ESSAYS ON INTELLECTUAL PROPERTY PROTECTION AND PRODUCT STANDARDS IN THE GLOBAL ECONOMY

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To my grandmother Keyun Sun

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CHAPTER I

IS THERE A CASE FOR NON-DISCRIMINATION IN THE INTERNATIONAL PROTECTION OF INTELLECTUAL PROPERTY?

Introduction

The agreement on the Trade Related Aspects of Intellectual Property (TRIPS) was easily the most controversial outcome of the Uruguay round of multilateral trade negotiations (1986-95). Due to this far-reaching agreement, all WTO members - regardless of their economic status and/or innovative capabilities - are obligated to adopt certain minimum standards of protection for all major types of intellectual property such as copyrights, patents, and trademarks.[1] For example, TRIPS mandates that the duration of patent protection granted by WTO members must be at least 20 years. In addition to such harmonization, an equally important aspect of TRIPS is that it requires intellectual property policies of WTO members to abide by certain fundamental principles, such as *non-discrimination*.[2] The non-discrimination requirement in TRIPS manifests itself in two forms: the principle of national treatment (NT) that forbids discrimination between domestic and foreign firms/nationals with regard to the protection of intellectual property and the most favored nation (MFN) clause that prohibits discrimination between foreign nationals originating from different countries.[3]

[1] See Maskus (2000) for a comprehensive discussion of the economics of intellectual property rights protection in the global economy and the international externalities that a multilateral agreement such as TRIPS attempts to internalize.

[2] To be sure, the principle of non-discrimination predates TRIPS but historical international intellectual property treaties (such as the Paris and Berne conventions) were not backed by a powerful dispute settlement procedure like the one that is available to WTO members today.

[3] The NT requirement is specified in Article 3 of TRIPS which says that "each Member shall accord to the nationals of other Members treatment no less favorable than that it accords to its own nationals with regard

Our primary objective in this chapter is to evaluate the case for NT in the protection of intellectual property. At first glance, the inclusion of NT in TRIPS seems hardly worthy of discussion; after all, NT is a central principle of all other multilateral agreements of the WTO. So why should TRIPS be any different? Nevertheless, we show in this work that the desirable properties of NT in the context of trade in goods and services do not automatically carry over to the domain of intellectual property. To investigate the economic effects of requiring countries to follow NT in the protection of intellectual property, we utilize an adapted version of the Grossman and Lai (2004) model of international patent protection and innovation.[4] Our conceptual approach is straightforward and informative: we simply compare equilibrium outcomes and welfare in the absence of NT with those obtained in its presence. While our model focuses on patent policy, the insights it yields should also be relevant for other instruments of intellectual property protection such as copyrights and trademarks.

In accordance with Article 3 of TRIPS, Grossman and Lai (2004) focus on non-discriminatory patent policies and show two major results. First, countries tend to offer too little patent protection in an open economy setting. Second, the harmonization of patent protection across countries is neither necessary nor sufficient for achieving efficiency since it does not address the underlying problem of under-protection. In the present chapter, we build on their insights by examining the implications of the non-discrimination constraint on national patent policies imposed by NT thereby adding to our understanding of the economic consequences of TRIPS.[5]

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to the protection of intellectual property." MFN is contained in Article 4 which says that "any advantage, favour, privilege or immunity granted by a Member to the nationals of any other country shall be accorded immediately and unconditionally to the nationals of all other Members." These twin principles of non-discrimination are found in some shape or form in every multilateral trade agreement of the WTO.

[4] Their work builds on Nordhaus (1969) who first addressed the question of optimal patent policy in a closed economy.

[5] In Grossman and Lai (2004) as well as in our model, all innovation is conducted by the private sector. See Scotchmer (2004) for an analysis of intellectual property treaties in a model where R&D is conducted by both the private and the public sector.

Issues surrounding the international protection of intellectual property have often been examined in the literature through the lens of North-South models of international trade and endogenous innovation.[6] While these models provide important insights, they do not derive optimal patent policies: instead they either consider the effects of marginal changes in an exogenously given rate of Southern imitation or examine policies that, on the margin, lower incentives for (endogenous) imitation. Thus, by design, they do not address the implications of core TRIPS principles such as NT for equilibrium patent policies and welfare.

While little is known about how NT operates in the context of intellectual property, the effects of non-discrimination in the use of domestic tax instruments such as sales taxes are fairly well-understood in the literature. Horn (2006) makes the important point that while NT with respect to internal taxes and other such domestic instruments can prevent countries from pursuing legitimate objectives, trade agreements that do not contain such a clause can be easily subverted by national governments who have an incentive to favor domestic firms over foreign ones. Thus, according to this view, NT serves as a line of defense against beggar-thy-neighbor tendencies of individual nations.[7]

Horn's (2006) basic query is no less relevant in the realm of intellectual property: when and why does it make sense to constrain national policies in the manner specified by NT? To be sure, incentives to pursue beggar-thy-neighbor policies are pervasive in the context of intellectual property.[8] After all, a major reason the US and, to a lesser extent, the EU pushed hard for a

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[6] Much of this literature follows Grossman and Helpman (1991) who provide a comprehensive and unified treatment of the two leading approaches - i.e. the variety expansion model and the quality ladders model. Further building on this work, Helpman (1993) analyzes how a decline in Southern imitation affects global welfare both in the steady state and during the transition path.

[7] Saggi and Sara (2008) take Horn's analysis further by studying the role of NT when countries are heterogeneous in market size and/or the quality of goods produced and the mutual agreement over NT is endogenously determined. Horn, Maggi, and Staiger (2010) examine the role of NT from the perspective of incomplete contracts.

[8] Lerner (2002) notes that prior to the emergence of major international agreements on intellectual property, discrimination against foreign patent applications was quite common during the mid-19th century across

multilateral agreement on intellectual property during the Uruguay round negotiations was that major developing economies such as Brazil, China, and India were offering little or no intellectual property protection to their firms, a policy environment that fostered widespread imitation and reverse-engineering of Western technologies by local firms in such countries. But does the presence of such beggar-thy-neighbor incentives necessarily generate a rationale for non-discrimination in the protection of intellectual property? Our analysis below shows that it does *not*.

Our baseline model considers a world of two countries and analyzes the effects of NT when trade between them is not subject to any frictions or barriers. Somewhat expectedly, we find that in the absence of a NT requirement, each country finds it optimal to grant weaker protection to foreign firms relative to domestic ones. This discrimination arises because governments do not care about the effects of their policies on the profits earned by foreign firms. However, we show that discrimination against foreign firms on the part of both countries does not have any welfare consequences. To understand the intuition for this surprising result, first note that a firm's incentive for innovation depends upon the level of *effective global protection* available to it under alternative policy regimes, where the level of effective global protection is defined as a weighted sum of the patent protection granted by each country, with a country's weight being equal to its market size. The reason NT fails to generate any welfare improvement under free trade in our model is that what each firm gains in terms of higher patent protection abroad if discrimination is replaced by NT is exactly offset by what it loses at home so that the effective global protection facing firms remains unchanged.

In Section 4, we show that this invariance of innovation incentives and welfare to NT does not obtain in the presence of trade frictions. When international trade is subject to frictions - such

the world. Discriminatory measures used against foreigners included shorter duration of patents, higher fees, shorter extensions, and premature patent expirations. See also Goldstein (2001).

as transportation and/or communication costs - *NT lowers innovation incentives by reducing the effective global protection enjoyed by firms*. The intuition for this result is as follows. While trade frictions lower export profits and make foreign patent protection relatively less important for incentivizing innovation in each country, NT actually calls for each country to provide more of such protection rather than less. From the viewpoint of firms, in the presence of trade frictions favorable discrimination granted at home in the absence of NT more than offsets the negative incentive effects of unfavorable discrimination suffered abroad. Consumer welfare considerations reinforce the argument in favor of discrimination: due to trade frictions, the consumer surplus obtained by each country from foreign innovations is smaller than that obtained from domestic ones.[9] Indeed, we show that for any positive level of trade frictions, it is actually *jointly optimal* to have each country offer a lower level of patent protection to foreign firms relative to domestic ones, a policy configuration precluded by NT.

We also find that a reduction in trade frictions reduces each country's incentive to discriminate against foreigners since domestic consumers derive greater benefits from foreign innovations when trade is freer. This result points to a potential synergy between the acceptance of international disciplines on intellectual property and the degree of trade liberalization in the global economy. It is worth noting here that TRIPS agreement followed almost five decades of multilateral trade liberalization achieved over eight separate rounds of trade negotiations conducted under the auspices of the General Agreement on Tariffs and Trade (GATT). As is well known, pre-TRIPS rounds of GATT negotiations were successful in lowering the average global tariff on industrial goods from over 40% to under 4% (Bagwell and Staiger, 2002). Our analysis suggests that such multilateral trade liberalization during GATT years may have helped pave the

[9] The empirical link between the protection of intellectual property and the volume and pattern of international trade was first established by Maskus and Penubarti (2001). See Maskus and Yang (2013) for a more recent investigation of related issues.

way for TRIPS by making international disciplines on intellectual property more palatable to countries.

Our analysis also shows that differences in market size across countries affects incentives for discrimination in somewhat surprising ways. An important result in this regard is that if the market size of a country increases relative to the other, its incentive to discriminate against foreign firms *declines* while its level of patent protection increases. Intuitively, as a country's market size increases, its weight in determining the level of effective global protection increases as does the benefit it enjoys from foreign innovations. Indeed, if one country becomes arbitrarily large relative to the other, its incentives for patent protection essentially converge to those of a closed economy since foreign consumers become a negligible part of the calculus determining optimal patent policies.

Our result that a larger market has a weaker incentive to discriminate against foreign nationals seems to accord quite well with the fact that, during the Uruguay round, multilateral disciplines on intellectual property were pushed strongly by the two largest economies in the world (i.e. the US and the EU). From the perspective of these economies, TRIPS was primarily a means for getting developing countries to accept disciplines such as NT and MFN along with an increase in the degree of intellectual property protection that they had to extend to innovators. Furthermore, the model also clarifies that small developing countries not only have a weaker incentive to protect intellectual property because their own markets are too small to affect global innovation, they also lose more from having to follow the non-discrimination principle of NT. In this regard, it is noteworthy that in accordance with the general principle of special and differential treatment at the WTO, when TRIPS was ratified in 1995, developing countries were given an additional five years to achieve TRIPS compliance while the least-developed countries had until 2006 to do so, which was then further extended to 2013 in general, and to 2016 for the enforcement of pharmaceutical patents and laws applying to trade secrets.

Since an increase in market size asymmetry reduces the degree of discrimination in the larger market while it raises it in the smaller market, the average degree of discrimination declines in our model as markets become more unequal in size. For analogous reasons, the degree of effective global protection increases with market size asymmetry. Both of these factors imply that the global welfare loss generated by NT declines as markets become more asymmetric in size. This aspect of our model contrasts sharply with analyses of international trade agreements over conventional policy instruments such as tariffs and internal taxes since coordination over these traditional instruments as well as non-discrimination requirements with respect to their use generally become harder to implement as countries become less similar to each other - see, for example, Park (2000), Horn (2006), and Sara and Saggi (2008). In such models, as a country gets larger (i.e. has more market power) it tends to typically increase its tariff or tax but such a change immiserizes the other country. By contrast, in the present context, as the larger country increases its patent protection and lowers its discrimination against foreign firms, the smaller country's welfare increases as does its ability to *lower* its own protection since innovation incentives of firms depend only on the effective global protection that they receive, and not on its composition across countries. Thus, the type of international spillovers that an international agreement over intellectual property helps internalize are fundamentally different in character from those internalized by trade agreements over tariffs and other trade policies.[10] However, the different nature of spillovers in the context of patent protection is not the key driving force behind our surprising findings. Positive international spillovers created by patent protection only imply that there exists global under-protection of

[10] Bagwell and Staiger (1999 and 2002) argue that the GATT/WTO principles of MFN and reciprocity help achieve efficiency when international trade agreements are motivated by the presence of terms of trade externalities between countries.

patents. The key reason discriminatory patent policies dominate NT in the presence of trade frictions is that such frictions make each country's innovation relatively less responsive to foreign patent protection and by forcing each country to offer the same level of protection to domestic and foreign firms, *NT reduces the overall effectiveness of patent protection as an instrument for encouraging innovation*.

Our work echoes an emerging empirical literature that examines how effectively countries practice non-discriminatory IPR policies during the post-TRIPS era. Rather surprisingly, existing evidence suggests that even WTO members tend to discriminate against foreign innovators in practice. For example, Webster et. al. (2014) find that, all else equal, both European and Japanese patent offices are more likely to grant patents to domestic applicants relative to foreign ones. In similar vein, using data for Canada, Mai and Stoyanov (2014) find that Canadian firms are substantially more likely to win court cases when the dispute involves foreign firms as opposed to other Canadian firms. Consistent with these empirical findings, our work shows that countries indeed have incentives to use discriminatory patent policies in the absence of NT. More importantly, our work establishes that the use of such discriminatory patent policies can be welfare-enhancing relative to NT when international trade is subject to frictions.[11]

Baseline Model

To study NT in the international protection of intellectual property, we utilize the two-sector model of ongoing innovation developed by Grossman and Lai (2004). Before describing policy choices, we summarize the underlying economic environment. The world consists of two

[11] Lai (2007) also examines incentives for discriminatory patent policies in the absence of NT. However, he only considers a world of free trade and does not analyze how innovation and welfare differ across the two types of patent regimes (i.e. discrimination and NT).

countries: Home (H) and Foreign (F). In each country, a traditional sector produces a homogeneous good (which serves as the numeraire) while a modern sector produces a variety of differentiated goods. The representative consumer maximizes her lifetime utility

$$U(t) = \int_t^{\infty} e^{-\rho z} u(z) dz, \tag{I.1}$$

where ρ is the subjective discount rate and $u(\cdot)$ is the instantaneous utility function given by

$$u(z) = y(z) + \int_0^{n(z)} h(x(i,z)) di, \tag{I.2}$$

where $y(z)$ and $x(i,z)$ represent respectively the consumptions of the homogeneous good and the ith differentiated good at time z and $n(z)$ denotes the measure of differentiated goods that are still alive at time z. As in Grossman and Lai (2004), the function $h(\cdot)$ is assumed to satisfy the following regularity conditions (i) $h' > 0$ and $h' < 0$; (ii) every variety of differentiated goods is purchased in equilibrium (i.e. $h'(0) = \infty$); and (iii) optimal monopoly price of a typical differentiated good is finite (i.e. $-xh''/h' < 1$).

Given the preferences in Eqs. (I.1) and (I.2), the representative consumer first chooses the consumption of differentiated goods and then purchases the homogeneous good with the remainder of her income (which is assumed to be positive). There are M_i consumers in country i, where $i = H, F$, so that M_i measures country i's market size for differentiated goods.

There are two factors of production: capital (K) and labor (L). The amount of labor needed to produce one unit of the numeraire or that of a typical differentiated good in country i equals a_i. The total labor resource in country i, L_i, is assumed to be sufficiently large so that a positive amount of the numeraire good is produced in equilibrium in each country. Since the market for the numeraire good is assumed to be perfectly competitive, the wage rate in country i simply equals the marginal product of labor in the traditional sector: i.e. $w_i = 1/a_i$.

Prior to being produced, a differentiated good must be first invented by R&D which requires a combination of labor (L) and human capital (K). For simplicity, the research technology in country i is assumed to take the Cobb-Douglas form

$$\phi_i(z) = A[L_{Ii}(z)/a_i]^{\alpha}(K_i)^{1-\alpha}, \tag{I.3}$$

where $\phi_i(z)$ is the flow of innovations at time z, $A > 0$ is a constant, $L_{Ii}(z)$ is the labor allocated to innovation, a_i represents labor productivity, and K_i represents the fixed stock of human capital.[12]

A differentiated good has a finite life span (τ) during which it generates positive utility for consumers. At the end of its life span, a differentiated good produces zero utility for consumers and is therefore no longer produced. Given the technology specified for innovation in Eq. (I.3), during each time period z, $\phi_i(z) + \phi_j(z)$ newly invented goods enter country i's market while a measure of $\phi_i(z - \bar{\tau}) + \phi_j(z - \bar{\tau})$ existing goods die and exit the market. As a result, the growth in the measure of differentiated good at a given point in time is $\dot{n}_i = \phi_i(z) - \phi_i(z - \bar{\tau}) + \phi_j(z) - \phi_j(z - \bar{\tau})$. We focus on the steady state of the world economy where the measure of differentiated good in both markets remains constant over time, i.e. $\dot{n}_i = 0$.

After it has been invented, a differentiated good can be targeted by imitators. To protect differentiated goods from imitation, the government in each country grants patent rights to inventing firms. While the patent is in effect, the patenting firm charges its optimal monopoly price. Let π be the instantaneous per capita profit of a monopolist producing a patented differentiated

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[12] Our major results continue to hold when the production function for research has a CES form of the type $\phi_i(z) = A\{\alpha \left[\frac{L_{Ii}(z)}{a_i}\right]^{\beta} + (1-\alpha){K_i}^{\beta}\}^{1/\beta}$ with $\beta \leq 0$. As is well-known, the Cobb-Douglas production function obtains when $\beta = 0$. In the more general CES case, the assumption that $\beta \leq 0$ has two implications. First, the responsiveness of innovation to patent protection decreases as the latter rises. Second, patent protection policies of different countries are strategic substitutes for one another. We consider both these features to be quite realistic.

good so that $\pi = (p_m - a_i w_i)x_m$ where $a_i w_i = 1$. Let the index of patent protection be defined as

$$\Omega = (1 - e^{-\rho\tau})/\rho \,, \tag{I.4}$$

where ρ is the rate of time preference.[13] By design, the present value of expected per capita profits from patenting a newly invented good equals $\Omega\pi$. After the expiration of its patent, a differentiated good can be imitated free of cost. Imitation drives the price of the good to its competitive level so that the post-imitation profits of an innovator equal zero.

When analyzing optimal patent protection, Grossman and Lai (2004) focus on policies that abide by the non-discrimination principle of NT. As we noted earlier, Article 3 of TRIPS indeed requires countries to extend the same patent protection to all firms regardless of their national origin. One of our key objectives, however, is to examine the implications of the constraint that NT places on the patent policies of individual nations. To do so, we allow countries to *discriminate* between domestic and foreign firms by formulating and implementing patent protection policies that depend upon the national origin of firms. Accordingly, let country i extend patent protection Ω_{ii}^R to domestic firms and Ω_{ij}^R to foreign ones under regime R, where $R = D$ (discrimination) or NT and $\Omega_{ii} = \Omega_{ij}$ under NT.

Under regime R, a firm from country i that is successful in innovation earns total profit $\pi M_i \Omega_{ii}^R$ in the home market and $\pi M_j \Omega_{ji}^R$ overseas. The value of a typical innovating firm from country i therefore equals $v_i^R = (M_i \Omega_{ii}^R + M_j \Omega_{ji}^R)\pi$. Firms make decisions about their labor inputs

[13] In Grossman and Lai (2004) a patent is assumed to have two dimensions: length τ and the degree of enforcement ω where $\omega \in [0,1]$. But since ω plays no role in our analysis that is separate from patent length, we normalize ω to 1.

for R&D based on their expected total profits in the global market. The first-order condition determining demand for labor in country i under regime R where $R = D$ or NT is

$$v_i^R = \frac{F_i(L_{Ii}, K_i)}{L_{Ii}} = w_i.$$

Let C_m and C_c be the instantaneous (per capita) consumer surplus levels under monopoly and competition respectively, i.e. $C_m = h(x_m) - p_m x_m$ and $C_c = h(x_c) - p_c x_c$. Let $\bar{T} = (1 - e^{-\rho\bar{\tau}})/\rho$ be the present value of a 1 dollar flow over the entire useful life of a typical patented product. Then, the present value of surplus enjoyed by a typical consumer in country i over the entire life of a domestic differentiated product can be written as

$$C_m \Omega_{ii}^R + C_c(\bar{T} - \Omega_{ii}^R)$$

and that derived from a foreign differentiated good as

$$C_m \Omega_{ij}^R + C_c\big(\bar{T} - \Omega_{ij}^R\big).$$

Let Λ_0 denote the welfare derived from goods invented prior to the implementation of the patent policy. We may then write country i's national welfare under regime R where $R = D$ or NT, as

$$W_i^R = \Lambda_0 + \tfrac{w_i}{\rho}(L_i - L_{Ii}^R) + \tfrac{M_i \phi_i^R}{\rho}[C_m \Omega_{ii}^R + C_c(\bar{T} - \Omega_{ii}^R)] + \tfrac{M_i \phi_j^R}{\rho}\big[C_m \Omega_{ij}^R + C_c\big(\bar{T} - \Omega_{ij}^R\big)\big] + \tfrac{\pi \phi_i^R}{\rho}\big(M_i \Omega_{ii}^R + M_j \Omega_{ji}^R\big). \tag{I.5}$$

Similarly, let aggregate world welfare be defined simply as the sum of national welfare of each country

$$WW^R = \sum_i W_i^R. \tag{I.6}$$

We proceed by deriving equilibrium policies under discrimination and then impose the NT constraint on each country to see how it affects equilibrium policies and welfare. It is obvious that, in our model, the unilateral imposition of NT on a country can only make it worse off since even in the absence of NT it can always choose not to discriminate if it is welfare-maximizing to do so. But the more subtle issue, and the one that we address below, is how the simultaneous adoption of NT by both countries affects market outcomes and welfare.

Effects of NT in the Absence of Trade Frictions

We begin with the scenario where international trade is not subject to any frictions or barriers. An important implication of this assumption is that from a social welfare perspective, patent protection abroad is just as valuable to firms as patent protection in their domestic markets. In Section 4, we will show that the introduction of trade frictions breaks this equivalence which, in turn, has implications for equilibrium policies and welfare under the two types of patent regimes.

Discriminatory Patent Protection

In what follows, we derive the non-cooperative Nash equilibrium where each country simultaneously and independently determines its domestic and foreign patent protections, treating these protections in the other country as given. The objective of each government is to maximize national welfare. In particular, we assume interior solutions for both the NT and discrimination regimes, meaning that patent protections implemented by governments lie strictly between 0 and $\bar{T}$.

Let us first consider the case where countries are free to implement discriminatory patent policies. Following Grossman and Lai (2004), it turns out to be more intuitive to derive the best response curves of countries by equating each country's marginal benefit of patent protection to the associated marginal cost, taking the policies of the other country as given.

Consider the patent policies of country i. A marginal increase in its domestic protection Ω_{ii} raises the value of all domestic innovators by extending their monopoly tenures. This leads to more R&D investment and a greater variety of differentiated goods invented by such firms. Each new differentiated good generates a discounted per-consumer surplus of $\frac{1}{\rho}[C_m\Omega_{ii}^R + C_c(\bar{T} - \Omega_{ii}^R)]$ over its lifetime. It follows that country i's marginal benefit of domestic protection Ω_{ii} is

$$\frac{M_i}{\rho}\frac{\partial\phi_i^D}{\partial\Omega_{ii}}[C_m\Omega_{ii} + C_c(\bar{T} - \Omega_{ii})] \qquad \text{(I.7)}$$

where $\frac{\partial\phi_i^D}{\partial\Omega_{ii}}$ represents the response of local innovation to a small change in domestic patent protection.

In the Appendix, we show that

$$\frac{\partial\phi_i^D}{\partial\Omega_{ii}} = \frac{\gamma\phi_i^D M_i}{M_i\Omega_{ii} + M_j\Omega_{ji}}$$

where $\gamma = \frac{\alpha}{1-\alpha}$ represents the responsiveness of innovation to the value of an innovation in elasticity form. Plugging this expression into Eq. (I.7), one obtains the following expression for country i's marginal benefit of raising domestic protection

$$\frac{1}{\rho}\frac{\gamma\phi_i^D M_i^2}{M_i\Omega_{ii}+M_j\Omega_{ji}}[C_m\Omega_{ii}+C_c(\bar{T}-\Omega_{ii})]. \tag{I.8}$$

On the other hand, a marginal increase in domestic patent protection allows all existing innovators to charge monopoly prices for a longer time period. This causes a loss of consumer surplus, which is partially offset by the greater monopoly profits accruing to domestic innovators. Since ϕ_i^D new goods are invented per unit of time, country i's discounted marginal cost of domestic patent protection Ω_{ii} equals

$$\frac{M_i\phi_i^D(C_c-C_m-\pi)}{\rho}. \tag{I.9}$$

Equating the marginal benefit (I.8) of domestic patent protection Ω_{ii} to its marginal cost (I.9) and rearranging terms gives the first order condition determining Ω_{ii}[14]

$$C_c-C_m-\pi=\frac{\gamma M_i}{M_i\Omega_{ii}+M_j\Omega_{ji}}[(C_m-C_c)\Omega_{ii}+C_c\bar{T}]. \tag{I.10}$$

Eq. (I.10) describes country i's best response Ω_{ii} to the degree of patent protection that country j extends to country i (Ω_{ji}). It is easy to see from Eq. (I.10) that since $C_m<C_c$, Ω_{ii} is a decreasing function of Ω_{ji}: country i finds it optimal to lower the patent protection that it grants to local innovating firms if they receive more protection from country j. The intuition behind this is straightforward. An increase in Ω_{ji} increases the value of innovation made by country i's firms and thereby encourages them to invest more in R&D. However, due to diminishing returns in R&D, country i's marginal benefit of extending patent protection to its own firms is lower when Ω_{ji} is

[14] The second-order conditions can be shown to hold for both countries.

larger. As a result, Ω_{ii} has to fall in order to bring the marginal benefit back to the level of the marginal cost, namely, $C_c - C_m - \pi$. This implies that Ω_{ii} and Ω_{ji} are substitutable patent policies.

Observe from (I.10) that in the absence of NT, changing country j's domestic protection Ω_{jj} has no direct effect on country i's decision regarding its domestic protection Ω_{ii}. This is not the case under NT, since a country cannot choose its domestic and foreign patent policies separately.

Following the above logic, the best response curve for country i's foreign protection, Ω_{ij}, can be obtained as

$$C_c - C_m = \frac{\gamma M_i}{M_i \Omega_{ij} + M_j \Omega_{jj}} \left[(C_m - C_c)\Omega_{ij} + C_c \bar{T} \right]. \qquad \text{(I.11)}$$

It is important to note from this first order condition that country i's marginal cost of strengthening its foreign protection Ω_{ij} is not mitigated by π, because the monopoly profits generated by extending such patent protection accrue to foreign firms. It follows that a country's marginal cost of foreign patent protection is necessarily larger than that of domestic protection, which is the sole reason for why it has an incentive to implement discriminatory patent policies (as shown below). It is also clear from Eq. (I.11) that Ω_{jj} and Ω_{ij} are substitutes for each other: if country j increases its domestic patent protection Ω_{jj} then country i will find it optimal to lower its foreign protection Ω_{ij}.

We can show the following:[15]

[15]Proofs of all propositions that are not in the text are provided in the Appendix.

Proposition I.1. *In the absence of NT, each country's patent policy discriminates in favor of domestic firms:* $\Delta\Omega_i^* \equiv \Omega_{ii}^* - \Omega_{ij}^* > 0 \ for \ i,j = H,F$.

Proposition I.1 is similar in spirit to the findings of Horn (2006) and Saggi and Sara (2008) who focus on NT in the context of tax policies. In particular, they show that if NT is not binding then each country will tax foreign firms more severely because their profits do not count as part of national welfare. The logic here is the same: discriminatory patent policies arise naturally from the fact that countries care about profits accruing to domestic firms but not foreign ones. The key question that follows is whether eliminating such discrimination via NT brings about efficiency gains, which will be addressed in the analysis below.

