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The case for non-discrimination in the international protection of intellectual property

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Abstract

We evaluate the case for non-discrimination in the international protection of intellectual property. If trade is not subject to any frictions then requiring national treatment (NT) in patent protection does not have any consequences for innovation (and welfare) since unfavorable discrimination abroad is fully offset by favorable discrimination at home. In the presence of trade frictions, however, such international offsetting in patent protection is incomplete and innovation incentives are actually lower under NT. The formation of a free trade agreement increases the effective global protection available to members without affecting the protection available to the non-member.

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1 Introduction

One of the most important and controversial outcomes of the Uruguay Round of multilateral trade negotiations (1986-95) was the Agreement on the Trade Related Aspects of Intellectual Property (TRIPS). This far-reaching agreement calls for WTO members to adopt certain minimum standards of protection for all major types of intellectual property such as copyrights, patents, and trademarks.[1] For example, TRIPS requires that the duration of patent protection granted by all WTO members must be at least 20 years. In addition to such harmonization, an equally important aspect of TRIPS is that it requires member countries to adopt certain fundamental principles, such as *non-discrimination* in the protection of intellectual property.[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] Our primary objective in this paper is to evaluate the case for such non-discrimination in the protection of intellectual property. To achieve this objective, we utilize an adapted version of the Grossman and Lai (2004) model of endogenous patent protection with ongoing innovation.[4] While the model focuses on patent policy, the insights it yields are 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-

[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 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.

discriminatory patent policies in an open economy setting and show two major results. First, countries tend to offer too little protection to intellectual property in an open economy setting. Second, the harmonization of intellectual property 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 paper, we build on their insights by examining the implications of the non-discrimination constraints on national patent policies imposed by NT and MFN thereby adding to our understanding of the economic consequences of TRIPS.[5]

Issues surrounding the international protection of intellectual property have most frequently been examined in the literature through the lens of North-South models of international trade and technology transfer.[6] However, such models 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, they do not address the implications of core TRIPS principles of NT and MFN for equilibrium patent policies and welfare.

While non-discrimination in the use of domestic tax instruments such as sales taxes has received significant attention in the literature, little is known about its effects in the realm of intellectual property protection. 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 are invariably inclined 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:

[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.

[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. A recent paper by Horn, Maggi, and Staiger (2010) examines the role of NT from the perspective of incomplete contracts.

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 key reason the US and the EU (to a lesser extent) pushed hard for a 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 provide a rationale for requiring non-discrimination in the protection of intellectual property? Our analysis below shows that it *does not*.

Our baseline model considers a world comprised of two countries and analyzes the effects of NT under the assumption that there exist no trade frictions between them. 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 foreign firms. However, we show that *such 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 the sum of each country's national index of patent protection multiplied by its market size. The reason NT fails to generate any welfare improvement in our model is that what each firm gains in terms of protection abroad if discrimination is replaced by NT is exactly offset by what it loses at home so that 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 barriers. When trade is subject to barriers, *NT*

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

actually lowers innovation incentives by reducing the effective global protection enjoyed by firms. The intuition is that even though trade barriers lower export profits thereby making domestic patent protection relatively more important for incentivizing innovation in each country, NT calls for each country to provide more of such protection rather than less. Indeed, from the viewpoint of firms, 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: trade frictions reduce the volume of trade so that consumer surplus generated by foreign innovations is smaller than that generated by domestic ones.[9] Indeed, we show that with any positive level of trade frictions, it is jointly optimal for each country to offer a relatively lower level of patent protection to foreign firms, a policy configuration precluded by NT.

We also investigate how changes in the level of trade barriers between countries alter patent protection and the effects of NT. Here we find that reciprocal trade liberalization between countries lowers each country's incentive to discriminate against foreigners. This result points to a synergy between the acceptance of international disciplines on intellectual property protection and the degree of trade liberalization in the global economy. It is worth mentioning here that the TRIPS agreement followed almost five decades of global trade liberalization achieved during eight separate rounds of multilateral trade negotiations preceding the Uruguay round. As is well known, these pre-TRIPS rounds of trade negotiations were successful in lowering the average global tariff on industrial goods from over 40% to under 4% (see Bagwell and Staiger, 2002).

