geq 0$. Next, note that

$$\frac{\partial G(.)}{\partial \gamma} = 2n(m-\gamma) + 2m > 0$$

and that $G(m,n,\gamma)|_{\gamma=0} = n(m-1)^2 > 0$. This means that $G(m,n,\gamma) > 0$ for all γ. Thus, we must have

$$w^I \geq w^{IG}$$

(iii) Taking the difference of (23) and (40) yields

$$w^I - w^G = \frac{n^2(\mu-1)^4 - (\mu+n)^2 \gamma^2}{16(\mu+n)^2 t},$$

which is decreasing and strictly concave in γ, positive at $\gamma = 0$, and equal to 0 at $\gamma = \gamma^f$.

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