Firms make R&D decisions based on the duration of patent protection in each country as well as its market size. The level of effective global protection received by firms from country i under discriminatory patent policies equals

$$P_i^* = M_i\Omega_{ii}^* + M_j\Omega_{ji}^*$$

where $i = H,F$. How does the level of effective global protection P_i^* vary with the national origin of firms? We can show the following:

Lemma I.1. *When countries implement discriminatory patent policies, the effective patent protection available to firms is equal across countries:* $P_i^* = P^*, i = H,F$.

Lemma I.1 implies that the incentives for innovation are the same for firms in either country. Intuitively, when country i protects its own firms more than country j protects its own firms - as would be true if the market size of country i is larger - then country i also protects foreign firms more than country j. Indeed, if country i is much larger than country j, it is possible for it to grant better protection to foreign firms than they receive from their own government even when country

i discriminates against foreign firms. Such international offsetting of patent protection equalizes incentives for innovation across countries.

Since

$$M_i \Omega_{ii}^* + M_j \Omega_{ji}^* = M_j \Omega_{jj}^* + M_j \Omega_{ij}^*,$$

it follows that

$$M_i \Delta\Omega_i^* = M_j \Delta\Omega_j^* \Leftrightarrow \Delta\Omega_i^* / \Delta\Omega_j^* = M_j / M_i$$

which we state as:

Proposition I.2. *The relative degree of discrimination ($\Delta\Omega_i^*/\Delta\Omega_j^*$) practiced by a country is inversely proportional to its relative market size (M_i/M_j), i=H, F.*

A country's weight in determining the level of effective global protection facing innovators increases with its own market size, as does the benefit it enjoys from foreign innovations. Therefore, the country with the larger market has a weaker incentive to discriminate against foreign nationals. As we noted in Section 1, in typical models of international trade agreements, as a country gets larger (i.e. has more market power) it tends to typically increase discrimination against foreign sellers. By contrast, the opposite happens here: if one country gets larger, the other country benefits from a reduction in patent discrimination faced by its firms abroad as well as from an increase in the degree of global patent protection (which leads to more innovation).

Patent Protection Under NT

Now suppose that each country must choose a non-discriminatory patent protection level that applies to all innovating firms, regardless of national origin. A detailed analysis of the NT regime is provided in Grossman and Lai (2004). Here, we focus on comparing outcomes under NT with those under discrimination. The best response curve for country i under NT can be written as follows

$$C_c - C_m - \mu_i = \frac{\gamma M_i}{P_i\left(\Omega_i, \Omega_j\right)}\left[(C_m - C_c)\Omega_i + C_c\bar{T}\right] \tag{I.12}$$

where $P_i\left(\Omega_i, \Omega_j\right) = M_i\Omega_i + M_j\Omega_j$ and $\mu_i = \frac{\phi_i^{NT}}{\phi_i^{NT}+\phi_j^{NT}}$ is the proportion of innovation that occurs in country i. Since the R&D production function is Cobb-Douglas in nature, it turns out that

$$\mu_i = \frac{K_i}{K_i + K_j} < 1,$$

i.e., μ_i is determined solely by the relative human capital stocks of countries and is unaffected by their patent policies.

Observe from Eqs. (I.10), (I.11), and (I.12) that country i's marginal cost of patent protection under NT is strictly in between the marginal costs of granting patent protection to domestic firms and foreign firms under discrimination:

$$C_c - C_m - \pi < C_c - C_m - \mu_i\pi < C_c - C_m.$$

This inequality follows from the fact that a country only cares about profits of local firms while NT forces it to treat all firms symmetrically. As a result, the profit of a typical innovating firm is discounted by μ_i, where which increases in its home country's human capital (K_i). This means that when a large share of the global innovation is carried out by local firms, the marginal cost of patent protection facing a country declines. In general, since NT forces countries into a scenario where the marginal cost of patent protection is a weighted average of the marginal costs associated with the discriminatory protection levels accorded to domestic and foreign firms, intuition suggests that NT might induce countries to select a level of protection that lies in the interval (Ω_{ii}, Ω_{ij}) - a conjecture we formally confirm below:

Proposition I.3. *(i) Under NT, each country selects a level of patent protection that exceeds the protection it grants to foreign firms under discrimination but falls short of that which it gives to its domestic firms: $\Omega_{ij}^* < \Omega_i^{NT} < \Omega_{ii}^*$ for i,j=H,F. If countries are symmetric then $2\Omega_i^{NT}=\Omega_{ii}^*+\Omega_{ij}^*$ for i,j=H,F.*

(ii) The effective global protection available to firms as well as global welfare under NT is the same as that under discrimination: $P^{NT} = M_i\Omega_i^{NT} + M_j\Omega_j^{NT} = P^*$.

To see more explicitly why welfare under NT is the same as that under discrimination, from Eq. (I.6) we can rewrite world welfare under regime R as

$$WW^R = \sum_i \Lambda_{i0} + \frac{1}{\rho}\sum_i w_i(L_i - L_{Ii}^R) + \frac{C_c\bar{T}}{\rho}\sum_i \phi_i^R M_i - \sum_i \phi_i^R P_i^R \left[\frac{C_c - C_m - \pi}{\rho}\right].$$

Observe from this that in the absence of NT, world welfare depends only upon the effective protection levels $P_i^R = M_i\Omega_{ii}^R + M_j\Omega_{ji}^R$ available to firms from both countries under regime R (where $R = NT$ or D) since P_i^R pins down all the other endogenous variables such as the allocation of resources to R&D (L_{Ii}^R) and the rates of innovation (ϕ_i^R). But from Proposition I.3 we already know that $P_i^* = P^{NT}$. As a result, world welfare is invariant to whether or not the underlying patent regime abides by NT.[16] Therefore, mandating NT is neither necessary nor sufficient for achieving efficiency provided international trade is not subject to any frictions.

The welfare neutrality of NT in our model is a rather novel finding in the context of the literature on NT. As we noted earlier, models in which NT applies to taxation typically find results favorable to NT. Further, even in the context of patent protection, in a two period model Bond (2005) has shown that, holding constant the level of patent protection given to domestic firms, eliminating discrimination against foreign firms raises global welfare. The driving force behind this result is as follows: since each country offers less patent protection to foreign firms, the switch from discrimination to NT holding domestic protections constant increases overall patent protection thereby alleviating the inefficiency caused by the under-protection of patents in the non-cooperative Nash equilibrium. But our analysis shows that since it is optimal for both countries to lower their domestic patent protection when each of them increases its patent protection towards foreign firms, NT by itself does not raise welfare since it leaves the effective protection levels facing innovating firms unchanged.

Grossman and Lai (2004) showed that the Nash equilibrium under NT gives rise to under-protection of intellectual property due to the positive international externalities generated by national patent protection policies. From the above analysis, it is not hard to see that the free rider problem that plagues the Nash equilibrium under NT continues to exist even when countries institute discriminatory patent policies. While there is under-protection of patent protection in our model as well, our analysis highlights that a move towards increasing patent protection to

[16] It is worth emphasizing that our model considers the simultaneous adoption of NT by both countries. One might also be interested in knowing the welfare consequences of a unilateral violation of NT by a single country, particularly since actual trade disputes among WTO members, particularly outside the realm of TRIPS, often involve a violation of the NT clause. We can show that given that country j abides by NT, a unilateral violation of NT by country i increases the effective global patent protection facing its firms while lowering that facing foreign firms, thereby increasing the rate of innovation in country i while lower it in country j.

foreigners driven by NT does not occur in isolation since each country simultaneously lowers the protection it grants to domestic firms. In fact, changes in patent protection granted to domestic firms as a result of NT exactly offset the increased protection granted to foreign firms so that NT does not alter the effective global protection available to firms. In this way, our model is able to separate the impact of NT on welfare from the increase in overall patent protection that results if NT is interpreted as a policy that brings up the patent protection granted to foreign nationals holding constant the protection granted to domestic firms.

NT in the Presence of Trade Frictions

Since the welfare neutrality of NT in the benchmark model is driven by the complete offsetting of patent protection across countries when discriminatory policies are eliminated via NT, it is worth asking whether such international offsetting also obtains in the presence of trade barriers and/or frictions. We now address this issue and show that when trade frictions exist, NT induces incomplete offsetting of patent protection across countries and actually ends up lowering the effective level of global patent protection.

Trade Frictions and Discrimination

Before deriving the effect of trade frictions on the incentives for discrimination in patent protection, we make three simple observations. First, trade frictions reduce the surplus consumers derive from foreign goods. Second, by making it costlier for firms to export, trade frictions lower export profits of firms (while having no effect on their domestic profits).[17] Third, trade frictions

[17] Trade frictions do not affect domestic profits since each firm selling a patented product is a monopoly in its local market.

do not affect the surplus consumers derive from goods whose patents have expired, regardless of where they were invented, since imitated goods are produced locally in each market so that there is no trade in such goods.

Denote the (inverse of) the degree of trade frictions between countries by $\theta,$ where $0 \leq \theta \leq 1$ and $\theta = 1$ represents free/costless trade while $\theta = 0$ indicates the complete absence of trade. In the presence of trade frictions, denote the consumer surplus derived from a patented imported good by θC_m while the export profits earned by a firm by $\theta\pi$. This parsimonious formulation of trade frictions (i.e. as being captured by a single parameter θ) is adopted purely for expositional simplicity.[18] Our results below hold as long as trade frictions lower the consumer surplus derived from foreign goods and the export profits of innovating firms, even if they do so in a non-linear fashion and/or at very different rates. All we require is that the due to the presence of trade frictions, the (per-capita) consumer surplus derived from imports be lower than that derived from locally produced goods and that the export profits (per-capita) of a firm be smaller than its domestic profits.

It is worth noting that in the context of patent protection, a world with prohibitive trade frictions ($\theta = 0$) is not the same as one in which the two economies are fully autarkic in the sense of being completely shut off from each other. In particular, if technology transfer does not depend on trade (i.e. if ideas can flow across national borders without trade in goods - see Rivera-Batiz and Romer, 1991), then a country can imitate foreign goods even in the complete absence of international trade (i.e. $\theta = 0$). As a result, one would expect a country to have less incentive to

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[18] If $h(x) = \varsigma^{1/\varepsilon}\frac{\varepsilon}{\varepsilon-1}x^{\frac{\varepsilon-1}{\varepsilon}}$ where $\varepsilon > 1$ and $\varsigma > 0$ and trade barriers are of the ice-berg type, then it is straightforward to show that consumer surplus from imports and overseas profits earned by firms equal θC_m and $\theta\pi$ respectively, where $\theta = (1+t)^{1-\varepsilon}$ is the inverse measure of trade frictions and $t > 0$ is the ice-berg type trade cost. Lai and Yan (2013) embed this formulation of trade costs in a model of patent protection with firm heterogeneity and FDI and show that trade liberalization helps alleviate the problem of under-protection in Nash equilibrium. Even in their model, trade frictions lower overseas profits and consumer surplus derived from imported goods. Thus, allowing for firm heterogeneity and FDI does not affect the main channel that renders foreign patent protection less effective than domestic protection in our model.

protect intellectual property when $\theta = 0$ relative to the autarky case. Indeed it is possible to show, for example, that patent protection under NT when $\theta = 0$ is lower in both countries relative to the autarkic level.

The key question we address below is: How do trade frictions affect incentives for discrimination? The overseas profit earned by a firm from country i equals $\theta M_i \Omega_{ji} \pi$ so that the corresponding firm value equals

$$v_i^D(\theta) = (M_i \Omega_{ii} + \theta M_j \Omega_{ji})\pi.$$

As is clear from above, due to the presence of trade frictions ($\theta < 1$) patent protection in export markets (i.e. Ω_{ji}) is relatively less valuable for firms than protection in their domestic markets (i.e. Ω_{ii}).

Now consider country i's decision regarding patent protection. The marginal cost of extending domestic protection remains unchanged relative to free trade since trade frictions do not affect the consumption of domestic goods and the profit firms make in their domestic markets. A country's marginal benefit of domestic protection, however, is different as trade frictions do affect the value of domestic firms by reducing their export profits and therefore the influence of foreign patent protection Ω_{ji} on their innovation incentives.

The marginal benefit of extending domestic protection Ω_{ii} equals

$$\frac{1}{\rho} \frac{\gamma \phi_i^D M_i^2}{M_i \Omega_{ii} + \theta M_j \Omega_{ji}} [(C_m - C_c)\Omega_{ii} + C_c \bar{T}].$$

Note that holding constant Ω_{ji} (i.e. the protection domestic firms get abroad), the marginal benefit of increasing Ω_{ii} (i.e. the protection to domestic firms) decreases with θ. All else equal, a reduction in trade frictions makes Ω_{ji} a more effective substitute for Ω_{ii} due to increased export profits of firms.

Country i's best response curve for domestic protection Ω_{ii} can be written as

$$C_c - C_m - \pi = \frac{\gamma M_i}{M_i \Omega_{ii} + \theta M_j \Omega_{ji}} [(C_m - C_c)\Omega_{ii} + C_c \bar{T}]. \qquad \text{(I.13)}$$

Regarding the protection extended to foreign firms, note that consumers in country i only derive a surplus of θC_m units from buying a patented foreign good. Since consumers always buy the good from domestic imitators once the patent expires, the corresponding surplus post imitation equals C_c. Thus, the marginal cost of raising foreign protection equals

$$\frac{M_i \phi_j^D (C_c - \theta C_m)}{\rho}.$$

As is clear, holding constant the rate of innovation, the marginal cost of protecting foreign firms increases with trade frictions.

Country i's marginal benefit of protecting foreign firms can be written as

$$\frac{1}{\rho} \frac{\gamma \theta \phi_j^D M_i^2}{\theta M_i \Omega_{ij} + M_j \Omega_{jj}} [(\theta C_m - C_c)\Omega_{ij} + C_c \bar{T}].$$

Note that holding constant Ω_{jj} (i.e. the protection foreign firms get from their own government), the marginal benefit of increasing Ω_{ij} (i.e. the protection given by country i to foreign firms) increases as trade frictions fall.

The best response curve for Ω_{ij} is given by

$$C_c - \theta C_m = \frac{\gamma \theta M_i}{\theta M_i \Omega_{ij} + M_j \Omega_{jj}} \left[(\theta C_m - C_c)\Omega_{ij} + C_c \bar{T}\right]. \qquad \text{(I.14)}$$

Using the above best response curves, we can show the following:

Proposition I.4. *As trade frictions between countries fall (i.e. θ increases), each country increases the degree of patent protection granted to foreign firms $\Omega_{ij}(\theta)$ while decreasing that granted to domestic firms $\Omega_{ii}(\theta)$. Furthermore, a reduction in trade frictions increase the degree of effective global patent protection in both countries, i.e.,* $\frac{\partial P_i^*(\theta)}{\partial \theta} > 0$ *where* $P_i^*(\theta) = M_i\Omega_{ii}^*(\theta) + \theta M_j \Omega_{ji}^*(\theta)$.

We now compare NT and discrimination in the presence of trade frictions. As before, a typical firm's value under the NT regime equals

$$v_i^{NT}(\theta) = (M_i\Omega_i + \theta M_j\Omega_j)\pi.$$

It is important to note that due to the existence of trade frictions, v_i will in general be different from v_j even under NT, which further implies that firms in different countries may face different levels of effective patent protection.[19]

Under NT, the cost and benefit of a marginal change in patent protection depend upon the level of trade frictions. As the derivation is similar to before, we simply report country i's best response curve for Ω_i without presenting the relevant details:

$$C_c - (\mu_i + \theta\mu_j)C_m - \mu_j\pi = \frac{\gamma M_i\mu_i}{M_i\Omega_i + \theta M_j\Omega_j}[(C_m - C_c)\Omega_i + C_c\bar{T}] + \frac{\gamma\theta M_i\mu_j}{\theta M_i\Omega_i + M_j\Omega_j}[(\theta C_m - C_c)\Omega_i + C_c\bar{T}]. \tag{I.15}$$

We next investigate the efficiency impact of NT. To facilitate this analysis, we assume that countries are symmetric in all respects ($M_i = M_j = M$, $K_i = K_j = K$ and $a_i = a_j = a$). This is a

[19] Recall that when trade is free, all firms receive the same effective level of global patent protection under NT.

useful simplification for three reasons. First, it helps isolate the effect of trade frictions on the international patent regimes. Second, the issue of non-discrimination is as relevant, if not more, in a North-North type setting of relatively similar countries as it is in a North-South setting where there are significant differences across countries with respect to market size and human capital. Third, although analytical solutions under NT are difficult to calculate when countries are asymmetric, we analyze the social planner's problem and show that the key argument in favor of discrimination does not rest on the assumption of symmetry. Finally, in Section 5, we use numerical examples to study Nash equilibrium outcomes under asymmetry and show that our result that the equilibrium under discrimination is more desirable does not require symmetry.

Effective Patent Protection

Denote the symmetric Nash equilibrium level of patent protection under NT by $\Omega^*(\theta)$. Under discrimination, let $\Omega_d^*(\theta)$ be the patent protection granted by each country to domestic firms and $\Omega_f^*(\theta)$ that given to foreign firms. We can then show the following:

Proposition I.5. *Suppose countries are symmetric and there exist trade frictions between them (i.e.* $0 \leq \theta < 1$*). Then the following hold:*

(i) The degree of effective global protection received by firms under NT is lower than that under discrimination:

$$P^{NT}(\theta) = M(1+\theta)\Omega^*(\theta) < P^*(\theta) = M(\Omega_d^*(\theta) + \theta\Omega_f^*(\theta)).$$

(ii) The gap between the degree of effective patent protection under discrimination and NT decreases as trade frictions fall (i.e. $P^*(\theta) - P^{NT}(\theta)$ *declines with* θ*).*

When trade frictions exist, from the viewpoint of firms, protection abroad matters less for profitability than protection at home. As a result, trade frictions make foreign protection relatively less effective in inducing innovation in each country. However, NT forces each country to treat firms the same even though their innovation incentives respond more to domestic protection. As a result, NT blunts the effectiveness of patent protection for incentivizing innovation so that, in equilibrium, the effective degree of protection chosen by countries under NT ends up being lower. This result is important because it shows that while there is under-protection of intellectual property under both NT and discrimination in our model, this problem is more severe under NT. Thus, somewhat paradoxically, in the presence of trade frictions allowing countries to discriminate against foreign nationals with respect to patent protection actually leads to stronger innovation incentives in the global economy.

The intuition behind Proposition I.5 can also be understood by examining the marginal benefit and cost of strengthening patent protection. Suppose that $P^{NT}(\theta) \geq P^{*}(\theta)$. Then we can show that the marginal benefit of patent protection is larger under discrimination for both countries. Moreover, it exceeds the marginal cost of patent protection so that each country would want to increase its total patent protection. This implies that $P^{NT}(\theta) \geq P^{*}(\theta)$ cannot be sustained as a Nash equilibrium. As a result we must have $P^{*}(\theta) > P^{NT}(\theta)$.

We now consider the problem of choosing jointly (or socially) optimal domestic and foreign patent protection for country i's firms (i.e. Ω_{ii} and Ω_{ji}).

Social Welfare

The jointly optimal policies solve

$$\underset{\Omega_{ii},\Omega_{ji}}{Max}\, WW^D(\theta) \text{ where } WW^D(\theta) = \sum_i W_i^D\,(\theta).$$

To derive the first order conditions for this problem, it is useful to separately consider the social marginal benefits and costs of patent protection in each country. Following our previous discussion, the social marginal cost of domestic patent protection in country i (i.e. Ω_{ii}) equals

$$\frac{M_i\phi_i^D}{\rho}(C_c - C_m - \pi) \tag{I.16}$$

while the social marginal benefit is

$$\frac{\gamma}{\rho}\frac{M_i\phi_i^D}{P_i}\left[(C_m - C_c)\left(M_i\Omega_{ii} + M_j\Omega_{ji}\right) + \left(M_i + M_j\right)C_c\bar{T} - (1-\theta)C_m M_j\Omega_{ji}\right] \tag{I.17}$$

where $P_i = M_i\Omega_{ii} + \theta M_j\Omega_{ji}$.

Analogously, we can write the social marginal cost and benefit of Ω_{ji} as

$$\frac{M_j\phi_i^D}{\rho}(C_c - \theta C_m - \theta\pi) \tag{I.18}$$

and

$$\frac{\gamma}{\rho}\frac{M_j\phi_i^D\theta}{P_i}\left[(C_m - C_c)\left(M_i\Omega_{ii} + M_j\Omega_{ji}\right) + \left(M_i + M_j\right)C_c\bar{T} - (1-\theta)C_m M_j\Omega_{ji}\right]. \tag{I.19}$$

respectively. Observe from Eq. (I.18) that when calculating the social cost of extending patent protection to foreign firms in country i, the social planner accounts for the export profits earned by these firms, which is why the term $\theta\pi$ appears in Eq. (I.18) but not in Eq. (I.19).

We can write the first order conditions for Ω_{ii} and Ω_{ji} by equating the respective marginal cost of each type of protection to its marginal benefit. For Ω_{ii} we have

$$C_c - C_m - \pi = \frac{\gamma}{P_i}\left[(C_m - C_c)\left(M_i\Omega_{ii} + M_j\Omega_{ji}\right) + \left(M_i + M_j\right)C_c\bar{T} - (1 - \theta)C_m M_j \Omega_{ji}\right] \tag{I.20}$$

while for Ω_{ji} it is

$$C_c - C_m - \pi + \frac{1-\theta}{\theta}C_c = \frac{\gamma}{P_i}\left[(C_m - C_c)\left(M_i\Omega_{ii} + M_j\Omega_{ji}\right) + \left(M_i + M_j\right)C_c\bar{T} - (1 - \theta)C_m M_j \Omega_{ji}\right]. \tag{I.21}$$

Note that for all $\theta < 1$ the right-hand sides of both FOCs are the same, but the left-hand side of Eq. (I.21) is larger. This implies that, except for the extreme case where each country is at a corner solution, both FOCs cannot hold simultaneously. In particular, if $\Omega_{ii} < \bar{T}$ (i.e. Eq. (I.20) holds), then it must be that Eq. (I.21) does not hold so that $\Omega_{ji} = 0$.[20] We can now state:

Proposition I.6. *In the presence of trade frictions (i.e. $\theta < 1$), social optimality calls for each country to discriminate against foreign firms, i.e. $\Omega_{ij}^{w} < \Omega_{ii}^{w}$ for i,j=H,F.[21] Furthermore, if it is optimal to offer firms less protection in their domestic markets than the useful lifetime of products*

[20] The case where $\Omega_{ii} = \bar{T}$ is discussed in the Appendix.

[21] Since under this scheme of jointly optimal protection firms receive less protection abroad than they do at home, for any given innovation, foreign consumers begin to enjoy greater surplus (arising from local imitation) sooner than domestic ones. Indeed, if markets are unequal in size we can show that the degree of jointly optimal protection for firms in each country is increasing in the relative size of the other country's market: $\frac{\partial \Omega_{ii}^{w}}{\partial (M_j/M_i)} > 0$.

(i.e. $\Omega_{ii}^{w} < \bar{T}$), then it is optimal to give them no patent protection in their export markets (i.e. $\Omega_{ji}^{w} = 0$).[22]

In fact, for the case where markets are symmetric ($M_i = M_j = M$), we can use the first order condition in Eqs. (I.20) and (I.21) to write

$$\frac{\partial WW^D(\theta)}{\partial \Omega_{ii}} - \frac{1}{\theta}\frac{\partial WW^D(\theta)}{\partial \Omega_{ji}} = \frac{\phi_i^D M(1-\theta)C_c}{\theta} > 0 \; for \; all \; 0 < \theta < 1. \qquad \text{(I.22)}$$

This equation explicitly shows that the net marginal social benefit of extending domestic patent protection to firms is strictly higher than the marginal benefit of foreign patent protection so long as their exist trade frictions between countries. Observe that this holds even when the human capital stocks of the two countries are unequal.

The central point of Proposition I.6 is that trade frictions drive a wedge between the social value of domestic and foreign patent protections and social optimality calls for assigning a higher priority to domestic protection in each country. In other words, from the perspective of joint welfare, we care not only about the level of patent protection but also its composition across countries. In contrast, Grossman and Lai (2004) show that, under free trade, efficiency depends only on the level of total patent protection in the global economy and not on its composition across countries. In our model, this is easily verified by taking $\theta = 1$ in Eq. (I.22), so that domestic and foreign protections have equal net benefit. Proposition I.6 shows that, in the realm of patent protection, the presence of trade costs makes it socially optimal to discriminate in favor of local innovators in each country. It is noteworthy that such discrimination is desirable even when

[22] A corner solution for foreign protection might not arise if there exist enforcement costs that are increasing in the level of patent protection. Under such costly enforcement, foreign protection may be utilized even if domestic protection does not reach the boundary $\bar{T}$. Even so, the rationale for discrimination would remain since such enforcement costs would presumably also apply to foreign protection, and might even be higher than those for domestic protection.

beggar-thy-neighbor incentives are completely missing (as they are when countries maximize joint welfare).

Bond (2005) has shown that it can be socially optimal to globally discriminate in favor of firms from one country provided the elasticity of innovation in that country with respect to patent protection is relatively higher. Note, however, that Bond's analysis provides conditions under which it is socially optimal to provide favorable treatment to firms from one country in both countries whereas we consider whether it can ever be optimal to have firms from both countries enjoy favorable treatment in their respective domestic markets, an inquiry that is more in line with the actual spirit behind the national treatment clause. Furthermore, our analysis shows that the mere existence of trade barriers is sufficient to make such type of discrimination socially desirable; one does not need the elasticity of innovation with respect to patent protection to be unequal across countries, although that could be an additional contributing factor in our framework as well if our model were extended to incorporate it.

An interesting implication of the presence of trade frictions is that it socially desirable to discriminate more in favor of goods that are harder to trade. Specifically, in the extreme hypothetical case where all goods are non-tradable (i.e. $\theta = 1$), there would be no reason to protect foreign firms at all since their innovation incentives would be unresponsive to patent protection granted by countries other than their own. Indeed, if $\theta = 0$ protecting foreign innovations would only delay domestic consumption of newly invented foreign goods by the duration of the patent without affecting the foreign rate of innovation.

Comparing the first-order conditions determining the Nash equilibrium with those under joint welfare maximization, it is easy to see that the marginal cost of patent protection under the Nash equilibrium (as perceived by each country) is no less than the true social cost while the marginal benefit of such protection is smaller if effective protection under the two scenarios is the same (i.e.

if $M_i\Omega_{ii}^w = M_i\Omega_{ii}^* + \theta M_j\Omega_{ji}^*$). Thus, in an interior solution we must have $M_i\Omega_{ii}^* + \theta M_j\Omega_{ji}^* < M_i\Omega_{ii}^w$, i.e. there is under-protection in Nash equilibrium even in the presence of trade frictions, although the magnitude of the externality from foreign protection is reduced. Another interesting observation about discriminatory patent policies is that while coordination always leads to weaker foreign protection, in an asymmetric Nash equilibrium a country's foreign protection can actually exceed the foreign country's domestic protection. This is because the larger country tends to discriminate less while the smaller country tends to free ride more. Notably, even though the smaller country may be "sheltered" by the policies of the larger one, Proposition I.6 indicates that this is not justified from an efficiency point of view.

Further Analysis

In this section, we extend our model in two directions. First, we examine the effects of NT in a North-South setting where countries are asymmetric with respect to market size and/or their human capital stocks. Second, to capture the effects of trade policy variables, we consider a setting where the degree of trade openness facing firms depends upon their national origin - i.e. the access enjoyed by firms from country i to country j's market is not necessarily the same as that enjoyed by firms from country j to country i's market. The analysis of this scenario allows us to address how the incentives for discrimination vary with domestic and foreign trade policies.