Our analysis shows that differences in market size across countries can affect incentives for discrimination in rather 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. Therefore, a larger market has a weaker incentive to discriminate against foreign nation-

[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.

als, a result that seems to accord quite well with the fact that multilateral disciplines on intellectual property were pushed strongly by the two largest economies in the world (EU and the USA) during the Uruguay round. 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.

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 rather than less. 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]

In section 5, we extend the model to the case of three countries to examine the incentives countries might have to disregard the most favored nation (MFN) rule in the protection of intellectual property. Since we focus only on patent protection, NT implies

[10] Bagwell and Staiger (1999) 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.

MFN in our model and we need to allow discrimination against foreign nationals relative to domestic ones in order to be able to examine incentives for discrimination across one's trading partners.[11] Since the most widespread deviation from MFN that is observed in the enactment of traditional trade policies takes the form of free trade agreements (FTAs) such as the North American Free Trade Agreement (NAFTA), we ask whether the presence of discriminatory trade frictions creates a rationale for discrimination in the protection of intellectual property. An important finding here is that a country has an incentive to grant stronger patent protection to the trading partner on whom its trade barriers are lower. This intuitive result is consistent with the strengthening of intellectual property protection that has been observed among member countries of FTAs such as NAFTA. Indeed, some commentators have even dubbed several recent trade agreements of the US (such as the US-Jordan FTA) to be *TRIPS-plus in nature* since members of such FTAs seemed to have agreed to disciplines over intellectual property that go even beyond those required under TRIPS – see, for example, Biadgleng and Maur (2011) and Fink (2005). Though discrimination in the degree of patent protection across one's trading partners violates MFN, we show that the effect of such discrimination on the country that is discriminated against can actually be positive due to enhanced innovation in the favored country.

We also examine how coordination between members of an FTA alters their patent policies. We consider two scenarios: one where the FTA in question is small in the sense that patent policies of the rest of the world are unaffected by changes in patent policies of FTA members and another where they adjust endogenously. Under both scenarios, coordination between FTA members raises effective global protection available to firms in *all* countries. Since there is under-protection of intellectual property protection in the model, this change is welfare improving even though it violates MFN. If policies in the rest of the world are endogenous then coordination between FTA members results in a decline in the degree of external protection received by them. However, even with such an endogenous adjustment of patent policies of the rest of the world, the effective

[11] One can imagine a scenario where certain patent rules and regulations apply only to foreign firms. For example, the procedure for applying for a patent might be substantially different for foreign and domestic firms for legitimate reasons. Under such a situation, the issue of NT with regard to the processing of patent applications would not be of great relevance but MFN would certainly matter.

degree of global protection faced by firms increases due to coordination between FTA members.

2 Baseline model

To study NT in the international protection of intellectual property, we utilize the open economy 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 countries: Home (H) and Foreign (F). Each country has two sectors: a traditional sector that produces a homogeneous good and a modern one that invents a variety of differentiated goods through research and development (R&D). An invented differentiated good has a finite life span ($\overline{\tau}$) during which it generates positive utility for consumers. At the end of its life span, the differentiated good produces zero utility and exits the market.

In both countries, the representative consumer maximizes her lifetime utility

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

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

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

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), $h(.)$ 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 (1) and (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.

On the production side, differentiated goods are invented by firms via 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:

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

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

The amount of labor needed to produce one unit of each good (either homogeneous or differentiated) 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 homogeneous good is produced in equilibrium in each country. Labor is mobile between sectors but not across countries. We take the homogeneous good as the numeraire. Since the market for the homogeneous 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. $w_i = 1/a_i$.

Given the technology specified for innovation in (3), $\phi_i(z) + \phi_j(z)$ newly invented goods enter country i's market during each time period z, while a measure of $\phi_i(z-\overline{\tau}) + \phi_j(z-\overline{\tau})$ 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 $\dot{n}_i(z) = \phi_i(z) - \phi_i(z-\overline{\tau}) + \phi_j(z) - \phi_j(z-\overline{\tau})$. We focus on the steady state of the world economy where $\dot{n}_i(z) = 0$, that is, the measure of differentiated good in both markets remains constant over time.