NT in a North-South Setting

In this sub-section, we discuss how the relative performance of NT and discrimination depends upon the degree of asymmetry across countries. This issue is important because what made TRIPS negotiations especially difficult was the clash between the views of developing and developed countries regarding the desirability of multilateral disciplines in the area of intellectual property. Furthermore, since WTO members differ markedly in terms of their economic capabilities and factor endowments, it is important to know how NT operates in such an environment. Section 4 showed that, in the presence of trade frictions, if patent policies are chosen to maximize joint welfare then NT is less efficient than discrimination, regardless of the degree of asymmetry across countries. What is interesting to know is whether this is also true in a non-cooperative Nash equilibrium when countries are asymmetric in terms of economic fundamentals and there is no policy coordination between them.

In particular, it seems useful to consider a North-South scenario where the North's market as well as the stock of its human capital is larger than that of the South: i.e. $M_i > M_j$ and $K_i > K_i$.[23] The non-linearity of first order conditions (FOCs) under NT (see Eq. (I.15)) makes it difficult to obtain analytical solutions under asymmetry. Nevertheless, we show below that the key driving forces behind NT being efficiency-reducing relative to discrimination continue to operate in a North-South setting. To this end, adding up FOCs for both countries under NT yields

$$2C_c - (1+\theta)C_m - \pi = \gamma\{\frac{\mu_i}{P_i^{NT}(\theta)}\left[(C_m - C_c)P_i^{NT}(\theta) + \left(M_i + \theta M_j\right)C_c\bar{T} - (1-\theta)\theta M_j \Omega_j(\theta)\right] + \frac{\mu_j}{P_j^{NT}(\theta)}\left[(C_m - C_c)P_j^{NT}(\theta) + \left(M_j + \theta M_i\right)C_c\bar{T} - (1-\theta)\theta M_i \Omega_i(\theta)\right]\}. \quad \text{(I.23)}$$

Similarly, adding the two FOCs under discrimination yields

[23] One may also assume that the North has higher labor productivity (i.e. $a_i < a_j$), but this will not change our analysis in a substantive way.

$$2C_c - (1+\theta)C_m - \pi = \gamma\{\frac{1}{2P_i(\theta)}\left[(C_m - C_c)P_i^{NT}(\theta) + \left(M_i + \theta M_j\right)C_c\bar{T} - (1-\theta)\theta M_j \Omega_j(\theta)\right] + \frac{\mu_j}{P_j^{NT}(\theta)}\left[(C_m - C_c)P_j^{NT}(\theta) + \left(M_j + \theta M_i\right)C_c\bar{T} - (1-\theta)\theta M_i \Omega_i(\theta)\right]\}. \tag{I.24}$$

Note that the left hand-side of both FOCs can be interpreted as the global marginal cost of patent protection, as it is the sum of marginal costs of patent protection across countries. Analogously, the right hand-side of both FOCs represents the global marginal benefit of patent protection. Observe that while the global marginal cost of patent protection under the two regimes is the same (since the left-hand sides of the two FOCs are identical), the global marginal benefit is not. Indeed, the global marginal benefit of patent protection under NT is lower than that under discrimination. This is because NT forces countries to overuse foreign protection when trade is subject to frictions, which other things being equal, tends to reduce the global marginal benefit of patent protection. Recall that this overuse of foreign protection under NT was the key driving force behind our analysis of the symmetric case so it is not surprising that this mechanism continues to exist under asymmetry. Indeed, observe that the incentive-reducing effects of trade frictions under NT, captured by the terms $(1-\theta)\theta M_i \Omega_i(\theta)$ and $(1-\theta)\theta M_j \Omega_j(\theta)$ in Eq. (I.23), are larger than those under discrimination, captured by the terms $(1-\theta)\theta M_i \Omega_{ij}(\theta)$ and $(1-\theta)\theta M_j \Omega_{ji}(\theta)$. This is because $\Omega_i(\theta) > \Omega_{ij}(\theta)$ (θ) and $\Omega_j(\theta) > \Omega_{ji}(\theta)$ in equilibrium.[24] Intuitively, when countries consider raising domestic patent protection under NT, they are more conscious of the negative

[24] We have shown this is true under free trade, that is, $\Omega_i^{NT}(\theta) > \Omega_{ij}^*(\theta)$ and $\Omega_j^{NT}(\theta) > \Omega_{ji}^*(\theta)$ when $\theta = 1$. As θ falls, both $\Omega_{ij}^*(\theta)$ and $\Omega_{ji}^*(\theta)$ decrease. Indeed, the marginal benefit of extending patent protection to foreigners becomes infinitesimally small as θ approaches zero (see the right hand-side of Eq. (I.14)). This is not true for $\Omega_i^{NT}(\theta)$ and $\Omega_j^{NT}(\theta)$ since the marginal benefit of patent protection under NT has a positive lower bound due to the fact that such protection also extends to domestic firms and part of their innovation incentive stems from domestic profits that remain unaffected by trade barriers (see the right hand-side of Eq. (I.15)). Therefore, $\Omega_i^{NT}(\theta)$ and $\Omega_j^{NT}(\theta)$ cannot be lower than $\Omega_{ij}^{NT}(\theta)$and $\Omega_{ji}^{NT}(\theta)$.

incentive effects of trade frictions since the level of foreign protection has to raise by the same amount.

It is also worth noting that, as shown before, the above distortion generated by NT readily disappears when trade fractions vanish. When $\theta = 1$ domestic and foreign protections are equally effective so that the incentive-reducing terms in both Eqs. (I.23) and (I.24) drop out.

We conducted numerical simulations to further study NT under asymmetry. We now briefly discuss the results of this analysis. For simplicity, we consider a constant elasticity demand function ($x = p^{-\varepsilon}$ where $\varepsilon = 1.5$). With this specific demand function it can be shown that $C_m = \pi \approx 0.2C_c$. Also, we assigned the following values to the fundamental parameters of the model: $\alpha = 0.67, \gamma = 3, C_c = 5$ and $\bar{T} = 20$. Let $\rho \approx 1$ without loss of generality. These parameter values ensure interior solutions under discrimination and NT and our results are robust to variations in them. To normalize away any level effects, we fix the total world market size ($M_i + M_j$) and the stock of human capital ($K_i + K_j$).

Figure I.1 Discrimination versus NT: how trade openness matters

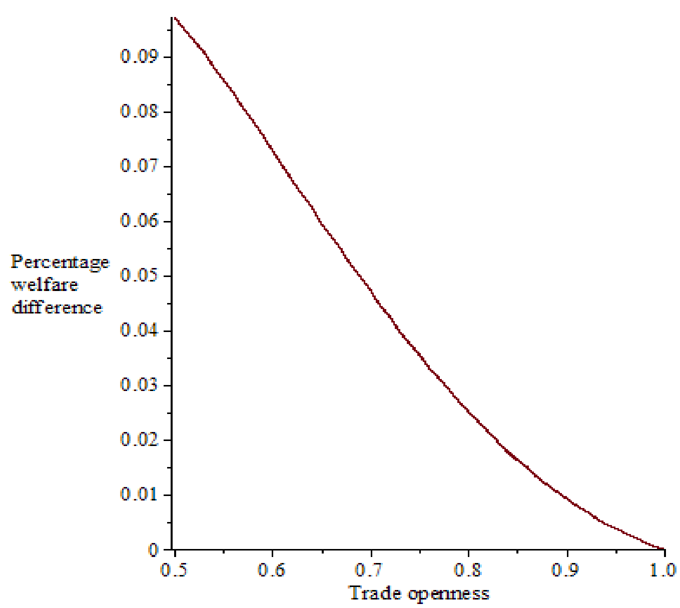


Figure I.1 shows how the welfare difference between discrimination and NT, i.e. $(WW^D - WW^{NT})/WW^{NT}$, varies with trade frictions θ, given $M_i = 10$, $M_j = 5$, $K_i = 2$ and $K_i = 1$. First note that so long as trade frictions exist ($\theta < 1$), discrimination generates strictly higher welfare than NT regardless of the level of such frictions. This is consistent with our results regarding the negative effects of NT under the presence of trade frictions. Moreover, as trade frictions fall (i.e. θ increases), the welfare differential between the two regimes converges to zero.

Table I.1 compares the levels of total effective patent protection and national welfare across the two regimes for three different levels of trade frictions. First note that the level of patent protection under NT lies in between the two discriminatory protections regardless of the level of trade frictions (i.e. $\Omega_i^{NT}/\Omega_{ii}^* < 1 < \Omega_i^{NT}/\Omega_{ij}^*$). This verifies the distortion that NT causes by the excessive use of foreign protection. Using the first four columns of Table I.1, it is easy to confirm that countries tend to discriminate less as trade frictions fall - i.e. $\Omega_{ij}^*/\Omega_{ii}^*$ and $\Omega_{jj}^*/\Omega_{ji}^*$ both decrease with θ - which is consistent with Proposition I.4. Note also that the North (i.e. country i) is worse-off under NT even if it receives more total effective protection under NT relative to discrimination: i.e. $W_i^{NT}/W_i^D < 1$ even though $P_i^{NT}/P_i^D < 1$. The reason is that the South (i.e. country j) under-innovates due to it receiving lower effective protection under NT relative to discrimination, generating a large welfare loss for the North that ends up offsetting the benefit conferred by the higher degree of effective protection received by its firms under NT. Finally, the last two columns of Table I.1 show that the welfare loss imposed on each country by NT increases with the level of trade frictions.

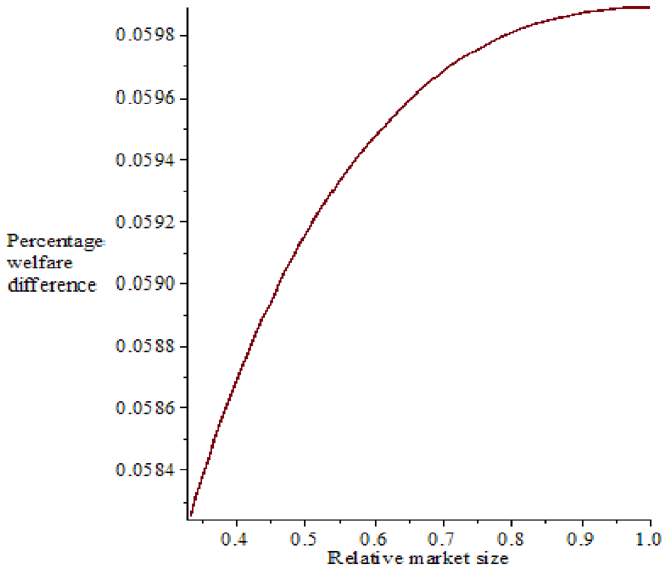
Table I.1 Equilibrium Patent Protection and Welfare in a North-South World

θ	$\Omega_i^{NT}/\Omega_{ii}^*$	$\Omega_i^{NT}/\Omega_{ij}^*$	$\Omega_j^{NT}/\Omega_{jj}^*$	$\Omega_j^{NT}/\Omega_{ji}^*$	P_i^{NT}/P_i^D	P_j^{NT}/P_j^D	W_i^{NT}/W_i^D	W_j^{NT}/W_j^D
0.8	0.948	1.186	0.593	1.544	1.011	0.964	0.980	0.959
0.9	0.955	1.122	0.699	1.280	1.005	0.986	0.993	0.984
1.0	0.967	1.073	0.807	1.135	1.000	1.000	1.000	1.000

To see how the welfare gap between NT and discrimination is affected by the degree of asymmetry between the two countries, we studied the effects of changes in their relative market size and human capital stocks. We first set $K_i = K_j = 1$ and $\theta = 0.75$ and consider the effects of reducing the gap between M_i and M_j in the above experiment to 0, fixing their sum (at 20). Figure I.2 shows that the welfare loss from NT is smaller when countries are more asymmetric in terms of market size. To understand the intuition behind this result, recall from Proposition I.2 that a country's incentive for discrimination is inversely related to its market size. Since an increase in market size asymmetry reduces discrimination in the larger market while it raises it in the smaller market, the average degree of discrimination declines in our model as markets become more unequal in size. For analogous reasons, the degree of effective global protection increases with market size asymmetry. Thus, the global welfare loss generated by NT declines as markets become more unequal in size. This finding suggests that the NT discipline may be a smaller concern in a North-South setting.

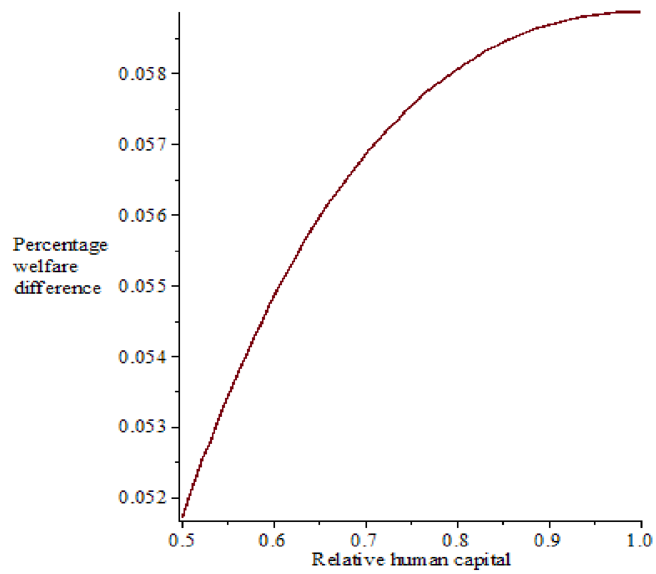
Finally, we illustrate the effects of asymmetric human capital stocks. To this end, we equalize market size across countries by setting $M_i = M_j = 7.5$ and bring K_i and M_j closer to 1.5 from 2 and 1 respectively. Again, we see in Figure I.3 that NT generates a smaller welfare loss when human capital stocks are less equal across countries. The intuition is different from that in the case of market asymmetry, however, as we have shown that relative capital stock does not affect a country's tendency for discrimination.

Figure I.2 Comparison When Market Size Differs Across Countries



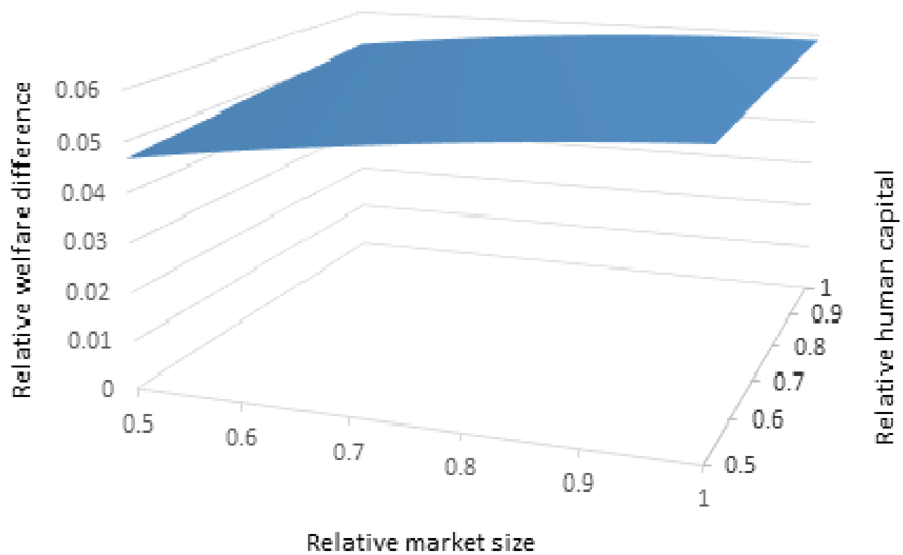
To see what drives our results, note that the North chooses stronger patent protection under NT as its human capital stock increases, since it is able to capture a larger share of global profits that result from innovation. In the meantime, Northern firms receive more total protection since the major component of their overall protection is Northern protection and the increase in such protection is not discounted by the level of trade frictions (θ). As a result, the North has a stronger incentive for innovation under NT, a pattern that promotes innovation and welfare. This helps explain why welfare under NT is higher when the distribution of human capital stock is more unequal across countries (although welfare under NT is still lower than that under discrimination).

Figure I.3 Welfare Difference with Asymmetric Human Capital Stocks



To check the robustness of our findings, we also conducted further numerical analysis by varying relative market size and human capital stock simultaneously. Figure I.4 plots the relative welfare difference between discrimination and NT for one such simulation. We utilize the same parameter values as Figure I.1 and set $\theta = 0.75$. In the figure, the horizontal axes represent the two country characteristics of interest, each varying from 0.5 (very asymmetric) to 1 (symmetric). The first observation is that discrimination yields higher world welfare regardless of the degree of asymmetry, as illustrated by the welfare difference plane which lies above zero everywhere. Moreover, as can be seen from Figure I.4, the welfare difference between NT and discrimination becomes larger as countries become more alike in either characteristic (i.e. market size or human capital). In particular, the plane peaks at the upper-right hand corner where both market size and human capital stock are equal across countries.

Figure I.4 Welfare Difference with Asymmetric Market Sizes and Human Capital Stocks



Trade Barriers and Patent Protection

Our analysis thus far assumes symmetric trade barriers in both directions since a single parameter θ captures the degree of trade openness of both countries. This approach is reasonable when trade frictions reflect underlying structural parameters such as transportation costs but is on weaker grounds if such frictions arise from tariffs and other trade policy barriers which can, and do, differ across countries. To understand how changes in national trade policies affect incentives for patent protection, we now extend our model to allow for the presence of asymmetric trade barriers. Let θ_i be the trade barriers facing imports flowing into country i, where an increase in θ_i implies unilateral trade liberalization on the part of country i. As before, such liberalization increases the export profits of country i's firms as well as the surplus consumers in country i derived from imported goods.

In the absence of NT, country i's FOCs for patent protection under asymmetric trade barriers can be written as

$$C_c - C_m - \pi = \frac{\gamma M_i}{M_i \Omega_{ii} + \theta_j M_j \Omega_{ji}} [(C_m - C_c)\Omega_{ii} + C_c \bar{T}] \tag{I.25}$$

and

$$C_c - \theta_i C_m = \frac{\gamma M_i}{M_i \Omega_{ii} + \theta_j M_j \Omega_{ji}} [(C_m - C_c)\Omega_{ii} + C_c \bar{T}]. \tag{I.26}$$

Country j's FOCs can be obtained by simply switching i and j.

To isolate the role of national trade barriers, we assume countries are symmetric in terms of market size and human capital. Given this, it can then be shown that country i's equilibrium levels of patent protections under discrimination are

$$\Omega_{ii}(\theta_i, \theta_j) = \frac{C_c \bar{T}[(1 + \gamma - \theta_j)C_c - \gamma\theta_j C_m + \theta_j \pi]}{(C_c - \theta_j C_m)[(2 + \gamma)(C_c - C_m) - \pi]} \tag{I.27}$$

and

$$\Omega_{ij}(\theta_i, \theta_j) = \frac{C_c \bar{T}[(\theta_i + \gamma\theta_i - 1)C_c - \gamma\theta_j C_m + \theta_j \pi]}{\theta_i (C_c - \theta_i C_m)[(2 + \gamma)(C_c - C_m) - \pi]}. \tag{I.28}$$

Consider now the effects of unilateral trade liberalization by country i on its own patent policies when it is free to implement discriminatory patent policies. Using Eq. (I.27) we have

$$\frac{\partial \Omega_{ii}(\theta_i, \theta_j)}{\partial \theta_i} = 0 \tag{I.29}$$

and

$$\frac{\partial \Omega_{ij}(\theta_i, \theta_j)}{\partial \theta_i} = \frac{C_c \bar{T}[\theta_i^2 C_c C_m + \gamma \theta_i^2 C_c C_m - 2\theta_i C_c C_m - \pi \theta_i^2 C_m - \gamma \theta_i^2 C_m + C_c^2]}{\theta_i^2 (C_c - \theta_i C_m)^2 [(2+\gamma)(C_c - C_m) - \pi]} > 0, \quad \text{(I.30)}$$

i.e., a reduction in own trade barriers does not affect country i's domestic protection but it increases the patent protection it grants to foreign innovators. Thus, own trade liberalization makes a country less willing to discriminate against foreign innovators with respect to its patent policies. The intuition is straightforward: since neither the profits of domestic innovators nor the surplus consumers enjoy from local goods depends upon local trade barriers, the value of patent protection granted to local firms is independent of local trade barriers.[25] On the other hand, the reduction of trade barriers by country i increases the profits foreign innovators derive from its market while also increasing the surplus consumers derive from foreign innovations. Both these factors increase the value of foreign innovations to country i, making it optimal to offer stronger patent protection to foreign innovators.

Note further that country i's domestic protection falls with foreign trade liberalization

$$\frac{\partial \Omega_{ii}^*(\theta_i, \theta_j)}{\partial \theta_j} = -\frac{C_c^2 \bar{T}(C_c - C_m - \pi)}{(C_c - \theta_i C_m)^2 [(2+\gamma)(C_c - C_m) - \pi]} < 0. \quad \text{(I.31)}$$

The intuition for this is that since $\frac{\partial \Omega_{ji}(\theta_i, \theta_j)}{\partial \theta_j} > 0$ (i.e. country j's foreign protection increases with its trade liberalization) and patent protection policies are strategic substitutes across countries, it is optimal for country i to lower the protection it extends to domestic firms when they start receiving more protection abroad. Finally, since country j's trade barriers affect neither consumer surplus in country i nor the profits of firms from country j in country i, we have:

[25] This result is driven by the fact that there is no product market competition in our model since each new differentiated good is unrelated to existing goods (i.e. is produced by a true monopolist).

$$\frac{\partial \Omega_{ij}(\theta_i, \theta_j)}{\partial \theta_j} = 0. \tag{I.32}$$

Let $\Delta\Omega_i(\theta_i, \theta_j) = \Omega_{ii}(\theta_i, \theta_j) - \Omega_{ij}(\theta_i, \theta_j)$ measure the degree of patent discrimination practiced by country i. It follows immediately from our results above that trade liberalization by either country reduces the degree of discrimination practiced by both countries, i.e.

$$\frac{\partial \Delta\Omega_i(\theta_i, \theta_j)}{\partial \theta_i} < 0 \tag{I.33}$$

and

$$\frac{\partial \Delta\Omega_i(\theta_i, \theta_j)}{\partial \theta_j} < 0. \tag{I.34}$$

An important implication of Eqs. (I.33) and (I.34) is that global trade liberalization makes countries less resistant to accepting NT with respect to their patent policies.

Conclusion

The TRIPS agreement was controversial from the start. Developing countries fought hard against the inclusion of any multilateral agreement on intellectual property in the WTO, just as major developed countries put their considerable weight behind it. In addition to increasing the level of intellectual property protection in developing countries, TRIPS made it illegal for WTO members to discriminate against foreign nationals via the NT principle.

At first glance, the inclusion of a non-discrimination principle in TRIPS hardly seems worthy of comment. After all, the idea of non-discrimination is the very foundation of the multilateral trading system. Yet, our analysis has shown that the desirable properties of NT in the context of trade in goods do not extend automatically to the domain of intellectual property.

The key driving force behind our results is that incentives for innovation depend upon the overall patent protection firms receive in the global economy and the composition of such protection matters only when international market access is hampered by trade frictions. Absent such frictions, NT is inconsequential since what firms lose abroad is offset by what they gain at home. While we focus mostly on a two-country setting, we show that the key driving force behind our analysis carry over to a multi-country scenario.

When access to foreign markets is hampered by trade frictions (i.e. transportation costs and/or trade policy barriers), the case for non-discrimination in patent protection is even weaker. The intuition here is simple as it is undeniable: in the presence of trade frictions, substituting domestic patent protection for foreign protection affords innovating firms a higher level of effective patent protection because, all else equal, exports are less profitable than domestic sales. Furthermore, consumer welfare considerations reinforce this argument: trade frictions make foreign innovation relatively less valuable to domestic consumers in each country by making foreign goods costlier (or by reducing the volume of trade). As a result, in our model, imposing a NT constraint on national governments actually reduces global innovation and welfare in the presence of trade frictions.

Finally, it is important to recognize that our findings do not necessarily imply that NT should not have been included as a fundamental principle in TRIPS. Rather, we see our findings as highlighting one potential efficiency cost of NT that arises from the wedge that trade frictions create between the incentive effects of domestic and foreign patent protection. NT may yield other benefits that are not captured by our model, such as lower enforcement and implementation costs, greater consistency across international trade agreements, and potentially lower costs of international coordination across countries. Inclusion of these potential benefits of NT can make it more desirable than discrimination.

CHAPTER II

INTERNATIONAL AGREEMENTS ON PRODUCT STANDARDS UNDER CONSUMPTION EXTERNALITIES: NATIONAL TREATMENT VERSUS MUTUAL RECOGNITION

Introduction

Over the last six decades or so, significant tariff reductions worldwide have brought increased attention to various types of non-tariff barriers to international trade.[1] A leading example of such types of trade barriers is technical barriers to trade (TBT) that arise from products having to meet specific standards in order to be authorized for sale in a given country. TBT are controversial because they can serve legitimate as well as protectionist purposes, with the line between the two often being obscure. In order to curb the protectionist use of TBT, member countries of the World Trade Organization (WTO) have entered into the Agreement on Technical Barriers to Trade - a multilateral agreement whose objective is to ensure that regulations, standards, testing and certification procedures do not create unnecessary obstacles to international trade. The European Union (EU), in the hope of paving the way for its common market, has adopted its own distinct approach to the regulation of TBT.[2]

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[1] As Baldwin (1970) vividly notes: "The lowering of tariffs has, in effect, been like draining a swamp. The lower water level has revealed all the snags and stumps of nontariff barriers that still have to be cleared away."

[2] See the Council Resolution 85/C 136/01 by the EU on a new approach to technical harmonization and standardization. The document is available online at http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex:31985Y0604(01).

A key difference between these two institutional arrangements is that while the WTO's agreement on TBT is based on the principle of national treatment (NT), the approach adopted by the EU rests on the rule of mutual recognition (MR). In a nutshell, NT mandates that product standards imposed on foreign firms should be no stricter than those on domestic firms - i.e. NT is essentially a non-discrimination requirement. By contrast, MR requires that a country's standards on foreign firms be the same as what those firms have to comply with in their home countries. Thus, under MR a good that is lawfully sold in one country can be sold in the other.

By design NT and MR are not compatible with each other: a country under NT has full control over the standards applied in its domestic market, while under MR standards on foreign firms are determined by their own countries. This salient distinction naturally sparks several important questions: Why have the WTO and the EU made different choices regarding NT and MR? Are these choices well-founded from a welfare perspective? In a broader sense, what are the determinants of the relative efficacy of these alternative types of agreements on product standards? This work argues that taking account of country heterogeneity in consumer preferences can shed useful light on these questions.

The work is built on two key ideas. First, consumers in different countries are likely to have different valuations regarding product quality. For example, consumers in countries with high GDP per-capita may put a higher premium on quality, a pattern that has received substantial empirical support from recent trade literature.[3] The second key idea underlying the analysis is that consumer preferences across WTO members are likely to be

[3] See, for example, Hallak (2006), Feenstra and Romalis (2014) and Caron et al. (2015). Specifically, these and other recent empirical studies have identified per-capita income as an important factor explaining the patterns of import and export quality across countries.

substantially more heterogeneous than those within the EU, because income dispersion amongst WTO members is substantially larger than that amongst EU members. For instance, while both organizations involve rich countries like Luxembourg, the EU's poorest country Bulgaria has a GDP per-capita that is thirty times higher than that of Malawi which is the poorest country in the WTO.[4] Building upon these two premises, our work offers new insights about the preferences of the WTO and the EU over different product standards agreements, by showing that an agreement based on NT is more palatable to countries with a higher degree of taste heterogeneity such as WTO members than one based on MR.

Our model is based on Costinot (2008) and Brander and Krugman (1983). We consider a world of two countries, each having a firm that sells in both markets. We analyze the case of quality standards. Specifically, consumption of the good produced by the two firms is associated with a negative externality, the degree of which determines the quality (or version) of the good. A key assumption of the model is that consumers of one country care relatively less about quality in the sense that they incur a smaller welfare loss from any given level of the negative consumption externality. As discussed above, such asymmetric preferences can arise due to differences in per-capita income across countries. The timing of decision making in the model is as follows. First, countries enter into a product standards agreement (based on either NT or MR). Second, given the constraint imposed by the relevant underlying principle (i.e. NT or MR), countries set product standards that mandate the quality of the good produced by .rms. Third, consumption and trade take place.

[4] Data on GDP per-capita come from the World Bank and are chosen for the year of 2013.

The model highlights two factors that can contribute to the performance of an international standards agreement: the nature of the institutional constraint imposed by the agreement and that of the strategic policy interaction induced by the constraint. The first factor affects the "second-best" outcome that can be possibly attained when an agreement is binding. In particular, an agreement that imposes a more stringent constraint undermines the second-best outcome by lowering the level of the highest possible social welfare. The constraint associated with an agreement can also affect the way in which countries strategically choose their national policies, which will in turn have substantive welfare implications. To isolate their respective effects, we consider two scenarios *while assuming NT or MR is always binding*. In the first scenario, countries coordinate their product standards to maximize joint welfare, while in the second they act non-cooperatively and each country chooses its standards to maximize its national welfare. The former scenario is important as it allows us to identify the welfare cost of the constraint related to each type of agreement by eliminating the confounding effects of strategic policy interaction. Once this objective is achieved, we allow countries to strategically choose their standards and examine how this new channel may alter the relative performance of NT and MR. Furthermore, to fully characterize the welfare effects of the constraints imposed by the two types of agreements, we also compare the constrained optimal policies in the first scenario with the first-best outcome obtained under no institutional constraints.

Our analysis starts with the characterization of the coordinated product standards subject to the constraint of NT or MR. As might be expected, for very high (low) levels of the externality, it is optimal for both countries to implement a strict (lenient) standard under either NT or MR. When the externality is moderate, optimal policies under NT are *differential*: a lenient standard is adopted by the country that is less averse to the externality while a strict standard is enforced by the other. A somewhat surprising result is that *differential policies are never optimal under MR*. This occurs because such policies give rise to a *mismatch* of standards under MR: although countries may have fairly divergent preferences over the consumption externality, they have to recognize each other's standards under MR even though they are fairly incompatible with domestic needs. Differential policies respecting MR hence represent an inefficient assignment of product standards. As a result, coordination under MR always leads both countries to choose identical standards regardless of the externality and the preference heterogeneity.

We next show that this feature plays an important role in determining the welfare consequences of the institutional constraints imposed by NT and MR. We find that NT yields weakly higher world welfare than MR for all levels of the externality and strictly dominates it when the externality is moderate. The reason is that the mismatch of standards restricts countries to use symmetric standards under MR, while such patterns of standards are dominated by the differential policies under NT for intermediate levels of the externality. An important implication is that the constraint imposed by MR is weakly costlier than that of NT from a welfare perspective. Furthermore, we show that as preference asymmetry increases between countries, NT outperforms MR over a larger range of the externality so the mismatch of standards induced by MR tends to appear more restrictive. This implies that the MR constraint becomes more stringent as compared to that of NT when countries possess more heterogeneous preferences.

To facilitate our comparative analysis, we further define *the effectiveness of NT relative to MR* as the ratio between the ranges of the externality in which NT and MR respectively yield higher world welfare. It follows that under coordination, NT tends to be more effective than MR between countries with a higher degree of preference heterogeneity. Provided policy coordination is possible, this finding indicates that from a welfare point of view, the WTO is more likely to favor NT compared to the EU as its member countries possess more dissimilar preferences. Thus our analysis provides a new insight that helps rationalize the observed choices by the two organizations regarding alternative standards agreements based on NT and MR.[5]

Notably, we also find that socially optimal product standards obtained free from institutional constraints are non-discriminatory, which indicates that coordination under NT in fact leads to the first-best outcome. An important implication of this observation is that imposing NT on product standards does not cause any welfare cost, while the constraint of MR gives rise to a welfare loss when the externality is moderate. Moreover, we show that country heterogeneity plays a vital role in driving a wedge in the welfare effects between NT and MR. Indeed, when countries are identical, both types of agreements induce the same (first-best) outcome so that even the MR constraint creates no welfare cost. This is because the mismatch of standards under MR vanishes when countries share the same preference.

[5] Notably, the Trans-Pacific Partnership (TPP) that was just reached in October 2015 also lays down specific rules about the regulation of TBT. Indeed, these rules are based on NT rather than MR, an outcome consistent with our insight given the considerable heterogeneity among TPP members.

When countries set their standards non-cooperatively, NT can be dominated by MR for certain levels of the externality. This is because countries under NT tend to overuse the strict standard: as NT requires lowering the standards on both firms, choosing the lenient standard generates a *positive* profit externality on the foreign firm. On the other hand, countries use too much of the lenient standard under MR since doing so confers a *negative* profit externality on the foreign firm. As found in Costinot (2008) under symmetric countries, this leads NT and MR to be favorable for relatively large and small levels of the externality. Interestingly, we show that this finding depends importantly on the assumption of symmetry. In particular, with heterogeneous country preferences, such a pattern could exist over multiple ranges of the externality, so that NT dominates MR for higher levels of the externality only in an "average" sense. An important policy implication is that, applying NT (MR) to goods with large (small) externalities is optimal between similar countries but can be inefficient when there exists a certain degree of heterogeneity in country preferences.

Our final task is to investigate the effect of country heterogeneity on the performance of NT and MR in the presence of strategic interaction. We find that the effectiveness of NT relative to MR first decreases and then increases in the degree of preference asymmetry across countries. Despite this non-monotonic relationship, as the decreasing trend only occurs for a reasonably small range of asymmetry, we argue that our results remain consistent with the observed institutional arrangements of product standards initiated by the WTO and the EU. In particular, we show that as long as preference heterogeneity within the WTO is larger than some mild threshold, the relative effectiveness of NT will be greater for the WTO so that it would view NT as more appealing than MR when compared to the EU.

The rest of the chapter proceeds as follows. Section 2 reviews related economic literature. Section 3 describes the model of quality standards. In Section 4 we compare NT and MR assuming countries can coordinate policies on product standards, while in Section 5 we investigate how the comparative assessment may be altered when countries strategically choose their standards. Section 6 concludes. We collect all the proofs in the Appendix.

Related Literature

To our best knowledge, this is the first study that analyzes product standards agreements while incorporating country heterogeneity. The paper that is most related to ours is Costinot (2008) albeit there are two important differences. First and foremost, the model in Costinot (2008) assumes identical countries so it cannot be used to examine the role of country heterogeneity. Second, we differentiate between contributions to the performance of a standards agreement from its institutional constraint and strategic interaction induced by the constraint. By contrast, Costinot (2008) focuses on non-cooperative settings of product standards so the comparison between NT and MR captures a mixed effect of the two forces.[6] Another closely relevant study is Markusen (2013) who also takes the perspective of asymmetric country preferences to examine government's incentives for setting environmental standards. Similar to our study, the paper analyzes both coordinated and Nash equilibrium policies, although the focus is not on the institutional arrangements such as NT and MR.

[6] To be sure, Costinot (2008) establishes the first-best outcome by examining coordination under no institutional constraints. We examine this scenario as well as coordination under NT or MR.

This work also relates to several theoretical studies that examine the welfare implications of a particular type of product standards agreement. Battigalli and Maggi (2003) provide an incomplete contract explanation about why NT has been taken as a rigid rule in the WTO. More recently, Staiger and Sykes (2011) apply the terms-of-trade framework to analyze the effect of NT on the regulation of product standards. The paper shows that the terms-of-trade effect gives rise to incentives for large countries to impose discriminatory standards that are overly stringent on foreign firms. Moreover, prohibiting such discrimination through NT may still lead to inefficiently stringent standards under certain circumstances. Toulemonde (2013) provides a welfare analysis of MR under differential learning ability of consumers about foreign norms. The paper identifies the winners and the losers (i.e. firms versus consumers) due to the adoption of an MR agreement. While these studies provide important insights, they focus only on a single type of standards agreement and ignore country heterogeneity.[7]

There also exists an established literature that examines the strategic incentives for countries to choose product standards. Inspired by Brander and Spencer (1985), Barrett (1994) analyzes and emphasizes the strategic use of environmental standards between countries whose firms compete on the world market. Boom (1995) examines the effect of asymmetric standards on market outcomes in a vertical differentiation model. Fischer and Serra (2000) study the incentives for a country to impose minimum standards when its own firm faces foreign competition in the home market. Gandal and Shy (2001) examine a country's decision to recognize foreign standards and characterize conditions under which countries are willing to form a standards union. Furthermore, Klimenko (2009) models

[7] Other related studies include Bagwell and Staiger (2001) and Suwa-Eisenmann and Verdier (2002). For a comprehensive treatment of the effect of TBT liberalization, see Baldwin (2000).

strategic interaction of national product standards in the context of technical compatibility. While our work also captures such strategic incentives, it differs from the above studies by placing a clear focus on the institutional aspect of product standards.

Finally, our analysis relates to several recent studies that examine the principle of NT in contexts other than product standards. As a seminal paper, Horn (2006) studies the welfare implications of the NT clause in the GATT for tariff and tax policies. Sara and Saggi (2008) extend Horn's work by introducing product and country heterogeneity. Most recently, Geng and Saggi (2015) evaluate the case for implementing NT in the international protection of intellectual property. An important lesson from this literature is that the performance of NT is likely to depend on the nature of the policy instrument. In particular, while NT helps induce more efficient tax policies, it tends to work against efficiency when applied to intellectual property protection. While these studies compare cases with and without NT, our work compares NT with MR as these are two observed regulatory frameworks for product standards. Our study contributes to this literature by showing that in the context of product standards, NT appears more desirable than MR from an overall perspective and this edge is enhanced in a world of more heterogeneous countries.

Model

Consider a world comprised of two countries: A and B. Each country has one firm that sells a homogeneous good with two versions: H and L. Consumption of version L generates a negative per-unit externality $\theta > 0$ and such externality is zero for version H. Version H on the other hand is more expensive to produce. We denote the unit costs of producing H and L with $c > 0$ and zero respectively. As an example, one may think of θ

as the degree of pollution generated by cars, with H and L being the "hybrid" and the "regular" models of a car. Following Costinot (2008) we assume the regularity condition that $c < 1/4$. Firms share identical technologies and compete à la Cournot in both countries.[8]

A representative consumer in either country buys at most one unit of the good. Consumer's utility in country i is given as

$$U_i = \begin{cases} u - p_i - s_i\varphi_i & \text{if she buys either version} \\ -s_i\varphi_i & \text{if she buys nothing} \end{cases} \qquad i = A, B \qquad \text{(II.1)}$$

where u represents consumer's willingness to pay for the good, p_i is the market price, φ_i denotes the magnitude of consumption externality, $s_i \in [0,1]$ is a parameter capturing how much consumers are affected by the externality. In particular, φ_i is defined as

$$\varphi_i = \theta_i q_{ii} + \theta_j q_{ji} \qquad i = A, B \qquad \text{(II.2)}$$

where q_{ii} and q_{ji} represent quantities sold by the domestic and the foreign firm respectively, θ_i and θ_j can be θ or zero depending on the version being sold. Thus, how much consumption externality a country incurs depends on both the quantity and the version of the good being consumed in its market.[9]

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[8] Following previous studies we implicitly assume that markets are segmented, so that firms can charge prices independently across countries. This is helpful to isolating the effect of country heterogeneity by controlling for the potential impact of market structure. A notable observation is that the EU actually involves a more integrated market than the WTO. Exploring how difference in market structure may affect the performance of product standards agreements is an important topic for future research.

[9] The formulation of φ implies that the consumption externality is local in the sense that it occurs within national boundaries. Local consumption externalities are not uncommon; examples include safety standards on cars, pesticide use in agricultural products, environmental standards on product packages, etc. We discuss the case of global externalities in Section 4.

To simplify the analysis, it is assumed that u is uniformly distributed over $[0,1]$. The market price can then be written as

$$p_i = 1 - (q_{ii} + q_{ji}). \tag{II.3}$$

A novel feature of our model is that consumers in the two countries may have heterogeneous preferences over product quality which is reflected by the extent of the consumption externality. Without loss of generality we assume that $s_A < s_B = 1$ and denote s_A with s. Therefore consumers in country A are relatively less affected by the negative consumption externality, implying that they value quality to a less extent. This could be due to the dispersion of per-capita income that leads to differential marginal utility of income across countries. In particular, our model can be interpreted as a North-South one with country A (B) belonging to the South (North). As we shall see, this simple structure of heterogeneous preferences retains tractability while generating rich strategic interactions between countries of national product standards.

Countries set product standards as a means for regulating the market. Let σ denote a generic standard that stipulates the version of the good that is legal to be sold. In particular σ can be either H (high or strict standard) or L (low or lenient standard). Standards are firm specific: let σ_{ij} be country i's standard for firm j, where $i, j = A, B$.[10] Under NT, countries have to treat foreign firms no worse than domestic ones, which implies $\sigma_{ii} \preccurlyeq \sigma_{ij}$ with "$\preccurlyeq$" meaning "being no stricter than". Since in our context countries do not have incentives to offer better deals to the foreigners, we simply assume equal treatment under NT, i.e. $\sigma_{ii} =$

[10] In principle countries may allow firms to produce more than one versions, but in that case firms would simply produce version L as the cost is lower. Therefore, without loss of generality we simply assume the choice of standard to be a singleton.

σ_{ij}.[11] Under MR, on the other hand, a country's standard on foreign firms is identical to what these firms follow in their home country, and this implies $\sigma_{ij} = \sigma_{jj}$. Alternatively speaking, a standard applies to all firms in a given market under NT while to a given firm in all markets under MR. It is important to note that under either type of agreement each country only needs to determine the standard for domestic firms (σ_{ii}): under NT this standard will automatically apply to foreign firms selling in domestic market, while under MR the standard on foreign firms is determined by their home countries. To economize notation, we will simply denote country i's standard as σ_i, with the understanding that σ_i applies to country i's market under NT but to country i's firm under MR. We use (σ_i, σ_j) to represent a generic policy combination for the two countries.

As an illustration, let $(\{\sigma_{ii}, \sigma_{ij}\},\{\sigma_{jj}, \sigma_{ji}\})$ be a full-fledged policy combination with $\{\sigma_{ii}, \sigma_{ij}\}$ and $\{\sigma_{jj}, \sigma_{ji}\}$ denoting country i and j's standards respectively. Then we have the following correspondences:

(i) $(H, H) = (\{H, H\}, \{H, H\})$ under both NT and MR,

(ii) $(L, L) = (\{L, L\}, \{L, L\})$ under both NT and MR,

(iii) $(H, L) = (\{H, H\}, \{L, L\})$ under NT and $(\{H, L\}, \{L, H\})$ under MR,

(iv) $(L, H) = (\{L, L\}, \{H, H\})$ under NT and $(\{L, H\}, \{H, L\})$ under MR.

We define country i's welfare under agreement r as

$$w_i^r(\sigma_i, \sigma_j, \theta) = cs_i^r(\sigma_i, \sigma_j, \theta) + \pi_i^r(\sigma_i, \sigma_j, \theta) + \pi_j^r(\sigma_i, \sigma_j, \theta), \tag{II.4}$$

[11] Treating foreign firms better is not optimal because firms across countries are identical, thus doing so only lowers domestic firm's profit without yielding extra gains.

where $r = N\ (NT)$ or $M\ (MR)$, $cs_i(\cdot)$ is consumer surplus, $\pi_i(\cdot)$ and $\pi_j(\cdot)$ represent firm's domestic and foreign profits. World welfare is defined simply as the sum of each country's welfare:

$$ww^r(\sigma_i, \sigma_j, \theta) = w_i^r(\sigma_i, \sigma_j, \theta) + w_j^r(\sigma_i, \sigma_j, \theta). \tag{II.5}$$

Importantly, difference in the performance of NT and MR hinges on two factors: the nature of the constraint related to the agreement and that of the strategic policy interaction induced by the constraint. To identify their respective effects, we assume NT or MR is always binding and consider two scenarios of policy determination. In the first scenario countries coordinate their product standards to maximize joint welfare, while in the second they non-cooperatively choose standards to maximize each's national welfare. In particular, as the effect of strategic interaction is shut down in the first scenario, any difference in the welfare effects must arise from different stringency of the constraints imposed by NT and MR.

In either scenario the interaction between countries and firms proceeds as follows:

Stage 1: countries simultaneously choose product standards, either cooperatively or non-cooperatively, subject to the NT or the MR constraint.

Stage 2: firms compete à la Cournot in both countries while following the standards chosen in the first stage.

We use backward induction to solve this game. Before studying the open economy with two countries, it would be helpful as a benchmark to examine firm behavior and optimal standards under autarky. To this end, note that in a closed economy domestic firm maximizes profit as

$$\max_q pq - I(\sigma = H)cq, \quad \text{(II.6)}$$

where $p = 1 - q$ given that u is uniformly distributed over $[0,1]$, $I(\cdot)$ is an indicator function equal to one if the standard is strict (i.e. $\sigma = H$) and zero otherwise. Solving the problem in Eq. (II.6) yields optimal outputs as $q(\sigma = H) = (1 - c)/2$ and $q(\sigma = L) = 1/2$. The firm's profit is calculated as $\pi(\sigma = k) = p(\sigma = k)q(\sigma = k)$ where $k = H, L$. Given the equilibrium market price, it is easy to see that only consumers with $u > \hat{u}(\sigma = k)$ would buy the product. It follows that consumer surplus and national welfare can be calculated as

$$cs(\sigma = k) = \int_{\hat{u}(\sigma=k)}^{1} (u - p(\sigma = k)\, du - s\theta(\sigma = k)q(\sigma = k),$$
$$w(\sigma = k) = cs(\sigma = k) + \pi(\sigma = k). \quad \text{(II.7)}$$

To maximize national welfare the government simply compares $w(\sigma = H)$ with $w(\sigma = L)$. It follows that optimal product standards would depend on the magnitude of the externality θ. In particular, we have

$$w(\sigma = H) > w(\sigma = L)\ if\ and\ only\ if\ \theta > \theta^{AU}, \quad \text{(II.8)}$$

where θ^{AU} is a threshold level of the consumption externality.[12] Condition (II.8) indicates that the strict standard is preferred if the externality is so large that it exceeds θ^{AU}, otherwise the lenient standard is welfare maximizing. Intuitively, the government faces a fundamental trade-off between lowering the production cost and curbing the negative externality. When θ is large the latter consideration is dominant, so implementing the strict

[12] To preserve space, we collect expressions of all the thresholds in the Appendix.

standard is desirable; otherwise the lenient standard is chosen to exploit cheaper production technology.

Moreover, it is straightforward to show that

$$\frac{\partial \theta^{AU}}{\partial s} < 0 \; and \; \frac{\partial \theta^{AU}}{\partial c} > 0. \tag{II.9}$$

The first inequality in Eq. (II.9) says that a country would be more likely to impose the lenient standard as it becomes more tolerant of the negative consumption externality. The second inequality indicates that as it is costlier to produce under the strict standard, the lenient standard becomes more appealing and will be chosen at a higher level of the externality. As we shall see, these mechanisms play a fundamental role as countries determine product standards in an open economy setting.

Coordination over Product Standards

Optimal Product Standards

We start by analyzing coordination over product standards subject to the constraint of NT or MR. Assume first that both countries sign an agreement based on NT that mandates equal treatment of firms. Countries then maximize world welfare as

$$\max_{\sigma_i, \sigma_j \in \{H,L\}} ww^N(\sigma_i, \sigma_j, \theta) \; s.t. \sigma_i = \sigma_{ii} = \sigma_{ij}. \tag{II.10}$$

As each country can choose either H or L, there are four possible policy combinations under NT: (H, H), (L, L), (H, L) and (L, H). As a useful result, it can be shown that

$$ww^N(L,H,\theta) > ww^N(H,L,\theta)\ for\ all\ \theta, \quad \text{(II.11)}$$

that is, (H,L) is never an optimal policy profile from the social point of view. The intuition is clear: given country A cares less about externalities, it is not efficient for it to implement a stricter standard than country B.[13] Furthermore, as with the case of autarky, optimal standards in the open economy depend on the magnitude of the externality θ. To see this, first note that for sufficiently large θ, it is optimal to impose the strict standard in both countries. As θ declines it becomes desirable to have countries switch to the lenient standard. In particular, it is jointly optimal to have country A loosen its standard first because its consumers suffer less from the negative externality. It can then be shown that there exists a unique threshold θ_{cu}^N such that

$$ww^N(L,H,\theta) > ww^N(H,H,\theta)\ if\ and\ only\ if\ \theta < \theta_{cu}^N. \quad \text{(II.12)}$$

That is, for θ below θ_{cu}^N country A should switch to the low standard while country B should maintain the high standard. As θ further decreases to a sufficiently low level, it becomes optimal to also have country B lower its standard. One can similarly show that there exists θ_{cl}^N such that this is the case given $\theta < \theta_{cl}^N$:

$$ww^N(L,L,\theta) > ww^N(L,H,\theta)\ if\ and\ only\ if\ \theta < \theta_{cl}^N. \quad \text{(II.13)}$$

Moreover, it can be verified that

$$\theta_{cl}^N < \theta_{cu}^N\ if\ and\ only\ if\ s < 1, \quad \text{(II.14)}$$

[13] While we have suppressed the details, in our model raising the standard in either country reduces trade flows and raises local prices, which is consistent with recent empirical findings in Fontagné et al (2015).

which implies that for $\theta_{cl}^N < \theta < \theta_{cu}^N$ differential standards (L, H) must be the unique optimal policy combination. To verify this is indeed the case, simply note that for $\theta_{cl}^N < \theta < \theta_{cu}^N$ Eqs. (II.12) and (II.13) together imply that world welfare is maximized at (L, H).

Moreover, to see how preference heterogeneity affects jointly optimal standards, we may readily derive the following:

$$\frac{\partial(\theta_{cu}^N - \theta_{cl}^N)}{\partial s} < 0.$$

As expected, when preference asymmetry increases (i.e. s falls), differential standards (L, H) become more desirable as they will be optimal over a larger range of the externality.

We summarize the main results so far in the following proposition:

Proposition II.1. *Suppose countries coordinate their product standards. Jointly optimal policies under NT are as follows:*

(i) When the externality is large, i.e., $\theta > \theta_{cu}^N$ both countries choose the strict standard (H, H);

(ii) When the externality is moderate, i.e. $\theta_{cl}^N < \theta < \theta_{cu}^N$, country A chooses the lenient standard and country B enforces the strict standard: (L, H).

(iii) When the externality is small, i.e. $\theta < \theta_{cl}^N$, both countries choose the lenient standard: (L, L).

(iv) As preference heterogeneity increases, i.e. s falls, the range of the externality $[\theta_{cl}^N, \theta_{cu}^N]$ in which differential policies (L, H) are optimal expands.

Proposition II.1 emphasizes that differential product standards (L, H) are necessarily optimal when countries have heterogeneous preferences and the externality is moderate.

The reason is that such a policy profile allows country A to take advantage of the lower production cost of version L, and the gain of doing so would dominate the mild rise in the impact of the negative consumption externality. Moreover, as country A becomes less affected by consumption externalities, it should implement L for even higher levels of the externality, which leads the parameter range in which (L, H) prevails to increase.

Now let us establish jointly optimal standards under MR. In particular, countries now maximize world welfare as follows:

$$\max_{\sigma_i, \sigma_j \in \{H, L)} ww^M(\sigma_i, \sigma_j, \theta) \ s.t. \sigma_i = \sigma_{ii} = \sigma_{ji}. \quad \text{(II.15)}$$

Hence the MR constraint essentially demands that each firm follows a same standard across countries. There are also four policy combinations consistent with MR: (H, H), (L, L), (H, L) and (L, H). Note that the latter two profiles are different from those under NT that are represented by the same notations.

To begin with, it is easy to check that

$$ww^M(L, H, \theta) = ww^M(H, L, \theta) \ for \ all \ \theta, \quad \text{(II.16)}$$

that is, when policies are differential between countries, world welfare is not affected by which country implements the low standard. This is because both versions are produced in each country whether (L, H) or (H, L) is implemented. Moreover, as firms have identical cost functions it does not matter which firm produces version H (or L). In either case market prices and outputs are exactly the same across countries, and so is consumer surplus. It follows that total profit, i.e. the sum of each firm's global profit, also remains unaltered. However, note that the distribution of profit may vary between firms: the firm whose home country imposes a lenient standard will enjoy a cost advantage in both markets and hence make a larger share of the total profit. Without loss of generality, we will assume (L, H) as the policy profile that is actually chosen by both countries.

Under MR it is jointly optimal for both countries to impose the strict standard if the externality is high. Moreover, it can be shown that there exists a threshold θ_{cu}^M such that

$$ww^M(L, H, \theta) > ww^M(H, H, \theta) \text{ } if \text{ } and \text{ } only \text{ } if \text{ } \theta < \theta_{cu}^M, \qquad \text{(II.17)}$$

that is, imposing the low standard by country A is preferred if the externality falls below the threshold θ_{cu}^M. Similarly, we can find θ_{cu}^M such that

$$ww^M(L, L, \theta) > ww^M(L, H, \theta) \text{ } if \text{ } and \text{ } only \text{ } if \text{ } \theta < \theta_{cl}^M, \qquad \text{(II.18)}$$

i.e. it is optimal for both countries to set the low standard when the externality is small. Importantly, it can be shown that

$$\theta_{cu}^M < \theta_{cl}^M. \qquad \text{(II.19)}$$

What Eq. (II.19) says is that for $\theta_{cu}^M < \theta < \theta_{cl}^M$, (L, H) must be dominated by either (H, H) or (L, L) and thus will not be welfare maximizing. This leaves (H, H) and (L, L) as the only candidate policy options. Comparing these two policy profiles, we find θ_{cm} such that

$$ww^M(H, H, \theta) > ww^M(L, L, \theta) \text{ } if \text{ } and \text{ } only \text{ } if \text{ } \theta > \theta_{cm}. \qquad \text{(II.20)}$$

Moreover, it can be readily checked that

$$\theta_{cu}^M < \theta_{cm} < \theta_{cl}^M. \qquad \text{(II.21)}$$

Eqs. (II.20) and (II.21) together imply that both countries should choose either the strict or the lenient standard under MR, with θ_{cm} being the threshold of the externality that determines the switch between the two policy combinations. Note that this observation holds for all $s \leq 1$ and so does not depend on the existence of preference asymmetry.

The following proposition summarizes the above major findings:

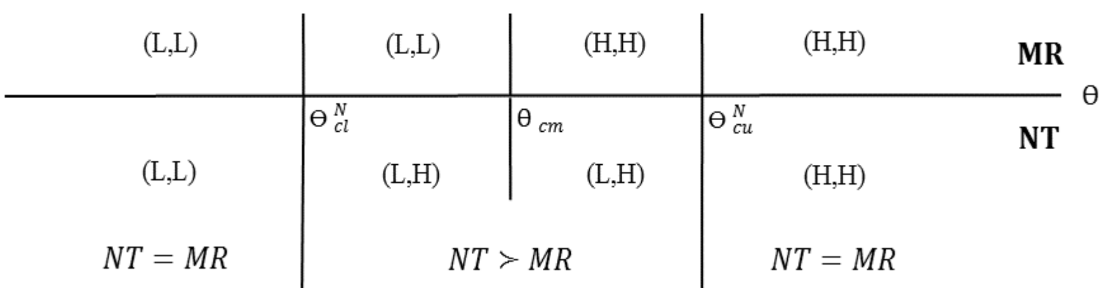
Proposition II.2. *Under MR, jointly optimal standards are symmetric regardless of the degree of preference heterogeneity. Specifically,*

(i) When the externality is large, i.e. $\theta > \theta_{cm}$*, both countries choose the strict standard* (H, H).