A differentiated good can be targeted by imitators after being invented. To protect goods from imitation, the government in each country grants patent rights to inventing firms. As in Grossman and Lai (2004) patent is assumed to have two dimensions: the length τ and the degree of enforcement ω where $\omega \in [0, 1]$. While the patent is in effect the patenting firm charges its optimal monopoly price. Let π be the instantaneous per capita profit of a monopoly firm producing a patented differentiated good so that

[12] Our major results continue to hold when the production function for research has a CES form of the type $\phi_i(z) = A[\alpha[L_{Ii}(z)/a_i]^{\beta} + (1-\alpha)K_i^{\beta}]^{1/\beta}$ with $\beta \leq 0$. As is well-known, the Cobb-Douglas production function obtains when $\beta = 0$. Restricting β to be non-positive 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.

$\pi = (p_m - aw)x_m$. Also define the index of patent protection as $\Omega = \omega(1-e^{-\rho\tau})/\rho$ 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 $\Omega\pi$.

A patented good, however, is imitated free of cost after the patent expires. Imitation drives the price of the good to its competitive level so that post imitation profits of an innovator equal zero. Let $\overline{T} = (1 - e^{-\rho\overline{\tau}})/\rho$ be the present value of a 1 dollar flow over the entire useful life of a typical differentiated product.

When analyzing optimal patent protection policies in the economic framework described above, 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 equal 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 levels that depend upon the national origin of firms. Accordingly, let country i extend 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 under regime R therefore equals $v_i^R = (M_i\Omega_{ii}^R + M_j\Omega_{ji}^R)\pi$. Firms make decisions about their labor inputs for R&D based on the expected total profits they can earn on the global market. The first-order condition determining demand for labor in country i under regime R where $R = D$ or NT is

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

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 $C_c = h(x_c) - p_c x_c$. The discounted surplus over the entire life of a domestic differentiated product enjoyed by a typical consumer in country i equals $C_m\Omega_{ii}^R + C_c(\overline{T} - \Omega_{ii}^R)$ whereas that derived from a foreign differentiated good is $C_m\Omega_{ij}^R + C_c(\overline{T} - \Omega_{ij}^R)$.

[13] Positive consumption of good y and perfect intertemporal substitutability of y in consumer preferences ensure that the interest rate is constant and equal to ρ.

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

$$\begin{aligned} W_i^R &= \Lambda_{i0} + \frac{w_i}{\rho}(L_i - L_{Ii}^R) + \frac{M_i \phi_i^R}{\rho}[C_m \Omega_{ii}^R + C_c(\overline{T} - \Omega_{ii}^R)] \\ &+ \frac{M_i \phi_j^R}{\rho}[C_m \Omega_{ij}^R + C_c(\overline{T} - \Omega_{ij}^R)] + \frac{\pi \phi_i^R}{\rho}(M_i \Omega_{ii}^R + M_j \Omega_{ji}^R) \end{aligned} \tag{4}$$

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

$$WW^R = \sum_i W_i^R \tag{5}$$

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 the unilateral imposition of NT on a country in our framework can only make it worse off since a country can always choose not to discriminate in patent protection 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.

3 Effects of NT under free trade

We begin with the scenario where international trade between Home and Foreign is not subject to any barriers or frictions. An important implication of this assumption is that from a social planner's view, patent protection abroad is just as valuable to firms as patent protection in their domestic market. Later, in section 4 we will see that the introduction of trade frictions breaks this equivalence which, in turn, has implications for equilibrium policies and welfare under the two regimes.

3.1 Discriminatory patent protection

In what follows, we focus on 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 $\overline{T}$. To this end, we need to derive the best response curves for each country from their welfare levels given in (4).

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 extending 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 local firms. This leads to more R&D investment and a greater variety of differentiated goods invented by such firms. Each differentiated good generates an discounted per-consumer surplus of $C_m\Omega_{ii} + C_c(\overline{T} - \Omega_{ii})$. It follows that country i's marginal benefit of raising domestic protection is

$$\frac{M_i}{\rho}\frac{\partial \phi_i^D}{\partial \Omega_{ii}}[C_m\Omega_{ii} + C_c(\overline{T} - \Omega_{ii})] \tag{6}$$

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

One can show that (see appendix)

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

where $\gamma = \frac{\alpha}{1-\alpha}$ represents the responsiveness of innovation to the value of an innovation in elasticity form. Plugging this expression into (6), one obtains country i's marginal benefit of raising domestic protection

$$\frac{1}{\rho}\frac{\gamma \phi_i^D M_i^2}{M_i\Omega_{ii} + M_j\Omega_{ji}}[(C_m - C_c)\Omega_{ii} + C_c\overline{T}] \tag{7}$$