(ii) When the externality is small, i.e. $\theta < \theta_{cm}$*, both countries choose the lenient standard* (L, L).

Figure II.1 depicts the optimal standards under NT and MR.

Figure II.1: Optimal Product Standards and World Welfare Under Policy Coordination



Why are differential policies such as (L, H) never be optimal under MR? The reason hinges on the fact that when it is optimal to impose a low standard exclusively in country A, MR mandates the standard to mechanically apply in country B. This renders the cost of imposing the low standard unnecessarily borne by country B whose consumers value quality to a greater extent. Therefore, the pattern of differential policies under MR is inefficient from the social point of view.

Finally, it is important to note that preference heterogeneity plays a key role in driving the distinct patterns of optimal policies between NT and MR. In fact, under symmetry (i.e. $s = 1$) it is straightforward to show that $\theta_{cu}^{M} = \theta_{cl}^{M} = \theta_{cm}$, that is, coordinated standards under NT become symmetric regardless of the externality. Hence optimal policies under the two types of agreements coincide:

Corollary II.1. *Suppose countries are symmetric, i.e.* $s = 1$. *Then coordination under NT or MR yields the same optimal product standards.*

Welfare Analysis

We now investigate the welfare implications of the constraints imposed by NT and MR. We first propose a simple measure for the effectiveness of NT relative to MR, which will be useful to characterizing the effect of preference heterogeneity on the relative performance of the two types of agreements.

Definition II.1. *Let the effectiveness of NT relative to MR be measured as*

$$r = \frac{m(D)}{m(E)}, \qquad \text{(II.22)}$$

where $D = \{\theta | \theta \ for \ which \ NT \ yields \ strictly \ higher \ world \ welfare\}$, $E = \{\theta | \theta \ for \ which \ MR \ yields \ strictly \ higher \ world \ welfare\}$ *and* $m(\cdot)$ *denotes the Lebesgue measure on* R.

Moreover, if the denominator of r *is zero, i.e. MR never dominates NT, then we define* $r = m(D)$.

If the numerator of r *is zero, i.e. NT never dominates MR, then define* $r = \frac{1}{m(E)}$.

Thus, in a rough sense r simply reflects the relative range of θ for which NT is preferred to MR in terms of world welfare. A larger r indicates that NT yields higher world welfare over a greater portion of θ and will become more effective relative to MR. By definition we may consider r as a relatively "conservative" measure as compared to one based on the absolute changes in the range of θ such as $m(D) - m(E)$. This is because when r rises $m(D) - m(E)$ must also increase, but the converse may not be true. In the following analysis we will use r as the index for the evaluation of the efficacy of NT and MR.

It is also worth noting that a presupposition underlying the definition of the index r is that different levels of the externality contribute equally to calculating the relative effectiveness of alternative standards agreements. It can be expected that higher levels of externality may carry more weight as they could have larger impacts on social welfare. For tractability we have abstracted from this consideration. Nevertheless, as will be seen, NT tends to dominate MR for large values of the externality, and such dominance is amplified as preference asymmetry increases between countries. Thus, if NT performs relatively better between more asymmetric countries, a result that we will establish, then our findings would in fact be strengthened if also accounting for the gravity of externalities.

Now let us compare the welfare implications of NT and MR. An important observation is that NT yields weakly higher world welfare than MR for all θ, because optimal policies under MR are restricted to symmetric standards, while those under NT involve both symmetric and differential ones. In particular, it is easy to see that for $\theta \geq \theta_{cu}^N$ and $\theta \leq \theta_{cl}^N$, the two agreements are equally efficient by inducing the same optimal policies. For $\theta_{cl}^N < \theta < \theta_{cu}^N$, however, NT would dominate MR as symmetric standards are available under NT but are not chosen (see Figure II.1). By Definition 1, the effectiveness of NT relative to MR can then be written as

$$r_1 = \theta_{cu}^N - \theta_{cl}^N. \tag{II.23}$$

Moreover, it is easy to check that

$$\frac{\partial r_1}{\partial s} < 0.$$

Hence r_1 increases as s falls, implying that NT is relatively more effective between countries with a higher degree of heterogeneous preferences over the externality. These findings are summarized in the following proposition.

Proposition II.3. *Suppose countries coordinate their standards to maximize joint welfare.*

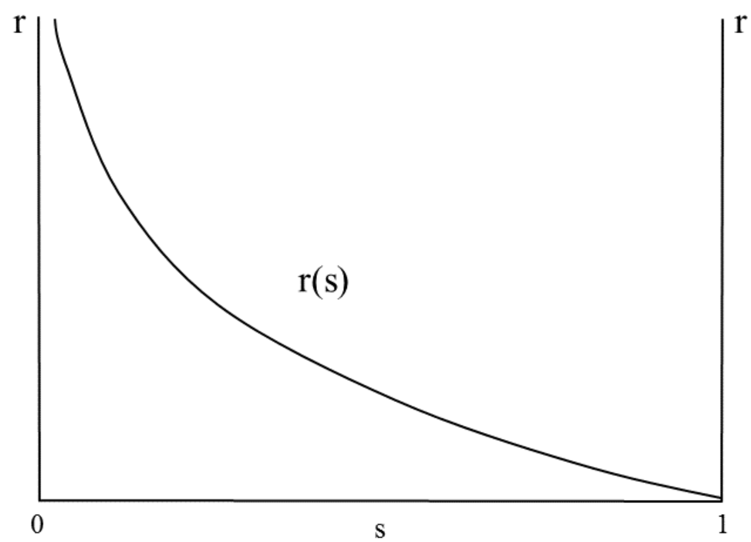
(i) NT yields weakly higher world welfare than MR for all levels of the externality. In particular, world welfare is strictly higher under NT for intermediate levels of the externality: $\theta_{cl}^N < \theta < \theta_{cu}^N$.

(ii) NT becomes relatively more effective than MR as countries possess more heterogeneous preferences over the externality.[14]

[14] Note that the reasoning is robust to how preference asymmetry is generated. Suppose instead $s_A = 1$ and s_B rises above 1, i.e. country B now cares more about negative externalities in an absolute sense. Then it is straightforward to check that NT will dominate MR over some new range $[\tilde{\theta}_l^N, \tilde{\theta}_u^N]$, and as s_B increases it can be shown that $\tilde{\theta}_l^N$ falls while $\tilde{\theta}_u^N$ remains unchanged. As a result $\tilde{\theta}_u^N - \tilde{\theta}_l^N$ continues to expand so that NT would still dominate MR for a larger range of the

Figure II.1 shows the weak dominance of NT while Figure II.2 depicts how the effectiveness of NT relative to MR varies with preference heterogeneity.

Figure II.2: Effectiveness of NT Relative to MR Under Policy Coordination



Proposition II.3 is important in two aspects. First, it characterizes the welfare cost or the stringency related to the constraints imposed by NT and MR. Part (i) of the proposition indicates that when country preferences are heterogeneous, the MR constraint tends to generate a weakly larger welfare cost than that of NT, thus being more stringent from a social point of view. Moreover, part (ii) says that the welfare cost of MR relative to NT tends to increase as the degree of preference asymmetry rises. The intuition for these results is clear. Under MR countries have to recognize foreign standards which may be rather different from domestic norms if preferences are fairly different across countries. This generates a negative international spillover represented by a mismatch of product standards

externality. This further implies that our results would remain valid if both s_A and s_B vary and diverge from each other. The intuition is that the relative performance of NT to MR depends on the degree of asymmetry in country preference rather than its magnitude.

that would affect both countries. In contrast, countries under NT have full control over the standards to be implemented in their domestic markets and therefore do not suffer from this mismatch problem. When countries coordinate their policies, they take this into account by foregoing differential policies under MR to avoid the mismatch problem. However, this reduces the available choice set by leaving them with symmetric policy profiles alone, which are less efficient than the differential ones under NT given the externality is moderate. As country heterogeneity increases, the constraint of MR appears relatively more stringent than that of NT because the differential policies under NT are optimal under a larger set of circumstances.

Second, part (ii) of the proposition indicates that although NT always weakly dominates MR, countries with more heterogeneous preferences would see NT as preferable to MR *to a greater extent*. This property could shed light on the observed choices by the WTO and the EU regarding their respective agreements on product standards. Specifically, let s_{WTO} and s_{EU} be the degrees of preference asymmetry for the WTO and the EU respectively and simply assume $s_{WTO} > s_{EU}$, that is, the WTO involves member countries with more heterogeneous preferences. Proposition II.3 then implies that our index r will take a greater value for the WTO than for the EU, that is, NT should appear more appealing to the WTO as the welfare improvement it induces over MR is larger for WTO members. On the other hand, the EU's preference for MR might seem puzzling at first sight since MR never dominates NT for all levels of the externality. However, it turns out that MR may involve other benefits which we do not explicitly model here, such as the avoidance of conversion cost for the exporting firms.[15] These extra gains could make MR favored by the EU but not the WTO, as the latter would benefit from NT more.

Interestingly, Proposition II.1 to II.3 together may also speak to the harmonization of product standards across countries, a principle that has been implemented to some extent in the EU.[16] Our analysis implies that the need for harmonization may depend on the nature of the standards agreement. In particular, an agreement based on MR would guarantee harmonization provided countries can coordinate their standards. In the meantime, our results also indicate that harmonization without qualifications (i.e. for all θ) is necessarily suboptimal between heterogeneous countries. In particular, while applying harmonized standards is desirable for very high or low levels of the externality, it is not so when the externality is moderate. As a specific example, consider the externality as pollution. Then Proposition II.3 implies that harmonization over $\theta_{cl}^{N} < \theta < \theta_{cu}^{N}$ would lead to either "race to the bottom" (i.e. uniform low standards (L, L)) or "green protection" (i.e. uniform high standards (H, H)) as compared to the optimal outcome under NT (i.e. (L, H)).

It is also useful to examine the first-best policies that are obtained under no institutional constraints. Similar reasoning as above indicates that, starting with uniform strict standards when the externality is very large, it is socially optimal to switch to the lenient standard first in country A and then in country B as the externality continues to decline. Moreover, we show in the Appendix that it is always optimal for either country to

[15] A conversion cost is the expenditure that occurs when firms switch between two different versions of a product. By definition c in our model, i.e. the production cost for the H version, should not be considered as a conversion cost because it does not arise when firms switch from H to L.

[16] In particular, the European Commission requires that a harmonized standard should be developed by recognized European Standards Organizations: CEN, CENELEC, or ETSI. There have been harmonized standards formulated for various industries such as chemicals, construction healthcare engineering, etc. Whether to adopt harmonized standards remains voluntary.

apply the lenient standard on both firms. In other words, discriminatory policies characterized by imposing the low standard on just one firm in either market are never efficient. Importantly, this implies that the optimal policies under NT are in fact consistent with the first-best outcome. Thus, we know that *while there can be an efficiency cost to imposing the MR constraint, such a cost is zero for NT*. We state this result in the following proposition:

Proposition II.4. *Coordination under NT leads to the first-best outcome. Therefore, optimal world welfare is not affected by the institutional constraint of NT, but it is reduced by the constraint of MR when the externality is moderate.*

Note that heterogeneity in country preferences plays a key role in driving a wedge in the welfare implications between the two types of agreements. In fact, by Corollary II.1 we immediately know that when countries are identical, world welfare is identical under both agreements for all levels of the externality:

Corollary II.2. *Under symmetric countries, NT and MR are equally effective, i.e. they yield the same world welfare for all levels of the externality.*

Global Externalities

In the real world some externalities can move across national borders and so are global in nature. In this section we investigate how global externalities may affect the relative performance of NT and MR. As the key driving force that gives NT an edge when externalities are local is the mismatch of standards induced by MR, we examine whether this mechanism would be altered in the presence of global externalities. To this end, we assume that the externality is caused by both domestic and foreign consumptions of the good:

$$U_i = \begin{cases} u - p_i - s_i(\varphi_i + \delta\varphi_j) & \text{if she buys either version} \\ -s_i(\varphi_i + \delta\varphi_j) & \text{if she buys nothing} \end{cases} \qquad i = A, B \quad \text{(II.24)}$$

where δ measures the impact of the externality arising from foreign consumption. We further assume that $\delta < 1$, i.e. the foreign externality causes a smaller damage on consumer utility than the domestic one. With the specification as in Eq. (II.24), we can use similar reasoning as above to find thresholds of θ that characterize the optimal standards under the two types of agreements. In particular, starting with uniform strict standards, we can find $\theta_u^{N\prime}$ under NT such that country A switches to the lenient standard, and $\theta_l^{N\prime}$ such that country B also does so. Moreover, it can be shown that

$$\theta_u^{N\prime} > \theta_l^{N\prime} \text{ if and only if } \delta < 1. \qquad \text{(II.25)}$$

Therefore, for $\theta_l^{N\prime} < \theta < \theta_u^{N\prime}$ differential policies (L, H) remain optimal under NT. Along similar lines, we can find $\theta_u^{M\prime}$ and $\theta_l^{M\prime}$ under MR which correspond to θ_u^M and θ_l^M under local externalities. Importantly, we can show that

$$\theta_u^{M\prime} > \theta_l^{M\prime}. \qquad \text{(II.26)}$$

As with the case of local externalities, condition (II.26) says that differential policies (L, H) are never optimal under MR. This leaves (H, H) and (L, L) as the only candidate policy combinations. It follows that there exists θ'_{cm} such that (H, H) is chosen for $\theta > \theta'_{cm}$ and (L, L) is preferred otherwise. As the pattern of optimal standards remains unchanged under global externalities, we know NT continues to weakly dominate MR and yields strictly higher world welfare for $\theta_l^{N\prime} < \theta < \theta_u^{N\prime}$. The reason is similar as before: over this range of θ symmetric standards are chosen under MR but they are inferior to the differential standards (L, H) under NT. Moreover, it is easy to check that fixing any δ, the range of θ in which NT strictly dominates MR (i.e. $(\theta_u^{N\prime} - \theta_l^{N\prime})$) expands, indicating that the effectiveness of NT relative to MR enhances between countries with more heterogeneous preferences. Therefore, under global externalities the mismatch of standards associated with MR remains, and our findings continue to hold.

Non-cooperative Product Standards

Nash Equilibrium

In this section we assume countries non-cooperatively set their product standards to maximize each's national welfare. This allows us to examine how the effectiveness of NT and MR may depend upon the strategic interaction of national product standards. Let us begin by characterizing the equilibrium outcome in the presence of NT. First, it is important to note that policy decisions under NT are independent across countries, i.e. the best response function for one country does not depend on the policy choice of the other.[17] The reason is that the non-discrimination constraint imposed by NT automatically eliminates the profit-shifting incentives as in Brander and Spencer (1985): in our context countries are

[17] An implication is that maximizing national welfare is equivalent to maximizing the sum of consumer surplus and firm's domestic profit, while the foreign profit will be determined by the other country's standard policies.

not able to shift profits to domestic firms via setting a higher standard exclusively on foreign competitors because doing so will violate NT.

Having that said, note that Nash equilibrium outcome depends critically on the magnitude of the externality. For sufficiently large θ, uniform strict standards must be the unique Nash equilibrium. To see why, note that due to preference asymmetry it is country A that always has a stronger incentive to loosen the standard as the externality becomes smaller. Hence we can identify θ_u^N below which country A would prefer the lenient standard such as

$$w_A^N(L,H,\theta) > w_A^N(H,H,\theta) \; if \; and \; only \; if \; \theta < \theta_u^N. \qquad \text{(II.27)}$$

Conversely, country A would stick with the strict standard when $\theta > \theta_u^N$. Moreover, country B would maintain the strict standard whenever country A does so because it views the negative externality as costlier. Therefore no country has an incentive to deviate to the lenient standard when $\theta > \theta_u^N$, which verifies that (H,H) is the unique Nash equilibrium.

Next we show that if the externality is sufficiently low, then (L,L), i.e. uniform lenient standards is the unique equilibrium. Note that starting from this outcome it is country B that is more willing to raise the standard as θ rises. This allows us to find θ_l^N which makes the following hold:

$$w_B^N(L,H,\theta) > w_B^N(L,L,\theta) \; if \; and \; only \; if \; \theta > \theta_l^N. \qquad \text{(II.28)}$$

Conversely, country B chooses the lenient standard as long as $\theta < \theta_l^N$. But whenever this is the case country A would also implement the lenient standard. Thus (L,L) is the unique Nash equilibrium for θ that falls below θ_l^N.

Moreover, as it can be shown that

$$\theta_l^N < \theta_u^N \text{ if and only if } s < 1, \tag{II.29}$$

we also need to solve for the equilibrium for $\theta_l^N < \theta < \theta_u^N$. Note that over this range neither (H, H) nor (L, L) can be an equilibrium outcome, because conditions (II.27) and (II.28) indicate that either country would have an incentive to deviate. Also note that given country A being less averse to the externality, it would never impose a lower standard relative to country B. This rules out (H, L) as an equilibrium for all θ. It follows that (L, H) must be the only possible equilibrium outcome. To see this is indeed the case, note that condition (II.27) indicates that country A would not have incentives to switch to the strict standard. Similarly, condition (II.28) tells us that country B also has no incentives to deviate to the lenient standard. Therefore, (L, H) is the unique Nash equilibrium over $\theta_l^N < \theta < \theta_u^N$.

It is also straightforward to examine the effect of preference asymmetry on the equilibrium outcome:

$$\frac{\partial(\theta_u^N - \theta_l^N)}{\partial s} < 0.$$

Hence as preference asymmetry increases (L, H) arises as an equilibrium outcome for more levels of the externality. We can summarize the above results as:

Proposition II.5. *Nash equilibrium standards under NT are as follows:*

(i) When the externality is large, i.e. $\theta > \theta_u^N$*, both countries choose the strict standard:* (H, H).

(ii) When the externality is moderate, i.e. $\theta_l^N < \theta < \theta_u^N$, *country* A *chooses the lenient standard while country* B *imposes the strict standard:* (L, H).

(iii) When the externality is small, i.e. $\theta < \theta_l^N$, *both countries choose the lenient standard:* (L, L).

(iv) As preference heterogeneity increases, i.e. s falls, the range of the externality θ *in which asymmetric equilibrium* (L, H) *arises expands.*

We may compare the policy outcomes with and without coordination to examine the effect of strategic incentives on the choice of standards. In particular, it is straightforward to derive that:

$$\theta_l^N < \theta_{cl}^N \; and \; \theta_u^N < \theta_{cu}^N. \qquad \text{(II.30)}$$

What Eq. (II.30) says is that countries are less willing to impose the low standard under NT when strategic incentives are present. The reason is that doing so under NT generates a positive externality for foreign countries: a lower standard has to apply to both firms and this raises foreign firm's profit by reducing its production cost. For instance, country B's firm makes a profit of $(1 - \mathrm{c})^2/9$ in country A under the high standard, while its profit rises to $1/9$ when country A switches to the low standard. The same holds for the profit of country A's firm earned in country B. This positive profit externality explains why NT leads to an overuse of the high standard as shown in Costinot (2008) between identical countries. As might be expected, Eq. (II.30) implies that this tendency continues to exist when countries have heterogeneous preferences over the externality.

Now consider Nash equilibrium under MR. By examining country A's incentives we can pin down the unique threshold θ_u^M above which both countries choose the strict standard. Specifically θ_u^M must satisfy

$$w_A^M(H,H,\theta) > w_A^M(L,H,\theta) \text{ if and only if } \theta > \theta_u^M. \qquad \text{(II.31)}$$

Along similar lines, one can show that there exists a threshold θ_l^M below which country B would turn to the lenient standard:

$$w_B^M(L,L,\theta) > w_B^M(L,H,\theta) \text{ if and only if } \theta < \theta_l^M. \qquad \text{(II.32)}$$

Thus both countries prefer the lenient standard as θ falls below θ_l^M. Furthermore, we make the following useful observation:

$$\theta_u^M > \theta_l^M \text{ if and only if } s < s_a^M, \qquad \text{(II.33)}$$

where $s_a^M \in (0,1)$ is a threshold for s. Eq. (II.33) indicates that θ_u^M can be larger or smaller than θ_l^M depending on the degree of preference asymmetry s. When preferences are similar across countries such that $s_a^M < s \leq 1$, we have $\theta_u^M < \theta_l^M$ which implies that both (H,H) and (L,L) could arise as equilibrium over $\theta_u^M < \theta < \theta_l^M$. In this case, we follow Costinot (2008) by focusing on the "most cooperative" outcome that would yield higher world welfare. To this end, recall that $ww^M(H,H,\theta) > ww^M(L,L,\theta)$ if and only if $\theta > \theta_{cm}$. Moreover, it is easy to check that $\theta_{cm} < \theta_u^M$. Hence (H,H) yields higher world welfare for all $\theta_u^M < \theta < \theta_l^M$ and will be the most cooperative outcome for later analysis.

Multiple equilibria arise under MR because of strategic dependence in the national product standards. In particular, it can be shown that standards between countries are strategic complements regardless of preference heterogeneity: a country is more likely to choose the standard that is enforced by its trading partner. Strategic complementarity occurs under MR due to the existence of profit-shifting incentives: as each country sets standards in both countries for its own firm, it is possible to adjust the standard so as to shift profits from foreign to domestic firm. This leads to a negative profit externality of lowering product standards under MR: when country A switches to the lenient standard, its firm would enjoy a reduced production cost and make more profit in both markets at the cost of country B's firm. This would make country B more willing to lower its standard as well to offset the negative shock to its firm. Particularly, the following can be shown to hold:

$$\theta_{cl}^{M} > \theta_{l}^{M} \text{ and } \theta_{cu}^{M} > \theta_{u}^{M}, \tag{II.34}$$

Eq. (II.34) indicates that the negative profit externality due to profit-shifting incentives make both countries tend to overuse the lenient standard under MR. Recall this is opposite to the pattern under NT in which countries are inclined to overuse the strict standard. Such a contrast arises exactly from the different nature of the profit externalities.

Interestingly, our analysis implies that multiple equilibria under MR would vanish if $s < s_{a}^{M}$, that is, when countries have sufficiently asymmetric preferences. In fact for $s < s_{a}^{M}$ we must have $\theta_{l}^{M} < \theta_{u}^{M}$, and over $\theta_{l}^{M} < \theta < \theta_{u}^{M}$ both (H, H) and (L, L) can no longer sustain as equilibrium because either country would have an incentive to switch the standard. Moreover, one can also rule out (H, L) as a viable equilibrium for all θ as given country A caring less about externality, it has no incentives to impose a higher standard than country B. Hence (L, H) is the unique equilibrium over $\theta_l^M < \theta < \theta_u^M$, as Eqs. (II.31) and (II.32) together imply that no incentives exist for either country to deviate.

Finally, given $\theta_l^M < \theta_u^M$ we can show that

$$\frac{\partial(\theta_u^M - \theta_l^M)}{\partial s} < 0.$$

Hence (L, H) would arise as a more prevalent equilibrium between countries with a higher degree of preference heterogeneity. We can state the following proposition:

Proposition II.6. *Nash equilibrium standards under MR depend on the degree of preference heterogeneity:*

a. When countries have preferences that are relatively alike, i.e. $s > s_a^M$*:*

(i) If the externality is large, i.e. $\theta > \theta_u^M$*, both countries choose the strict standard:* (H, H).

(ii) If the externality is small, i.e. $\theta < \theta_u^M$*, both countries choose the lenient standard:* (L, L).

b. When countries have sufficiently different preferences, i.e. $s > s_a^M$*:*

(i) If the externality is large, i.e. $\theta > \theta_u^M$*, both countries choose the strict standard:* (H, H).

(ii) If the externality is moderate, i.e. $\theta_l^M < \theta < \theta_u^M$*, country A chooses the lenient standard while country B imposes the strict standard:* (L, H).

(iii) If the externality is small, i.e. $\theta < \theta_l^M$*, both countries choose the lenient standard:* (L, L).

(iv) As preference heterogeneity increases between countries, asymmetric equilibrium (L, H) *arises for a larger range of the externality.*

Proposition II.6 generalizes the finding in Costinot (2008) which demonstrates that MR induces multiple equilibria under perfect symmetry. In particular, part (a) shows that multiple equilibria would occur as long as preferences are sufficiently similar between countries. Nevertheless, part (b) implies that multiple equilibria would disappear if consumer tastes become rather different between countries. The key reason is that greater preference asymmetry reduces the complementarity of national policies on product standards. To see this, note that as country A cares less about the externality, it tends to choose the lenient standard when the externality remains relatively high. This makes country B less likely to respond by lowering its standard because the welfare loss from incurring the externality is large. As a consequence, when strategic complementarity is sufficiently small, asymmetric standards (L, H) would arise as the unique Nash equilibrium.

We may also note a useful property of the threshold preference asymmetry s_a^M. The result would be useful to proving Proposition II.7 below.

Lemma II.1. *The threshold* s_a^M *is decreasing in* c. *In particular,* $s_a^M(c = 0) = 1$.

Lemma II.1 says that the profit-shifting incentives under MR, and hence the likelihood of multiple equilibria, depend on the cost differential between the two versions of the good. A lower c represents a smaller cost differential, which weakens the profit-shifting incentives since the gains from loosening the standard decline. This reduces the degree of strategic complementarity and makes multiple equilibria less likely to occur. In particular, as $c = 0$ the two versions of the good become indistinguishable so that strategic complementarity simply vanishes. This can be seen by noting that both θ_u^M and θ_l^M would collapse to θ_{cm} at $c = 0$, implying that unique equilibrium is guaranteed for all $s \leq 1$.

Finally, we make an observation regarding the Nash equilibrium under symmetric countries. As shown in Costinot (2008), both countries choose the lenient standard under NT at a lower level of externality than under MR, and neither agreement induces socially optimal outcome due to the existence of profit externalities. Thus unlike the case of coordination analyzed above, NT and MR no longer induce the same policy outcome in the presence of strategic incentives. Since Costinot (2008) examines Nash game, the difference in the equilibrium outcome between the two types of agreements reflects a compound effect from the two factors highlighted by our analysis: institutional constraint related to the agreement and strategic policy interaction. By Corollary II.1 we readily know that such a difference arises exclusively from strategic interaction as both agreements impose the same institutional constraint when countries are identical.

Welfare Analysis

We now examine the effectiveness of NT relative to MR under non-cooperative product standards. We first state the main results that summarize the comparison of the welfare effects for NT and MR and then discuss their implications:

Proposition II.7. *When countries set product standards non-cooperatively, the following hold:*

(i) NT and MR are equally effective for very large and small values of the externality, i.e. $\theta > \theta_u^M$ *and* $\theta < \theta_l^N$.

(ii) For intermediate levels of the externality $\theta_l^N < \theta < \theta_u^M$, *the performance of NT and MR depends on the preference heterogeneity* s.

(ii-a) For relatively large and small s (i.e. $s > \frac{3}{4}$ *and* $s < \frac{3}{5}$*), NT yields higher world welfare for relatively high levels of the externality, while MR dominates for relatively low levels of the externality.*

(ii-b) For intermediate levels of s (i.e. $\frac{3}{5} < s < \frac{3}{4}$*), the pattern in (ii-a) holds for two separate but consecutive intervals of* θ.

(iii) The effectiveness of NT relative to MR first decreases and then increases as preference heterogeneity rises.

The proof is relegated to the Appendix.

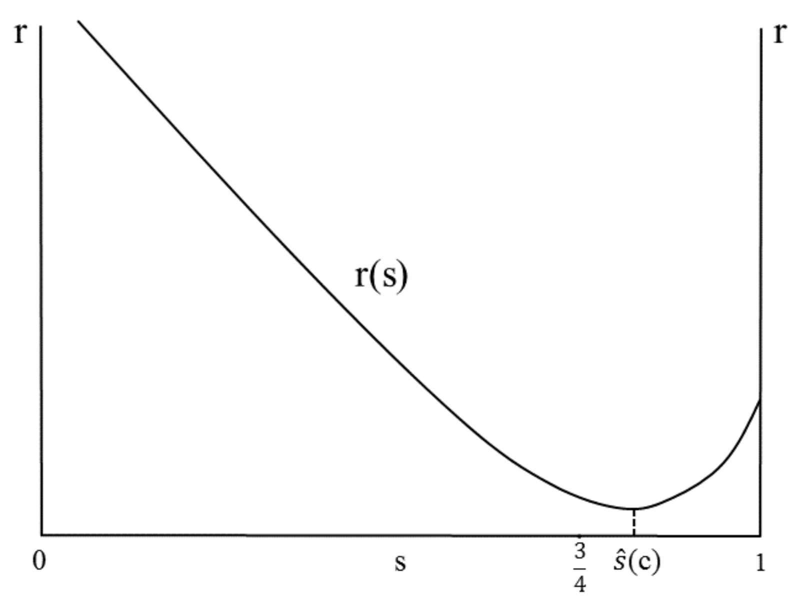
Part (i) of the proposition holds because for very large and small values of the externality both NT and MR induce the symmetric equilibrium outcome (i.e. (H, H) or (L, L)). In particular, we have $\theta_u^N < \theta_u^M$ as countries are more likely to switch to the low standard under MR. Thus (H, H) will be the equilibrium under both types of agreements as long as $\theta > \theta_u^M$. Similarly, for the lower end of θ we have $\theta_l^N < \theta_l^M$ so uniform low standards (L, L) attain for both agreements when $\theta < \theta_l^N$. It follows that world welfare is the same under NT and MR given $\theta > \theta_u^M$ and $\theta < \theta_l^N$.

Part (ii) of the proposition contains two notable messages. First, while NT always weakly dominates MR under coordination, with strategic policy interaction NT may yield lower welfare than MR over certain ranges of the externality. As discussed, this is because strategic incentives create a source of efficiency loss under NT by making countries tend to overuse the strict standard. Meantime, countries are also tempted to overuse the lenient standard under MR due to the strategic complementarity of national policies on product standards. These two forces together explain why NT on average dominates MR for large values of the externality but is less efficient when the externality is small. While this is the central finding in Costinot (2008), part (ii-a) of Proposition II.7 extends the result by showing that the pattern continues to hold when preference asymmetry is either large or small.

Second and perhaps more importantly, part (ii-b) of the proposition indicates that the pattern would exist for multiple ranges of θ when preference heterogeneity is moderate. The reason is subtle but hinges on emergence of asymmetric policies under NT. This can be illustrated for example from Figure II.6. In particular, the range $\theta_u^N < \theta < \theta_u^M$ is exactly the case examined in Costinot (2008) where equilibrium policies are symmetric under both agreements and NT (MR) dominates over larger (small) values within this range. However, the asymmetric equilibrium under NT now creates a new range $\theta_l^N < \theta < \theta_u^N$ where NT is likely to dominate MR, but due to strategic incentives NT outperforms MR only over the upper section $\theta_{cl}^N < \theta < \theta_u^N$. Therefore, the pattern in Costinot (2008) can be a local rather than a global feature given heterogeneous country preferences. This has important policy implications. In particular, Costinot proposes that for symmetric countries NT and MR should be enforced for relatively high and low levels of the externality. By contrast, our analysis shows that such a policy arrangement is optimal between similar countries but may be inefficient when there exists an intermediate level of country heterogeneity.

Moreover, recall that under coordination the effectiveness of NT relative to MR is monotonically increasing in the degree of preference asymmetry, whereas from part (iii) we know this relationship takes on a U-shape curve when strategic interaction is present. The intuition for this result is the following. For s close to one, the problem of standards mismatch is minimized under MR because symmetric policies such as (H, H) prevail. On the other hand, under NT the welfare cost arising from strategic incentives increases as preference asymmetry increases. This leads NT to become less effective as compared to MR when s falls while being close to one. As s continues to decrease, however, asymmetric equilibrium occurs under MR so the mismatch of standards starts to play out. This leads NT to be more desirable than MR as taste asymmetry further rises. Figure II.3 depicts how preference heterogeneity may affect the effectiveness of NT relative to MR in the presence of strategic interaction.

Figure II.3: Effectiveness of NT Relative to MR Under Nash Equilibrium



Finally, we argue that from the welfare perspective, NT would be considered as more appealing to the WTO than to the EU given the non-monotonic relationship between s and r. Indeed, our argument would hold as long as $s_{WTO} < \frac{3}{5}$, which is a mild condition given the existence of considerable heterogeneity among WTO members. To see why this condition suffices, note if $s_{EU} < \hat{s}(c)$ where $\hat{s}(c)$ is the turning point of the U-shaped curve in Figure II.3, then both s_{WTO} and s_{EU} are on the left part of the curve. This implies that r is always higher for the WTO than for the EU, which is the desirable result. If $s_{EU} > \hat{s}(c)$, i.e. s_{EU} being on the right part of the curve, then the largest possible r for the EU is $r_5(s = 1)$ where r_5 is defined by (A.22) in the Appendix. But it can be shown that

$$r_3(s) > r_5(s = 1) \text{ } if \text{ } and \text{ } only \text{ } if \text{ } s \leq \frac{3}{5}, \tag{II.35}$$

where r_3 is defined by (A.19) in the Appendix. As a result, r must take a larger value for the WTO than for the EU as long as s_{WTO}. Moreover, it is expected that some heterogeneity also exists within the EU so that we actually have $s_{EU} < 1$. In this case our argument would be strengthened as the value of r for the EU now becomes lower, indicating that the threshold for s_{WTO} will be even higher. Therefore, regardless of policy coordination, the WTO should be more likely to favor NT over MR when compared to the EU. Our analysis thus provides an insight that is consistent with the choices of the WTO and the EU between NT and MR as two main types of product standards agreements.[18]

[18] It is worth noting that our comparison is based on the assumption that the WTO and the EU have the same number of countries. Given that the WTO involves more countries, it should be subject to a larger effect of strategic interaction. But such effects will apply to both NT and MR and will work to cancel out one another when we calculate r for the WTO. Also note that this is not a concern under coordination because strategic interaction is completely ruled out.

Conclusion

This chapter argues that country heterogeneity has important implications for the relative effectiveness of alternative international agreements on product standards. To this end, we examine existing standards agreements based on two distinct principles: National Treatment and Mutual Recognition. We focus on a highly empirically relevant dimension of country heterogeneity which concerns consumer preferences for product quality. Employing a simple model of quality standards, we show that NT is more effective than MR between countries that exhibit more diverging preferences. Importantly, the key mechanism that makes MR relatively less desirable is the mismatch of standards induced between countries, a problem that does not arise under NT. Our findings therefore provide justifications for the observed choices of standards agreements by the WTO and the EU. We also find that when countries have heterogeneous preferences, the pattern in which NT and MR dominate respectively can be different from those between identical countries. In particular, with preference asymmetry NT may not always be preferred to MR for goods associated with high levels of externalities.

While our analysis provides some new insights, we have abstracted from several important considerations. For example, we ignore political incentives that can affect the adoption of certain trade agreements, while such incentives are widely applicable in the real world. Also, we have focused exclusively on product standards. Taking account of other policy instruments such as tariff and intellectual property protection could yield useful insights. Finally, while our study emphasizes the demand-side heterogeneity, countries can be different along multiple dimensions. For example, technology asymmetry across countries is also a prevalent phenomenon. Analyzing product standards agreements under alternative types of heterogeneity constitutes an interesting avenue for future research.

CHAPTER III

THE NATURE OF INNOVATIVE ACTIVITY AND THE PROTECTION OF INTELLECTUAL PROPERTY IN ASIA

Introduction

The Agreement on Trade Related Aspects of Intellectual Property Rights (TRIPS) was perhaps the most important and controversial outcome of the Uruguay Round (1986-95) and multilateral negotiations that led to its birth were rather contentious, with developing and developed countries expressing very different opinions about the need for a multilateral agreement on intellectual property rights (IPRs).[1]

TRIPS negotiations were driven by a deep-rooted sense of dissatisfaction in the United States with the state of IPR protection in the global economy, especially with the widespread imitation and piracy occurring in major developing countries (many of them Asian). Several major policy reports issued by leading governmental organizations in the United States (US) had raised concerns about the substantial losses being incurred by key US industries due to the lack of adequate IPR protection in foreign countries.[2]

Supported by the European Union and Japan, the US was successful in introducing IPRs into the multilateral negotiating agenda of the Uruguay Round that began in 1986 and culminated in 1995. Major developing countries such as Brazil, India, and China were not the only ones opposed

[1] See Maskus (2000) and Maskus (2012) for comprehensive overviews of the economics of IPRs in a global setting and extensive analysis of the various facets of TRIPS.
[2] See, for example, United States International Trade Commission (USITC) (1988), US-Chamber of Commerce (1987), and the annual reports issued by the office of the United States Trade Representative.

to the inclusion of any rules pertaining to IPRs into the multilateral trading system. There was widespread skepticism among academicians and other neutral observers regarding the merits of and the need for TRIPS. Indeed, it is fair to say that a shadow of skepticism hangs over TRIPS even today.

In a nutshell, TRIPS called for all members of the World Trade Organization (WTO) to adopt certain minimum standards with respect to the protection of IPRs and its main practical effect was to force developing countries to alter their IPR policies to bring them closer to those of rich countries, such as the USA. However, this adjustment was not expected to occur immediately. When TRIPS took effect on 1 January 1995, while developed countries were given only 1 year to ensure that their laws and practices were TRIPS - compliant, developing countries were given 5 years (until 2000). Least-developed countries had 11 years to achieve TRIPS compliance, until 2006 - which was then extended to 2013, in general, and to 2016 for pharmaceutical patents and trade secrets.

In this chapter, we critically examine recent changes in the volume and the nature of innovative activity in major Asian economies during the post TRIPS era. At the outset, we note that our analysis is descriptive in nature, and we do not mean to suggest that these changes in innovative activity were caused primarily by TRIPS, although it is difficult to believe that they were totally unrelated to TRIPS either. To limit the scope of the work, we focus on countries that have been major contributors to innovative activity within Asia since the ratification of TRIPS: Japan, China, India, South Korea, Singapore, and Malaysia. Among these, we pay special attention to China and India since the policy environment of these two large countries was significantly altered by TRIPS.

Wherever relevant, we provide a comparison of innovative activity in the BRICS (Brazil, Russia, India, and China) countries. We also briefly discuss the observed variation in the nature of innovative activity within Asia as well as BRICs during the post-TRIPS era. To this end, we examine not only the variation in the fields of technologies of patent applications across countries, but also in the ratio of the number of patent applications to utility models (as well as industrial designs). It is worth noting at the outset that since our analysis abstracts from institutional factors, it cannot shed light on the role that differences in national innovation systems play in determining the level and nature of innovative activity in different countries. In other words, our primary focus is on describing the variation in such activity across our chosen set of countries during the post-TRIPS era. Perhaps future research can explore factors that help explain this observed variation.

The Protection of Intellectual Property in the Global Economy Post TRIPS

A commonly used index for measuring the degree of patent protection available in a country is the Ginarte-Park (GP) index. This index is the sum of scores earned by a country in five separate categories pertaining to patent protection: coverage, membership in international treaties such as TRIPS, the duration of protection, enforcement mechanisms, and restrictions (such as compulsory licensing) that limit a patent-holder's control over its invention. The scores range from 0 to 5.

Table III.1: Ginarte-Park index, 1995-2010

Country	1995	2000	2005	2010
China	2.12	3.09	4.08	4.21
India	1.23	2.27	3.76	3.76
Japan	4.42	4.67	4.67	4.67
Malaysia	2.70	3.03	3.48	3.68
Singapore	3.88	4.01	4.21	4.21
South Korea	3.89	4.13	4.33	4.33
USA	4.88	4.88	4.88	4.88

Table III.1 reports the GP index for selected Asian countries and the USA during the post-TRIPS era. As one might expect, the degree of patent protection in the USA remains essentially flat at 4.88 (quite near the maximum possible value of 5.0) for the entire time period. Similarly, TRIPS had little effect on the degree of patent protection available in Japan, Korea, and Singapore.

As per Table III.1, the sharpest changes in patent protection occurred in China and India: the value of the index for India increased sharply from 1.03 to almost 3.76 while that for China, it doubled from 2.12 to 4.21. These are large changes with important economic implications not just for India and China but also for the rest of the world.

Patent Applications and Grants

Global patent applications have grown rapidly during the post TRIPS era. Indeed, global patent applications in 2011 were roughly twice that in 1997.[3] Asia has been the single biggest driver of global patent applications during the post-TRIPS era: its share of global patent applications has hovered around 50% during the 1997-2011 period. Over the same time period, North America's share increased slightly from roughly 20% to 25% whereas that of Europe fell from 20% to 15%.

Within Asia, the changes appear to have been rather dramatic.[4] The big story, of course, has been the emergence of China. In 1997, Japan dwarfed the other Asian countries in terms of patent applications and grants but it was overtaken by China in 2010. Indeed, so sharp and salient has been China's rise that patent filings in China during 2011 not only exceeded those in Japan but

[3] Unless otherwise noted, the data for the various figures and tables contained in this work have been taken from the World Intellectual Property Organization: http://ipstatsdb.wipo.org/ipstatv2/ipstats/patentsSearch.
[4] We limit our discussion to China, India, Japan, Malaysia, South Korea, and Singapore since these countries account for over 90% of the patent applications and grants in a typical year.

also the US, *making China the country with the largest number of patents filed (and granted) in 2011*. Roughly 25% of all patent applications filed in the world during 2011 were filed in China. The corresponding shares for the US and Japan were 24% and 16% respectively.

While these statistics pertaining to China's emergence are undoubtedly impressive, it is important to interpret them carefully. Count data on patent applications (and grants) tell us virtually nothing about the economic values or the qualities of the underlying technologies. Indeed there is widespread recognition in the Chinese leadership that while the number of patent applications in China has increased sharply along with investment in research and development (R&D), the quality of local patent applications remains relatively low. The first objective stated in the Chinese *Promotion Plan for the Implementation of the National Intellectual Property Strategy* is to "improve IP appraisal and assessment system… and *to shift the focus on IP quantity to IP quality*, and boost IP value."[5] Of course, the concern with patent quality is hardly unique to China: examples abound of trivial inventions that have been granted patents even in the USA.[6] Yet, using some additional data, we will argue below that this concern is especially acute for China.

Consider now the data on patents granted within Asia and the rest of the world. During 2011, nearly 1 million patents were granted world-wide, with roughly 40% of them accruing to non-residents, a clear reflection of the globalization of contemporary innovation. Roughly 7.88 million patents were in force globally during 2011, over 25% of these being in the USA.

From 1997 to 2011, the number of patents granted in Asia more than doubled. While more patents were granted in 2011 in all Asian countries, the sharpest increase was witnessed in China, where the number in 2011 was almost *50 times* that in 1997. This massive increase in the number

[5] This report is available at http://english.sipo.gov.cn/laws/developing/201204/t20120410_667158.html.
[6] See Maskus (2012) for some examples of patents granted by the United States that have attracted widespread criticism and helped fuel the concern that patent protection in the US has gone overboard.

of patents granted in China is even more impressive considering the fact that China's grant rate over this time period (of around 40%) was quite comparable to that of the Japan and USA.[7]

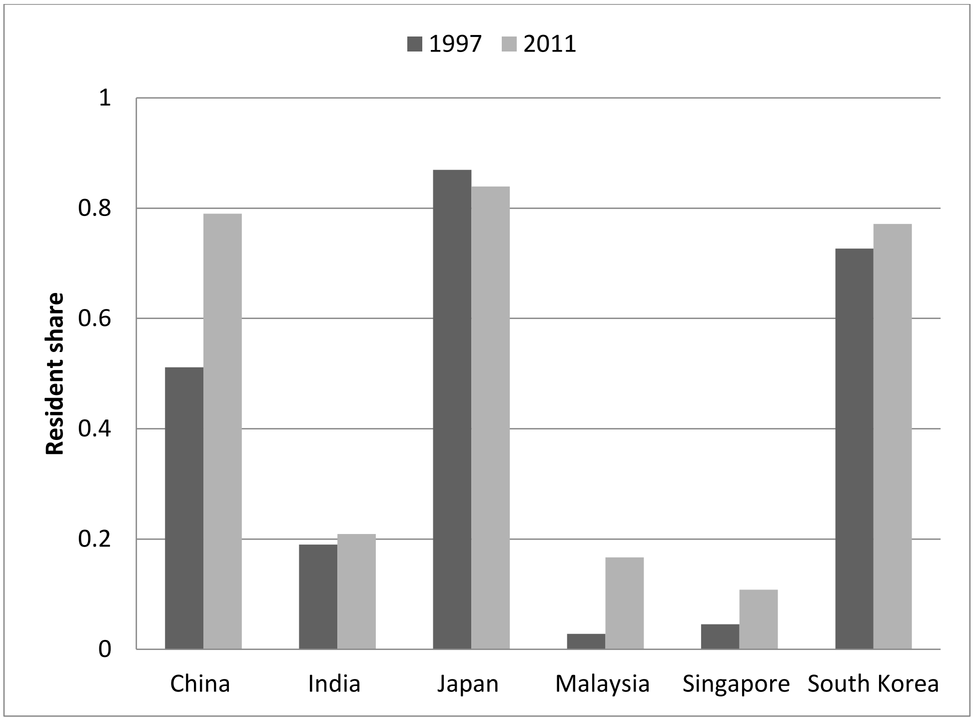
Patent applications in Asian countries vary substantially at the industry level. For example, from 1998-2012, while digital communications was the most important industry in China (accounting for 9% of all patent applications), the chemical and pharmaceutical industries dominated in India, accounting for 22% and 24% of applications, respectively. Indeed, India is unique among Asian countries, and perhaps in the world, in exhibiting such a heavy reliance on a few industries as engines of innovation. There is substantial overlap between Japan and Korea in terms of the key industries that drive innovation in these economies. Indeed, in both countries, the key industries driving innovation are electrical machinery, audiovisual technology, computer technology, semiconductors, and optics.

Since TRIPS has increased patenting incentives of both residents and non-residents, we next examine variation within Asia with regard to the role played by residents of each country in driving patenting activity in order to roughly gauge the share of innovation that is indigenously generated.

Figure III.1 shows the residents' share of patent applications in Asian countries. From 1997 to 2011, the share of local residents in total patent applications filed in China surged from around 50% to roughly 80%, while the increase in Malaysia was of an even higher order of magnitude. By contrast, in Japan, the share of local residents declined slightly, as it did in Asia overall. One could perhaps reasonably interpret the increase in the share of patents filed by residents in China as an indication of its enhanced ability to innovate.

7 We calculated ratios of patent grants to patent applications (lagged by 1 as well as 2 years). The estimated grant rate was then calculated by averaging these two ratios.

Figure III.1: Resident Share of Patent Applications

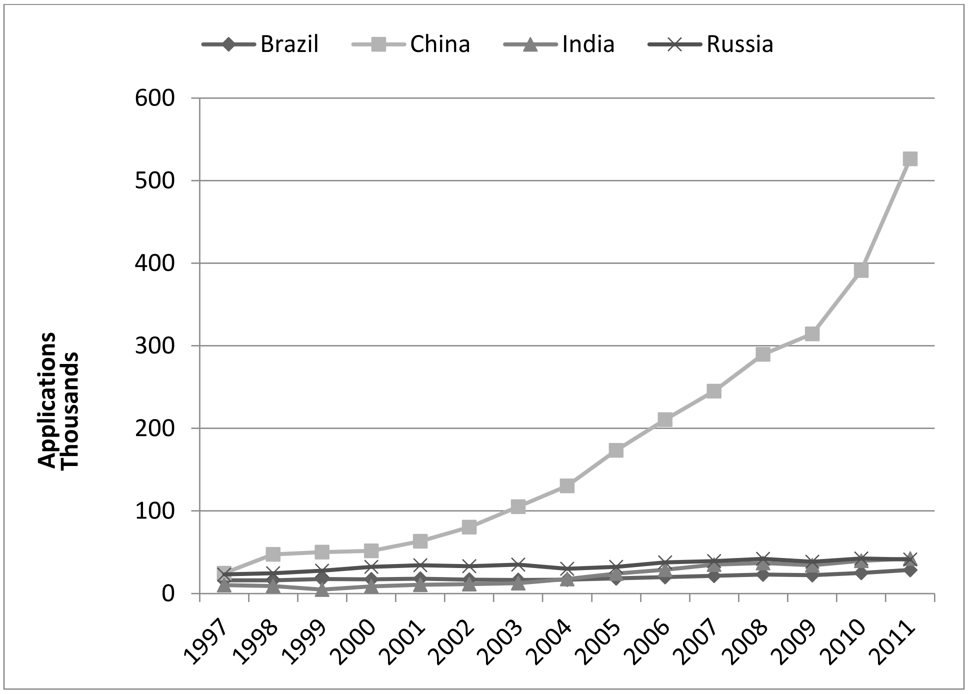


Patenting Activity Within BRICs

Much attention has been paid to the rise of BRICs during the last few decades and their economic performance relative to each other. It is interesting to compare BRICs from the viewpoint of innovative activity. Figure III.2 presents the raw data on patent applications in BRICs. This figure hardly needs explanation: China simply *dwarfs* the other BRICs countries in terms of patent applications filed during 1997-2011.

The two BRICS countries other than China and India exhibit a fairly different pattern of innovation than leading Asian countries such as Korea and Japan. For example, the major sources of innovation in Brazil are medical technology, civil engineering, furniture, and other special machines, with each of the industries accounting for roughly 6% of patent applications. For Russia, the important innovative industries are pharmaceuticals, medical technology, civil engineering, and food chemistry. The composition of industrial innovation in Russia is more like that of India as opposed to South Korea.

Figure III.2: Patent Applications in BRICs



Focusing only on patent filings and grants in individual during the post TRIPS era only gives us an incomplete picture of the innovative capacity of a country since these measures do not tell us much about the *stock* of intellectual property available to a country. For example, while patenting activity in China has increased rapidly during the post TRIPS era, in 2012 Japan had roughly twice the number of patents in force than China. However, relative to BRICs countries, the Chinese stock of patents in 2012 was rather large: China had roughly twice the number of patents in force relative to Brazil, more than four times that of Russia, and more than *twenty times* that of India. Since the variation in quality of patents across BRICs countries is likely to be a secondary concern, there is little doubt that, at least among the lower and middle countries, China has truly emerged as a major player in the field of innovation.

Outward Orientation of Patenting: A Measure of Quality

It stands to reason that firms have strong incentives to protect their most important inventions in foreign markets. As a result, we can obtain a rough gauge of the quality of a country's patent portfolio by examining the share of total patent applications that are filed abroad by its residents. If the residents of a country tend to file a small percentage of its patent applications abroad, it implies that a majority of domestic patent-holders do not find it worthwhile to seek protection in foreign markets, a position they are unlikely to take if their inventions are valuable and high quality.

As a benchmark, consider the behavior of US residents - widely perceived to be the most innovative country in the world. In 2000, 41% of all patent applications filed by the US residents worldwide were in foreign markets; in 2010 the analogous number was 44%. Table III.2 presents patent applications filed abroad by residents of Asian and BRICs countries as a share of their total applications.

Over the relevant time period, Japanese residents started to file an increasing share of its patents abroad; the same is true of Korea, although to a lesser extent. Not only is the ratio of foreign to domestic patenting quite small for China, it has not changed much during the post TRIPS era. By contrast, India exhibits a stronger tendency to file patent applications in foreign markets. The share of foreign patent applications as a share of total resident applications by Chinese residents is also quite small relative to the other BRICs countries. While hardly conclusive, this evidence supports the view that the quality of most patent applications in China may not yet be high enough to merit protection in global markets.

Table III.2: Patent Applications Filed Abroad by Residents

Country	2000 (%)	2005 (%)	2010 (%)
Brazil	15.9%	17.6%	26.3%
China	4.3%	4.6%	5.0%
India	23.6%	41.2%	40.5%
Japan	21.8%	30.6%	38.1%
Malaysia	8.9%	43.3%	36.5%
Russia	3.0%	8.3%	11.7%
Singapore	26.8%	70.0%	78.8%
South Korea	15.1%	24.9%	26.2%
USA	41.3%	45.8%	44.1%

Consider now the evidence from patents granted in foreign markets. In the year 2010, patents granted to US residents in foreign markets accounted for roughly 44% of their total number of patents. The corresponding percentages for Japan and Korea were 35% and 32% respectively. By contrast, only 6% of the patents granted to Chinese residents worldwide during 2010 were granted by other countries. Thus, an overwhelming percentage of patents granted to Chinese citizens in 2010 were granted domestically. It is worth pointing out that even residents of Brazil and India had a much higher rate of foreign patenting: in 2010, foreign patents accounted for approximately 61% of the total patents granted to residents of each country.

It stands to reason that the tendency to patent abroad is likely to be stronger for inventors residing in smaller countries. For example, 80% of the total patents granted to Singapore residents were from abroad. It is possible that the large size of the Chinese market reduces the incentives of Chinese residents to seek patents in other countries. But this cannot be an important part of the story for several reasons. First, the Chinese economy is highly export oriented and its firms have come to capture a large share of the global market in many industries. Why then would they not do the same in the context of innovation if it were possible for them to do so? Second, and perhaps more fundamentally, the decision to file for a patent application in another country depends upon a comparison of the *marginal* benefit of doing so relative to its *marginal* cost. If an innovation is of high quality, it ought to be valued world-wide. It is conceivable that a large domestic market creates incentives for investing in innovations that are only valuable locally, perhaps due to idiosyncratic differences in consumer tastes across countries. If so, residents of large countries could show a domestic bias in terms of innovation and patenting. However, this argument in no way changes the marginal calculus determining patent application behavior in foreign markets. Furthermore, as Table III.2 notes, residents of the largest market in the world, i.e. the United States, have a rate of foreign patenting that is roughly *ten times* that of Chinese residents.

Trends in Filings and Grants of Other Types of IPRs

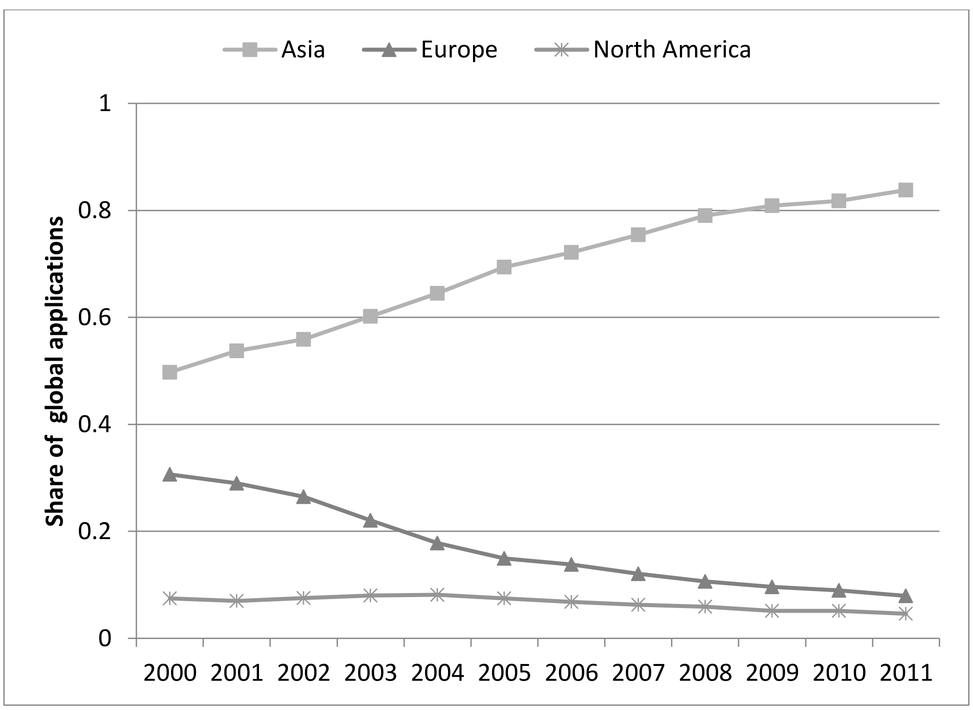
We next consider trends in filings and grants of industrial designs, utility models, and trademarks during the post TRIPS era.

Industrial Designs

An industrial design is an innovation pertaining to the functional, ornamental or aesthetic aspect of a good. Industrial designs differ from patents in several fundamental ways. First, while patented inventions are primarily technology-based, industrial designs generally have low technology content and can even be purely artistic innovations. Second, industrial designs tend to be much more market-oriented in the sense that industrial designers are generally motivated by consumer preferences when developing new designs. As a result, industrial designs are brought to market relatively more quickly and there tend to be fewer “junk” industrial designs. Under TRIPS, the minimum protection granted to industrial designs is 10 years (relative to 20 years for patents).

Global industrial design applications worldwide grew substantially over the time period 1997-2011. Notably, the average growth rate over this time period was 9.3%, the highest of all the forms of IPRs investigated in this chapter. Examination of regional data reveals that Asia has played a dominant role in driving world industrial design applications: Asia’s share of global industrial design applications rose from roughly 50% in 2000 to 84% by 2011. North America accounts for a very small share of global industrial design applications (only around 4.6% in 2011). Similarly, Europe’s share dropped rather sharply from around 31% in 2000 to 8% in 2011. Figure III.3 summarizes these observations.

Figure III.3: Geographic Variation in Industrial Design Applications



Consider now the variation within Asia. The foremost observation is that during 2011, China accounted for over 80% of all industrial design applications in Asia, sharp increase from its share of 38%. In 2011, China's share was about 20 and 10 times that of Japan and Korea respectively. Notably, as in the case of patents and trademarks, Japan's share of industrial applications has shrunk over time.

China's growth in industrial design applications is also striking within the context of BRICs. In 2001, the size of China's industrial design applications was about 16, 18 and 24 times larger than Brazil, India and Russia respectively. These remarkable ratios increased further to astounding levels of 76, 63 and 124 in 2011. Thus, the scale of innovative activity in China is getting progressively larger relative to other BRICs, a development that is surely going to have implications for the relative long run per capita incomes of these countries.

Utility Models

A utility model is an intellectual property right similar to a patent but it is granted for smaller inventions.[8] Although a utility model is granted only if an invention is novel, it does not necessitate a sufficiently large inventive step as compared to a patent. Indeed, utility models are sometimes called "petty patents". The approval process of utility model is often simpler and shorter, as patent offices in most countries do not review applications regarding their substance prior to registration. Moreover, the term of utility model is typically shorter, mainly ranging from 7 to 10 years with preclusion of extension or renewal.

[8] Not all countries grant utility models. For example, the US does not. Among Asian countries that we focus on, utility models are granted by all except India and Singapore.

The number of global applications for utility models more than quadrupled over 1997-2011 from one hundred and fifty thousand to more than six hundred and seventy thousand. This translates into an average growth rate of 11.2% per year. Notably, the growth of utility model applications has been even more striking in recent years. While the average growth rate over 1997-2008 was 6.8%, that over 2008-2011 was a remarkable 28.8%.

The dramatic growth of global applications for utility models was driven predominantly, once again, by China. While China accounted for about 33% of global utility model applications in 1993, its share had risen to 87.3% in 2011. This reflects an average growth rate of utility model applications of 19.2% in China over 1997-2011, and an even more remarkable growth rate of 37.4% over 2008-2011. Within Asia, today China is undoubtedly the dominant receiver of utility model applications: it accounted for 91.3% of these applications in 2011. Within BRICs, Russia follows China with the second largest number of applications. Notably, Russia and Republic of Korea are also the third and fourth largest offices for utility model applications.

Compared to patents, utility model applications tend to be more locally concentrated: residents enjoy a dominant share of these applications across countries. For example, China's resident share of utility model applications during 2011 was 99.3% while for patent applications the corresponding share was only 79%. Also, in 2011 China Hong Kong featured a low share of resident patent applications of about 1.3% whereas the share of resident utility model applications was 63.2%. This pattern is prevalent worldwide and reflects the fact that innovations seeking utility models are less likely to be world-class and hence not profitable enough to justify seeking protection overseas.

Our discussion above indicates that one might expect utility model applications to have higher a grant rate than patent applications. This hypothesis is strongly supported by data. For example, the estimated grant rate worldwide for utility models was 76.8% over 1997-2011 whereas that for patents was 44.3%.[9] Asian countries or BRICs for whom data are available all exhibit grant rates for utility model applications that exceed 70%, while the grant rates for patent applications are generally below 50%.

Trademarks

A trademark is a word, phrase, symbol, and/or design used to distinguish a good or service of one firm from those of other firms. Once a firm is able to establish a reputation for a high quality product, its trademark allows the firm to benefit from repeat purchases and word-of-mouth references as well as other forms of promotional activities. Unlike a patent, a trademark does not have any time limits: once established, a trademark can exist indefinitely.

The number of global applications for trademarks more than doubled during 1997-2011 from about two million to over four million. Like patents, the sharpest increase was observed in Asia where the number increased from about half a million to over two million. By contrast, the increase in North America was relatively modest. While evaluating these numbers, it is worth bearing in mind that some of the best known trademarks of the world – such as those of Coca Cola, Macdonald's, and Levis – have existed for a long time and fewer new applications may be filed in countries (such as the United States) that already have a large stock of well-known trademarks. Figure III.4 shows the global variation in trademark applications during 1997-2011.

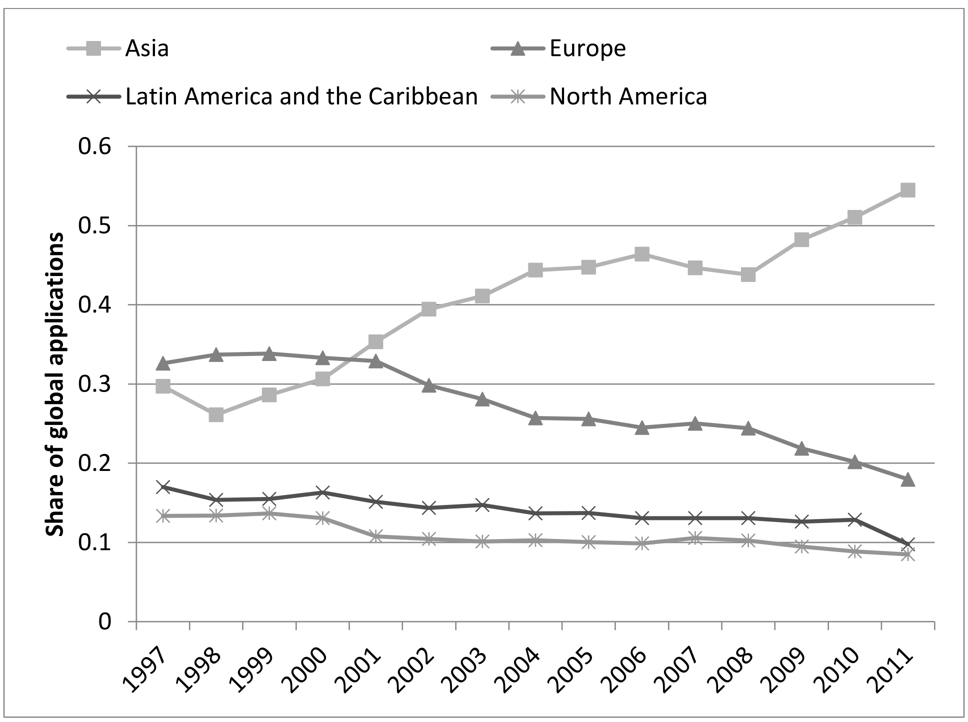
Perhaps the most noticeable aspect of this figure is the sharp increase in Asia's share of global trademark applications and the noticeable decline in Europe's share. Around 1997, both continents' share of global trademark applications was roughly 1/3rd but in 2011, Asia's share

[9] Since utility model applications are approved or rejected within a few months, we estimated the grant rate without lagging applications relative to grants.

exceeded 50% while that of Europe was below 20%. Over the same time period, North America's share declined from roughly 15% to under 10%.

Within Asia, China was once again the stand-out performer. When compared with BRICs countries, the increase in trademark applications in China is even more remarkable. While the number of trademark applications filed in all BRICs countries during 1997 was relatively similar (with most of them having fewer than 100,000 filings and China being below 200,000), such is no longer the case: in 2011, trademark applications in China were more than seven times that in India, the BRIC country with second largest number of trademark applications in 2011.

Figure III.4: Geographic Variation in Trademark Applications

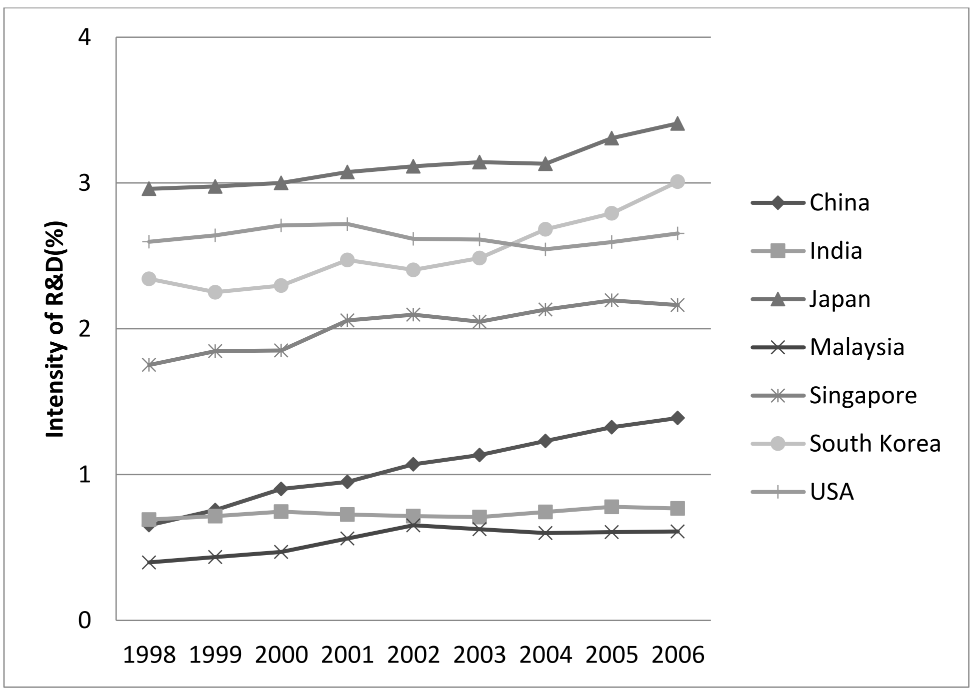


Other Evidence on Innovation

In this section, we examine how the efficiency of R&D as well as the nature of innovative activity has evolved in Asia during the post TRIPS era.

While patents and trademarks granted measure the output side of the R&D process, it is also useful to examine the input side. Figure III.5 presents data on R&D intensities (measured as R&D expenditures divided by GDP) during 1998-2006.

Figure III.5: Intensity of R&D in Asian Countries



Several useful observations can be made from this figure. First, R&D intensity increased in all countries. Second, the sharpest increase occurred in China where R&D intensity more than doubled during this time period. Third, and perhaps most noteworthy, Japan's R&D intensity in 2006 exceeded not only the other Asia countries but also that of the United States.[10]

It is also instructive to consider the variation across countries in terms of the productivity of R&D. We constructed a rough measure of R&D productivity by dividing the average patent granted to residents of each country during (2005-2010) by its lagged average R&D expenditure (during 2003-2005). This data is presented in Table III.3.

Table III.3: National R&D Productivity and Efficiency

Country	R&D productivity	R&D efficiency
China	1.86	0.02
India	0.36	0.03
Japan	1.02	0.16
Malaysia	0.26	0.14
Singapore	0.20	0.31
South Korea	3.29	0.12
USA	0.26	0.30

Table III.3 shows that R&D productivity in South Korea is much higher than that in other Asian countries. Surprisingly, South Korean productivity surpasses even that of US and Japan. It is important to interpret our metric of R&D productivity carefully since it totally disregards the quality of patents.

An alternative, and in some ways a preferable, measure of the efficiency of a country's R&D investment is the value of royalties payments received by it on world markets divided by its R&D

[10] However, given the size of the US economy, the absolute level of R&D expenditures in Japan during 2006 were less than half that of the US.

expenditure. Since current royalty income results from past R&D and because data on royalty payments for countries of interest is available only since 2000, we constructed a measure of R&D efficiency by dividing the average royalty payments received by each country during (2005-2010) by its lagged average R&D expenditure (during 2003-2005). Table III.3 reports this measure of R&D efficiency for the six Asian countries as well as the USA.

It can be seen that Singapore and USA have the highest levels of R&D efficiency, which is perhaps not unexpected given their superior environment for R&D activities. Japan and South Korea also feature moderately high levels of efficiency, although Japan's R&D performance seems lower than one might expect. The most striking observation, however, is that China actually represents the *lowest* R&D efficiency level. Once again, this is in sharp contrast to the recent surge of patent applications in China, suggesting that many of these innovations might be of low quality.

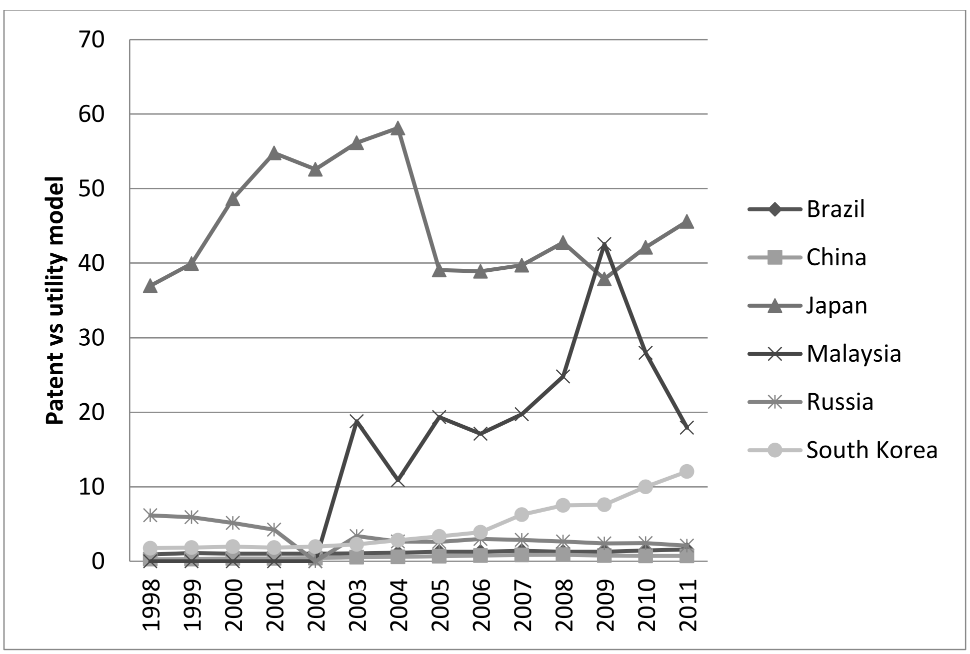
We should note here that royalty payments are only one channel via which innovators profit from their intellectual property. For example, instead of licensing its technology internationally, a firm may decide to produce a newly created product itself and export it to world markets. In such a situation, the return on its investment in innovation would show up as export revenues as opposed to royalties and licensing fees.

Since patents are granted for substantial innovations while industrial designs, and certainly utility models for relatively minor ones, further insight into the nature of innovative activity in Asia can be gained by considering how the ratio of patents to industrial designs as well as that to utility models have evolved during the period of our investigation.

Figure III.6 shows the ratio of patent to utility model applications from residents for countries that grant utility models.

Perhaps the most striking observation is that the ratio of patent to utility model applications is the *lowest* in China and has only marginally increased over time. This suggests that the Chinese pattern of innovation is skewed in favor of minor innovations relative to major ones. Moreover, even Brazil and Russia have slightly higher ratios than China although Russia's ratio has been declining. Korea shows an upward trend in this ratio since 2006, an indication that it is likely shifting away from minor innovations to major ones. Finally, perhaps not to anyone's surprise, Japan has a ratio of patent to utility model applications that is significantly higher than all other Asia countries; indeed its ratio in 2011 was more than sixty times that of China's. While differences in the ratio of patents to industrial designs between China and countries like Brazil and Russia are not significant, the gap between China and Japan is substantial and informative. It seems patently clear that China has some distance to go before it transforms into a major generator of world-class innovations.

Figure III.6: Nature of Innovation: Patents Relative to Utility Models

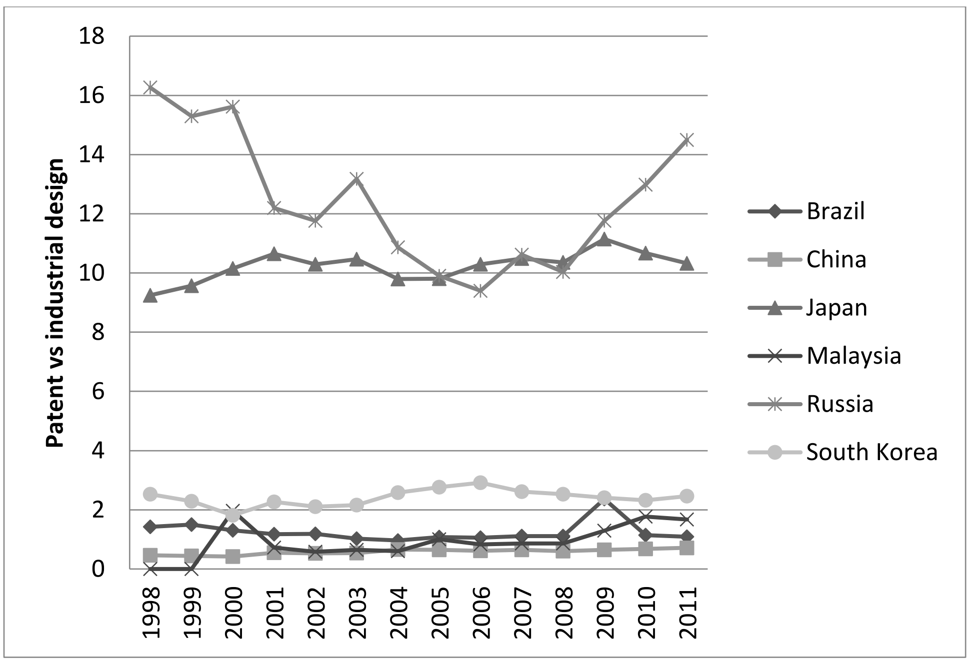


One may also look at the ratio of patent to industrial design applications of residents as an alternative way of capturing the nature of innovation. The calculated ratios are depicted in Figure

III.7. Once again, we see some similar patterns. For example, China again features the lowest ratio of all countries and the gap between it and Japan is huge.

Although the count data on filings and grants of various forms of IPRs is fairly informative in many respects, it does not tell us much about the effects of TRIPS in the market place. We now discuss the recent literature that addresses this.

Figure III.7: Nature of Innovation: Patents Relative to Industrial Designs



Evidence on the Economic Effects of TRIPS Mandated Reforms

As we discussed earlier, both China and India were largely opposed to TRIPS. The logic for their position was two-fold. One, strengthening IPRs would strengthen market power of rights holders and therefore raise local prices. Second, there was concern that strengthening IPR protection would hamper their ability to absorb foreign technologies thereby slowing down their technological progress and economic growth.

As Branstetter and Saggi (2011) note, TRIPS proponents countered that foreign firms are more likely to transfer technologies to markets where IPRs are better protected. Similarly, multinational firms might favor locations that offered stronger IPR protection, especially when locating subsidiaries handling recent technologies or conducting R&D.

Available empirical evidence supports the argument that TRIPS enforcement would be detrimental to consumer welfare (in the short run). For example, Chaudhuri et. al. (2006) conducted a counterfactual analysis based on a structural model of the antibiotic sub-segment of the pharmaceutical market in India and found that the elimination of local brands in the year 2000 would have resulted in significant welfare losses for Indian consumers. An interesting result of their empirical analysis was that local consumers in India showed a preference for local brands over foreign ones, perhaps due to the better developed distribution networks of local firms. While their analysis was confined to the Indian market, their findings with respect to the effects of TRIPS enforcement on prices would apply to developing countries at large since many of them import pharmaceuticals from India.

Since most developing countries are net buyers of patented goods, one would expect TRIPS to be regressive in the sense that it would cause income to be transferred from developing to developed countries. How large might such transfers be? McCalman (2001) estimates what the net present value of patents held by developed countries would have been in 1988 had the developing countries in his sample complied with TRIPS. His results indicate that these transfers ran into billions of dollars with the US benefitting more than other developed countries, a finding that fits well with the prominent role played by the US during TRIPS negotiations. On the other side of the equation, he finds that large developing countries such as Brazil and India stood to lose the most, a finding that is once again consistent with the vociferous opposition to TRIPS shown by these countries during Uruguay Round negotiations.

During the post-TRIPS era, net inflows of foreign direct investment (FDI) have increased to all major Asian countries under study except Japan. The rate of increase, however, varies across countries. Over 1997-2011, India experienced the highest average growth rate of net FDI inflows (of 17.9%). This was almost twice as high as that of Korea, which ranked second with a growth rate of FDI of 9.6%. However, despite its slower growth rate of 7.5%, China remains the country that receives the largest amount of FDI inflows in Asia. China also tops Asian countries under study in terms of the magnitude of FDI stock (7.1 trillion in 2011), with Singapore following closely behind (6.3 trillion in 2011). Nevertheless, the ratio of FDI to GDP for China is only of intermediate level, ranking below Singapore, Malaysia and India in 2011. Moreover, this ratio has been constantly declining for China while it has been increasing in India.

The global stock of FDI has also grown dramatically during the last decade or so: it increased from roughly $2 trillion in 1990 to over $22 trillion in 2012 (United Nations Conference on Trade and Development (UNCTAD), 2013). While most FDI flows still occur primarily between industrial countries, from 1990-2012, the share of global stock of FDI residing in developing countries increased from 25% to just over 33% (Maskus and Saggi, 2013).

Policy-makers and analysts value FDI not only because it can supplement domestic investment but also because FDI is a major channel of international technology transfer (Maskus, 2012). When measured by the receipts and payments of royalties and licensing fees, much of the global activity in technology transfer is within developed countries and occurs within the boundaries of multinational firms: in a typical year over 80 percent of global royalty payments for international transfers of technology are made from subsidiaries to their parent firms.[11]

[11] From 1990-2012, the royalties and licensing fee receipts of multinational firms increased from $27 billion to $235 billion (UNCTAD, 2013).

So dominant are multinational firms in the field of innovation that the R&D spending of some of the largest multinational firms exceeds that of many developing countries, even large ones. For example, in 2009 Toyota Motor Corporation invested more in R&D expenditures than India, a country of roughly 1.2 billion people (UNCTAD, 2010).

The relationship between FDI and IPR protection has received significant empirical scrutiny in the literature.[12] As the survey by Park (2008) notes, as far as US data is concerned, there appears to be a clear positive relationship between the degree of IPR enforcement in developing countries and investment by US firms, results derived from non-US data portray a more mixed picture.

Branstetter, Fisman, Foley, and Saggi (2011) study the impact of IPR reform on multinational production by focusing on the responses of U.S. multinationals to IPR reforms by sixteen countries in the 1980s and 1990s.[13] Their most important finding is that U.S.-based multinationals expanded the scale of their activities in reforming countries after they undertook IPR reforms. They also analyzed U.N. industry-level data and showed that industry-level value added increase after reforms, particularly in technology-intensive industries.

While much of the focus in the empirical literature has been on how stronger IPR enforcement can help attract FDI, less attention has been paid to how increased FDI might contribute to local innovation. In a recent paper, Branstetter et al. (2013) examine data on patents issued by the US to foreign residents and find that a majority of patents in China (as well as India) have been granted to researchers working for subsidiaries of multinational corporations (MNCs). They argue that this development and the general rise of international co-invention reflects an expanded international

[12] For a nuanced and detailed discussion of this literature, see Maskus (2000) and Maskus (2012).
[13] The Asian countries included in their sample were: China, Indonesia, Japan, Malaysia, Philippines, South Korea, and Taiwan.

division of labor within global R&D networks, much like the slicing of the global production chain across the world.

They also compare the quality of granted patents (as measured by citations) to Chinese or Indian indigenous inventions with those from (a) co-inventions with inputs from advanced economies and (b) co-inventions with inputs from advanced economies under the sponsorship of multinational firms. They find that co-invented patents tend to be of higher quality, as do the patents under the sponsorship of MNCs. Furthermore, they note that patents of purely indigenous firms in China and India tend to be of relatively lower quality, a finding that suggests that spillovers from MNCs to local companies in these countries have not yet materialized.

In a recent paper Hu and Jefferson (2009) investigate the factors that help explain the surge in Chinese patenting observed during the post-TRIPS era. They find that the intensification of R&D in China explains only a small percentage of the increase in patenting. Their analysis points to increased FDI as a significant explanatory factor behind increased Chinese patenting, along with the changes in Chinese patent law that took place in 2000 and China's accession to the WTO in 2001. Since the latter two factors were captured by year dummies (for 2000 and 2001) in their analysis, it is hard to be fully certain that the underlying factors were indeed patent reforms and China's WTO accession but it is difficult to imagine other more important and relevant policy changes in China during those two years.

Asian Emergence and the Current Policy Environment

The empirical evidence discussed in this chapter indicates that the scale of innovative activity in China has increased dramatically during the post TRIPS era. India too has experienced an increase in such activity, although to a much smaller extent. These facts are noteworthy because prior to the ratification of TRIPS, frictions between the US and China and US and India over violations of IPRs were fairly common. For example, both countries have been frequently listed under the Super 301 annual list of trading partners that have been deemed to be engaged in unfair trading practices by the US government. Does the changing global landscape of innovation imply that international frictions over the enforcement of IPRs are a thing of the past? This is almost surely not the case although the nature of underlying problems seems to have evolved.

Through-out the 1980s and early 1990s, US-China frictions over IPRs had to do with the widespread imitation of US products and technologies by Chinese firms as well as the infringement of copyrights. While these issues have not entirely gone away, several new ones have emerged in recent years. One of the major complaints that the US government has expressed about the current policy environment in China has to do with its policy of forcing foreign firms to share their technologies as a precondition for access to the local market. Starting in 1994, China started to impose specific technology transfer requirements on foreign firms wishing to enter its local market. This quid pro quo policy of exchanging market access for technology is best understood in the context of China's "indigenous innovation policy". This policy was first promulgated in 2009 by the Chinese Ministry of Science and Technology (MOST) when it provided conditions that would determine whether or not new products in six major industries could be viewed as having been the result of indigenous innovation. Only products that were deemed to be indigenous would be included in the catalog of approved government procurement lists, thereby setting up conditions for potential preferential treatment of indigenous innovation.

As Maskus (2012) explains, this focus on indigenous innovation can easily run afoul of the national treatment obligation of TRIPS and raised substantial concern among foreign enterprises owning IPRs. In response to these concerns and other external pressures, MOST circulated a revised and weaker draft of the indigenous innovation policy in 2010. At this time, there is considerable uncertainty regarding the true nature and actual implementation of this policy. Rest assured, if discrimination against foreign innovators becomes widespread or systemic, one would expect the dispute settlement process of the WTO to play an active role in refereeing and clarifying this Chinese policy.

During the Uruguay Round negotiations (when China was not a member of GATT), India was a leading opponent of strengthening IPR protection in developing countries. But TRIPS came to pass and India had to significantly alter its patent regime in order to comply with TRIPS. Since developing countries had been given up to 10 years to make their IPR regimes TRIPS compliant, India's introduced significant patent reforms in 2005. Prior to these policy changes, India did not recognize product patents for pharmaceuticals. As a result, prior to the 2005 patent reforms, reverse engineering and imitation were rampant in India and were indeed the key drivers behind the development of India's robust pharmaceutical industry. The explicit recognition of product patents in 2005 made an imitation based development strategy unviable for Indian. The focus now seems to have shifted toward increased collaboration with multinational firms in order to participate more vigorously in the global R&D chain, with an eye towards moving from imitation to innovation.

In 2012, frictions between India and the pharmaceutical multinational Bayer flared up when India issued a compulsory license for Bayer's cancer drug Nexavar. This episode raised the possibility that India could try to use its substantial manufacturing capacity in the area of pharmaceuticals to break patents held by foreign firms thereby weakening its IPR regime while still maintaining TRIPS compliance. However, since then India has not issued any further compulsory licenses; in fact, the Department of Industrial Policy and Promotion recently rejected a request for compulsory licensing because the Indian generic producer (BDR Pharmaceutical) seeking the compulsory license had failed to try to obtain a voluntary license from the patent-holder (Briston-Myers Squibb), as is required under TRIPS rules.

Concluding Remarks

The face of global innovation is changing, particularly within Asia. Like in world trade, the major story in the realm of intellectual property has been the emergence of China on the global stage. While one can question the quality of patents issued by China to domestic residents, their quantity is impressive and beyond dispute.

What are the implications of the changes in global landscape in the area of intellectual property that have been witnessed during the post TRIPS era? Perhaps the most important is this: the scope for frictions among major nations such as US and China may have been reduced with the emergence of Chinese innovation and with the recognition among China's policy-makers that they need to improve the quality of local innovation. This implies that China now has a stronger interest in protecting intellectual property than it did two decades or so ago when TRIPS was ratified.

A similar argument applies to the US-India relationship. Today, the Indian pharmaceutical industry is warmer to the idea of stronger intellectual property protection than it has ever been in the past. It is clear that stronger IPR protection is necessary for the Indian industry to participate in global R&D in a manner that is commensurate with its technological capabilities. If this process is hampered, it is difficult to see how India can transform itself from simply being a "pharmacy to the world" to an engine of innovation in the pharmaceutical sector, an area where it has developed significant technological capacity.

Till date, this capacity has not translated into any major new innovations, something that is more likely to happen if the Indian industry starts to collaborate more with major multinationals as opposed to merely playing an imitative role, as it has done in the past. Some of the emerging empirical evidence regarding the rise of international co-inventions suggests that this has indeed begun to happen.

APPENDIX

A.1 Proofs from Chapter I

Proof of Proposition I.1: Adding Eqs. (I.10) and (I.11) for countries i and j respectively yields

$$2(C_c - C_m) - \pi = \frac{\gamma}{M_i\Omega_{ii} + M_j\Omega_{ji}}\left[(C_m - C_c)(M_i\Omega_{ii} + M_j\Omega_{ji}) + (M_i + M_j)C_c\bar{T}\right]. \tag{A.1}$$

and

$$2(C_c - C_m) - \pi = \frac{\gamma}{M_j\Omega_{jj} + M_i\Omega_{ij}}\left[(C_m - C_c)(M_j\Omega_{jj} + M_i\Omega_{ij}) + (M_i + M_j)C_c\bar{T}\right]. \tag{A.2}$$

It is easy to see that the right-hand sides of Eqs. (A.1) and (A.2) are monotonic functions of total protections $M_i\Omega_{ii} + M_j\Omega_{ji}$ and $M_j\Omega_{jj} + M_i\Omega_{ij}$ respectively. And they must also be equal to each other since the left hands sides of the two equations are the same. It follows that we must have $M_i\Omega_{ii}^* + M_j\Omega_{ji}^* = M_j\Omega_{jj}^* + M_i\Omega_{ij}^*$. Hence Eqs. (I.10) and (I.11) immediately imply that $\Omega_{ii}^* > \Omega_{ij}^*$ for $i, j = H, F$. □

Proof of Proposition I.3: We first show part (ii). Adding up the first-order conditions for Ω_i and Ω_j under NT yields

$$2(C_c - C_m) - \pi = \frac{\gamma}{M_j\Omega_{jj} + M_i\Omega_{ij}}\left[(C_m - C_c)(M_j\Omega_{jj} + M_i\Omega_{ij}) + (M_i + M_j)C_c\bar{T}\right]. \tag{A.3}$$

Comparing Eq. (A.3) with either Eq. (A.1) or (A.2) and noting the monotonicity of the right-hand sides of these conditions regarding effective patent protection, we must have

$$P^{NT} = M_i\Omega_i^{NT} + M_j\Omega_j^{NT} = P^*, i = H, F$$

which establishes (ii).

Now notice that since $C_c - C_m - \pi < C_c - C_m - \mu_i\pi < C_c - C_m$, we must have

$$\Omega_{ii}^* > \Omega_i^{NT} > \Omega_{ij}^*, i, j = H, F$$

which is the desired result.

Finally, when countries are symmetric we may focus on the symmetric equilibria where $\Omega_{ii}^* = \Omega_{jj}^*$, $\Omega_{ij}^* = \Omega_{ji}^*$ under discrimination and $\Omega_i^{NT} = \Omega_j^{NT}$, under NT. Then Eqs. (A.1) and (A.3) together imply that

$$\frac{1}{\Omega_{ii}^*+\Omega_{ij}^*}\left[(C_m - C_c)(\Omega_{ii}^* + \Omega_{ij}^*) + 2C_c\bar{T}\right] = \frac{1}{2\Omega_i^{NT}}[(C_m - C_c)2\Omega_i^{NT}],\ i,j = H,F. \quad \text{(A.4)}$$

Monotonicity of both sides ensures that we must have $\Omega_{ii}^* + \Omega_{ij}^* = 2\Omega_i^{NT}$. □

Proof of Proposition I.4: One can obtain the first-order conditions for country j by reversing i and j in Eqs. (I.13) and (I.14). It is easy to show that

$$\Omega_{ii}^*(\theta) = \frac{C_c\bar{T}}{(2+\gamma)(C_c-C_m)-\pi}\left[(1+\gamma) - \frac{\eta\theta(C_c-C_m-\pi)}{C_c-\theta C_m}\right]$$

and

$$\Omega_{ij}^*(\theta) = \frac{C_c\bar{T}}{(2+\gamma)(C_c-C_m)-\pi}\left[\frac{(1+\gamma)(C_c-C_m)-\pi}{C_c-\theta C_m} - \frac{\eta}{\theta}\right],$$

where $\eta = M_j/M_i$. It follows that $\Omega_{ii}^*(\theta)$ decreases in θ since $\frac{\eta\theta(C_c-C_m-\pi)}{C_c-\theta C_m}$ is an increasing function of θ.

Similarly, $\Omega_{ij}^*(\theta)$ increases in θ since $\frac{(1+\gamma)(C_c-C_m)-\pi}{(C_c-\theta C_m)} - \frac{\eta}{\theta}$ is an increasing function of θ. Moreover, it can be shown that

$$P_i^*(\theta) = M_i\Omega_{ii}^*(\theta) + M_j\Omega_{ji}^*(\theta) = \frac{\gamma C_c\bar{T}}{(2+\gamma)(C_c-C_m)-\pi}\left[M_i + M_j\frac{\theta(C_c-\theta C_m)}{C_c-\theta C_m}\right]$$

Clearly, since $M_j\frac{\theta(C_c-\theta C_m)}{C_c-\theta C_m}$ is an increasing function of θ, $P_i^*(\theta)$ is increasing in θ. □

Proof of Proposition I.5: We know that $\Omega^*(\theta)$ satisfies the following first-order condition:

$$2C_c - (1+\theta)C_m - \pi = \frac{\gamma}{(1+\theta)\Omega^*(\theta)}[(C_m - C_c)(1+\theta)\Omega^*(\theta) + (1+\theta)C_c\bar{T} - \theta(1-\theta)C_m\Omega^*(\theta)]. \quad \text{(A.5)}$$

Similarly, $\Omega_d^*(\theta)$ and $\Omega_f^*(\theta)$ respectively satisfy the following first order conditions

$$C_c - C_m - \pi = \frac{\gamma}{\Omega_d^*(\theta)+\theta\Omega_f^*(\theta)}[(C_m - C_c)\Omega_d^*(\theta) + C_c\bar{T}]$$

and

$$C_c - \theta C_m = \frac{\gamma}{\Omega_d^*(\theta)+\theta\Omega_f^*(\theta)}\left[(\theta C_m - C_c)\Omega_f^*(\theta) + C_c\bar{T}\right].$$

Adding up the last two equations we obtain

$$2C_c - (1+\theta)C_m - \pi = \frac{\gamma}{\Omega_d^*(\theta)+\theta\Omega_f^*(\theta)}\left[(C_m - C_c)\Omega_d^*(\theta) + \theta\Omega_f^*(\theta) + (1+\theta)C_c\bar{T} - \theta(1-\theta)C_m\Omega_f^*(\theta)\right]. \quad \text{(A.6)}$$

Moreover, it can be shown that $\Omega_d^*(\theta) > \Omega_f^*(\theta)$, which further implies that . Since the right-hand sides of Eqs. (A.5) and (A.6) must be equal, and since both are decreasing functions of $\Omega_d(\theta) + \theta\Omega_f(\theta)$ and $(1+\theta)\Omega(\theta)$, we may conclude that

$$M\left(\Omega_d^*(\theta) + \theta\Omega_f^*(\theta)\right) > M(1+\theta)\Omega^*(\theta). \ \square$$

Proof of Proposition I.6: Here, we show that it is socially optimal to discriminate even when $\Omega_{ii} = \bar{T}$. Suppose $\Omega_{ii} = \bar{T}$ and $\Omega_{ij} < \bar{T}$. Here we must have $\Omega_{ji} > 0$ and $\Omega_{ij} = 0$. It follows that country *i* discriminates (i.e. $\Omega_{ii} > \Omega_{ij}$). To show country *j* also discriminates (i.e. $\Omega_{jj} > \Omega_{ji}$), suppose $\Omega_{ji} > 0$ (otherwise we are done). Note that the social planner's FOC for Ω_{jj} is given by

$$C_c - C_m - \pi = \frac{\gamma}{P_j(\theta)}\left[(C_m - C_c)\left(M_j\Omega_{jj} + M_i\Omega_{ij}\right) + \left(M_i + M_j\right)C_c\bar{T} - (1-\theta)C_m M_j\Omega_{ij}\right] \quad \text{(A.7)}$$

Since $\Omega_{ij} = 0$, this simplifies Eq. (A.7) as

$$C_c - C_m - \pi = \frac{\gamma}{M_j\Omega_{jj}}\left[(C_m - C_c)M_j\Omega_{jj} + \left(M_i + M_j\right)C_c\bar{T}\right] \quad \text{(A.8)}$$

Comparing Eq. (A.7) with Eq. (A.8), we see that the left-hand side of Eq. (A.8) is smaller than that of Eq. (A.7). This implies that the right-hand side of Eq. (A.8) is also smaller than that of Eq. (A.7). We next show that $P_i = M_i\Omega_{ii} + \theta M_j\Omega_{ji} \leq M_j\Omega_{jj}$. Suppose not, i.e., suppose we have $M_i\Omega_{ii} + \theta M_j\Omega_{ji} > M_j\Omega_{jj}$. Since $\theta \leq 1$, we have $M_j\Omega_{jj} < M_i\Omega_{ii} + \theta M_j\Omega_{ji} \leq M_i\Omega_{ii} + \theta M_j\Omega_{ji}$. Then it follows that the left-hand side of Eq. (A.8) is larger than that of Eq. (A.7), which constitutes a contradiction. Therefore, it must be that $P_i = M_i\Omega_{ii} + \theta M_j\Omega_{ji} \leq M_j\Omega_{jj}$.

Note that since Ω_{ji} is increasing in θ (so that it attains its maximum value at $\theta = 1$) while Ω_{jj} is independent of θ, if we can show that $\Omega_{jj} > \Omega_{ji}$ at $\theta = 1$ then it must be this inequality holds for all θ. When $\theta = 1$, we have $M_i\Omega_{ii} + M_j\Omega_{ji} = M_j\Omega_{jj}$. This immediately implies $M_j\Omega_{ji} < M_j\Omega_{jj}$ from which it follows that $\Omega_{ji} < \Omega_{jj}$, i.e. given that country i is discriminating, it is socially optimal to have country j discriminate under free trade. Moreover, Ω_{ji} falls while Ω_{jj} does not change as θ decreases, so $\Omega_{ji} < \Omega_{jj}$ continues to hold when $\theta < 1$. □

A.2 Proofs from Chapter II

Table A.1 Expressions for the thresholds of θ and s

Thresholds for θ				
Autarky	$\theta^{AU} = \frac{3(1-c)}{2s}$			
NT	$\theta_u^N = \frac{c(2-c)}{2s}$	$\theta_l^N = \frac{c(2-c)}{2}$	$\theta_{cu}^N = \frac{2c(2-c)}{3s}$	$\theta_{cl}^N = \frac{2c(2-c)}{3}$
MR	$\theta_u^M = \frac{c(20-3c)}{6s(1+c)}$	$\theta_l^M = \frac{c(20-17c)}{6(1-c)}$	$\theta_{cu}^M = \frac{c(8+3c)}{3(1+s)(1+c)}$	$\theta_{cl}^M = \frac{c(8-11c)}{3(1+s)(1-c)}$
Others	$\theta_{cm} = \frac{4c(2-c)}{3(1+s)}$		$\theta_{cn} = \frac{7c^2}{3(1-s+c+sc)}$	
Thresholds for s	$s_a^M = \frac{20-23c+3c^2}{20+3c-17c^2}$		$s_b^M = \frac{3(2-c)(1-c)}{20-17c}$	

Proof of Proposition II.4: First, we prove that it is not optimal to apply discriminatory standards in country A. Let us define θ_{c1}^D such that

$$ww(\{L,H\},\{H,H\}) > ww(\{H,H\},\{H,H\}) \textit{ if and only if } \theta < \theta_{c1}^D, \qquad \text{(A.9)}$$

where $\theta_{c1}^D = \frac{c(8+3c)}{6s(1+c)}$. Similarly, we can find θ_{c2}^D such that

$$ww(\{L,L\},\{H,H\}) > ww(\{L,H\},\{H,H\}) \textit{ if and only if } \theta < \theta_{c2}^D, \qquad \text{(A.10)}$$

with $\theta_{c2}^D = \frac{c(8-11c)}{6s(1-c)}$. It can be shown that

$$\theta_{c1}^D < \theta_{c2}^D. \qquad \text{(A.11)}$$

Therefore, for all θ such that it is optimal to choose the discriminatory policy profile $(\{L,H\},\{H,H\})$ over $(\{H,H\},\{H,H\})$, the NT profile $(\{L,L\},\{H,H\})$ would actually yield high world welfare than $(\{L,H\},\{H,H\})$. Hence social optimality requires country A to never discriminate against the foreign firm.

Now examine the case for country B. We can analogously find θ_{c3}^D that makes the following condition hold:

$$ww(\{L,L\},\{H,H\}) > ww(\{L,L\},\{L,L\}) \textit{ if and only if } \theta > \theta_{c3}^D, \qquad \text{(A.12)}$$

where $\theta_{c3}^D = \frac{c(8-11c)}{6(1-c)}$. Also we may calculate θ_{c4}^D such that

$$ww(\{L,L\},\{H,H\}) > ww(\{L,L\},\{L,L\}) \textit{ if and only if } \theta > \theta_{c3}^D, \qquad \text{(A.13)}$$

where $\theta_{c4}^{D}=\frac{c(8+3c)}{6(1+c)}$. It is straightforward to check that

$$\theta_{c3}^{D} > \theta_{c4}^{D}. \tag{A.14}$$

Hence whenever the discriminatory policy profile $(\{L,L\},\{H,H\})$ dominates $(\{L,L\},\{L,L\})$, it must also be dominated by the NT profile $(\{L,L\},\{H,H\})$. This implies that discrimination from country B is not socially optimal either. □

Proof of Proposition II.7: As the pattern of equilibrium varies with s, it would be helpful to compare the two types of agreements over various ranges of s. Given $c < 1/4$, lemma 1 implies that s is minimized at $s_a^M(c = 1/4) \approx 0.73$. Hence we may consider two cases: $s < s_a^M(c = 1/4)$ and $s_a^M(c = 1/4) \leq s \leq 1$. Note that in the former case unique equilibrium is guaranteed, while in the latter case multiple equilibria could occur depending on the value of c.

Case 1 (unique equilibrium is guaranteed). $s < s_a^M(c = 1/4)$.

We use four thresholds obtained above: θ_u^N, θ_l^N under NT and θ_u^M, θ_l^M under MR. First, it is easy to check that $\theta_u^N < \theta_u^M$, i.e. country A is more likely to choose lax standards under MR because (i) part of the externality is borne by country B; (ii) profit is shifted to the domestic firm. Similarly, we have $\theta_l^N < \theta_l^M$ implying country B also tends to lower the standard under MR for the same reasons. Next, it can be show that there exists a unique threshold s_b^M such that $\theta_u^N > \theta_l^M$ if and only if $s < s_b^M$. Moreover, it is straightforward to show that

$$s_b^M - s_a^M(c = 1/4) < 0.$$

Therefore we have two subcases to examine: $s < s_b^M$ and $s_b^M < s \leq s_a^M(c = 1/4)$.

Case 1.1. $s < s_b^M$.

Given $s \leq s_b^M$ the ordering of the thresholds is $\theta_l^N < \theta_l^M < \theta_u^N < \theta_u^M$. First note that for $\theta < \theta_l^N$ and $\theta > \theta_u^M$, NT and MR lead to the same policy profiles, i.e. (L,L) and (H,H) and are equally efficient. For $\theta_l^N < \theta < \theta_l^M$, NT induces (L,H) while the equilibrium under MR is (H,H). Recall that (L,H) dominates (H,H) if $\theta < \theta_{cl}^N$. Moreover, it can be shown that $\theta_l^N < \theta_{cl}^N < \theta_l^M$, implying that MR prevails over $\theta_l^N < \theta < \theta_{cl}^N$ while NT is favored over $\theta_{cl}^N < \theta < \theta_l^M$. Next consider $\theta_l^M < \theta < \theta_u^N$ where the equilibrium under MR changes to (L,H). We can then find θ_{cn} such that

$$\mathrm{ww}^N(L,H,\theta) > \mathrm{ww}^M(L,H,\theta) \text{ if and only if } \theta > \theta_{cn}, \tag{A.15}$$

Hence (L, H) under NT dominates (L, H) under MR if $\theta > \theta_{cn}$.[1] Then we need to compare θ_{cn} and θ_l^M. Some simple algebra shows that

$$\theta_{cn} < \theta_l^M, \tag{A.16}$$

which implies that welfare is always higher under NT for $\theta_l^M < \theta < \theta_u^N$. Finally consider the range $\theta_u^N < \theta < \theta_u^M$, where the externality is relatively high so that the equilibrium under NT is uniform high standards. We have shown that (H, H) is preferred to (L, H) if $\theta > \theta_u^M$. Moreover, it is easy to check that $\theta_{cu}^M < \theta_u^N$ if and only if $s < s_c^M$ where s_c^M is some threshold of s. But this must be the case because it can be verified that $s_c^M > s_b^M$, so whenever $s < s_b^M$ we must have $s < s_c^M$. Hence for all $\theta_u^N < \theta < \theta_u^M$ NT would yield higher welfare than MR.

Thus we have shown that over $s < s_b^M$, NT is more efficient for large values of the externality ($\theta_{cl}^N < \theta < \theta_u^M$) but is dominated by MR when the externality is small ($\theta_l^N < \theta < \theta_{cl}^N$). To compare the two agreements as asymmetry varies, note that by definition 1 we may write r in this case as

$$r_2 = \frac{\theta_u^M - \theta_{cl}^N}{\theta_{cl}^N - \theta_l^N}.$$

Direct calculation shows that

$$\frac{\partial r_2}{\partial s} < 0. \tag{A.17}$$

Eq. (A.17) implies that as countries become more asymmetric (i.e. s lowers), NT would become more desirable by yielding strictly higher world welfare for a larger proportion of the externality. Next we examine the case when $s_b^M < s \leq s_a^M(c = 1/4)$.

Case 1.2. $s_b^M < s \leq s_a^M(c = 1/4)$.

In this case we have $\theta_l^N < \theta_u^N < \theta_l^M < \theta_u^M$. Again, for $\theta > \theta_u^M$ and $\theta < \theta_l^N$ NT and MR induce identical equilibrium outcome and are indistinguishable from the efficiency point of view. Now consider $\theta_l^N < \theta < \theta_u^M$. We already know from Case 1.1 that MR dominates NT over $\theta_l^N < \theta < \theta_{cl}^N$. Also it can be shown that $\theta_{cl}^N < \theta < \theta_u^N$ if and only if $s < 3/4$. This must be the case given we are considering $s \leq s_a^M(c = 1/4)$. Hence for $\theta_{cl}^N < \theta < \theta_u^N$ welfare is higher under NT. Next for $\theta_u^N < \theta < \theta_l^M$, we need to compare (H, H) under NT with (L, L) under MR. Recall $\mathrm{ww}(H, H, \theta) > \mathrm{ww}(L, L, \theta)$ if $\theta > \theta_{cm}$. Note that we must have $\theta_{cm} < \theta_l^M$. Moreover, comparing θ_{cm} with θ_u^N we know

[1]The reason underlying the tradeoff between (L, H) under the two agreements is the following. The outcome (L, H) under NT can be more efficient because the lenient standard is exclusively applied in country A that values quality less. On the other hand, (L, H) under MR can dominate as it induces more intense competition in both countries. When θ is small the gain from enhanced competition dominates so that (L, H) under MR yields higher world welfare. On the other hand, welfare is higher for (L, H) under NT when θ is large because it prevents the lenient standard from being used in country B.

$$\theta_{cm} < \theta_u^N \; if \; and \; only \; if \; s < 3/5. \tag{A.18}$$

It can be checked that $s_b^M < 3/5$. Hence if $s_b^M < s \leq 3/5$, then NT dominates over $\theta_u^N < \theta_l^M < \theta_l^M$; if instead $\frac{3}{5} < s < s_a^M(c = 1/4)$, then MR performs better over $\theta_u^N < \theta < \theta_{cm}$ while NT dominates over $\theta_{cm} < \theta < \theta_l^M$.

Finally consider $\theta_l^M < \theta < \theta_u^M$, in which we compare (H, H) under NT with (L, H) under MR. We already know $\mathrm{ww}^M(H, H, \theta) > \mathrm{ww}^M(L, H, \theta)$ if $\theta > \theta_{cu}^M$. Moreover, we can check that $\theta_{cu}^M < \theta_l^M$. Hence NT dominates MR for all $\theta_l^M < \theta < \theta_u^M$.

Depending on s, we can calculate r in the following ways:

$$r_3 = \frac{\theta_u^M - \theta_{cl}^N}{\theta_{cl}^N - \theta_l^N} \text{ if } s_b^M < \mathrm{s} \leq 3/5, \tag{A.19}$$

$$r_4 = \frac{\theta_u^M - \theta_{cm} + \theta_u^N - \theta_{cl}^N}{\theta_{cm} - \theta_u^N + \theta_{cl}^N - \theta_l^N} \text{ if} \frac{3}{5} < \mathrm{s} \leq s_a^M(c = 1/4). \tag{A.20}$$

As by definition $r_3 = r_2$, we know immediately:

$$\frac{\partial r_3}{\partial s} < 0.$$

Moreover, some algebra indicates that

$$\frac{\partial r_4}{\partial s} < 0.$$

Thus for all $s_b^M < \mathrm{s} \leq s_a^M(c = 1/4)$, we have shown that NT becomes more palatable as countries possess more heterogeneous preferences.

Case 2 (possible multiple equilibria under MR): $s > s_a^M(c = 1/4)$.

In this case multiple equilibria could arise under MR depending on the value of c. In particular, for any $c < 1/4$ unique equilibrium obtains if $s(c = 1/4) < s \leq s(c)$ while multiple equilibria occur if $s(c) < s$. In the meantime we note that the relationship between θ_{cl}^N and θ_u^N depends on *s*. In particular, the following can be shown to hold:

$$\theta_{cl}^N < \theta_u^N if \; and \; only \; if \; s < 3/4. \tag{A.21}$$

Hence we will examine two subcases with $s < 3/4$ and $s \geq 3/4$. As shown in Case 1.2, when $< 3/4$ NT dominates for higher levels of the externality over $\theta_{cl}^N < \theta < \theta_u^N$, while if $s \geq 3/4$ MR dominates over the entire range. Also let ĉ be such that $s_a^M(c = \hat{c}) = 3/4$ which will be useful the following analysis.

Case 2.1. $s_a^M(c = 1/4) < \mathrm{s} < 3/4$.

Again, depending on the value of c, we have either unique equilibrium under MR for $3/4 < s < s(c)$ or multiple equilibria for $s(c) < s < 1$. But in both cases it is easy to see that NT dominates over $\theta_{cm} < \theta < \theta_u^M$ while MR is favored under $\theta_l^N < \theta < \theta_{cm}$. Therefore, we can always calculate r as

$$r_5 = \frac{\theta_u^M - \theta_{cm}}{\theta_{cm} - \theta_l^N}. \quad \text{(A.22)}$$

Finally, we show that r_5 first decreases and then increase as s falls from 1, with the turning point $s(c)$ being a function of c. Differentiate r_5 with respect to s and set the derivative equal to zero:

$$\frac{\partial r_5}{\partial s} = 0, \quad \text{(A.23)}$$

we can solve for a unique $s(c)$ such that Eq. (A.23) holds. It can be checked that $s(c)$ does belong to $[3/4,1]$. To see this, note it is possible to show that

$$\frac{\partial \hat{s}(c)}{\partial c} < 0, \quad \text{(A.24)}$$

i.e. $s(c)$ is monotonically increasing in c. Moreover, we have $s(c = 0) \approx 0.77 \in [3/4,1]$ and $s(c = 1/4) \approx 0.8 \in [3/4,1]$. Thus $s(c) \in [3/4,1]$ for all $c < 1/4$.

Moreover, it can be shown that: $\frac{\partial r_5}{\partial s} > 0$ for $s(c) < s \leq 1$ and $\frac{\partial r_5}{\partial s} < 0$ for $3/4 < s \leq s(c)$. Thus we know as s fall from 1, r_5 first decreases and then increases with the turning point being $s(c)$. □

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