On the other hand, a marginal increase in domestic patent protection allows local firms 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 firms. Since ϕ_i^D new goods are invented per unit of time, country i's discounted marginal cost of strengthening domestic patent protection Ω_{ii} equals

$$\frac{M_i\phi_i^D(C_c - C_m - \pi)}{\rho} \tag{8}$$

Equating the marginal benefit (7) to the marginal cost (8) and rearranging terms gives the first order condition determining country i's patent protection Ω_{ii} to its domestic firms:[14]

$$C_c - C_m - \pi = \frac{\gamma M_i}{M_i\Omega_{ii} + M_j\Omega_{ji}}[(C_m - C_c)\Omega_{ii} + C_c\overline{T}] \tag{9}$$

Equation (9) describes country i's best response Ω_{ii} to the degree of patent protection that country j extends to country i's firms (Ω_{ji}). It is easy to see from (9) that Ω_{ii} varies inversely with Ω_{ji} since $C_m - C_c < 0$: country i's protection to its own firms declines if they receive more protection from country j. The intuition behind this is straightforward. An increase in Ω_{ji} increases the value of country i's firms and thereby encourages them to invest more in R&D activity. Due to diminishing returns in R&D, country i's marginal benefit of extending more patent protection to its own firms is lower when Ω_{ji} is 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 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.

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

$$C_c - C_m = \frac{\gamma M_i}{M_i\Omega_{ij} + M_j\Omega_{jj}}[(C_m - C_c)\Omega_{ij} + C_c\overline{T}] \tag{10}$$

It is important to note from the above equation that the marginal cost of strengthening foreign protection Ω_{ij} is not mitigated by π, because the monopoly profits generated by extending such patent protection end up accruing to foreign firms. It follows that

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

a country's marginal cost of foreign patent protection is always 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 (10) 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]

Proposition 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 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 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 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 1 implies that the incentives for innovation are the same for firms in either country, even if one country is relatively more efficient in innovation. Intuitively, when country i protects its own firms more than country j protects its own firms – as would be

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

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

$$M_H\Omega^*_{HH} + M_F\Omega^*_{FH} = M_F\Omega^*_{FF} + M_H\Omega^*_{HF}$$

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 2: *The relative degree of discrimination ($\Delta\Omega^*_i/\Delta\Omega^*_j$) practised by a country is inversely proportional to its relative market size (M_i/M_j), $i = H, F$.*

As a country's relative market size increases, its weight in determining the level of effective global protection increases as does the benefit it enjoys from foreign innovations. Therefore, a larger market has a *weaker incentive to discriminate* against foreign nationals. As we noted earlier, 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 and the smaller country benefits from a reduction in discrimination its firms face abroad as well as an increase in overall patent protection.

3.2 Patent protection under NT

Now suppose that each country has to choose a non-discriminatory patent protection level that applies to every firm in the world. 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

$$C_c - C_m - \mu_i\pi = \gamma\frac{M_i}{P_i(\Omega_i, \Omega_j)}[(C_m - C_c)\Omega_i + C_c\overline{T}] \tag{11}$$

where $P_i(\Omega_i, \Omega_j) = M_i\Omega_i + M_j\Omega_j$ and $\mu_i = \frac{\phi_i^{NT}}{\phi_i^{NT}+\phi_j^{NT}}$ is the proportion of innovation that occurs in country i. Given our assumption that the R&D production function is Cobb-Douglas in nature, it turns out that $\mu_i = \frac{K_i}{K_i+K_j}$, i.e., μ_i is determined solely by the relative human capital stocks of countries and is unaffected by their patent policies.

Observe from above that the marginal cost of patent protection in country i 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 firm is discounted by μ_i 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 perceived by 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 $(\Omega_{ii}, \Omega_{ij})$ – a conjecture we formally confirm below.

Proposition 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 (5) we can rewrite world welfare under regime R as

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

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). But from Proposition 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.

Grossman and Lai (2004) showed that the Nash equilibrium under NT gives rise to under-protection of intellectual property relative to the socially optimal levels due to the positive internalities 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.

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 protection granted to domestic firms, an increase in the level of patent protection granted to foreign firms that eliminates discrimination increases global welfare. The driving force behind this result is as follows: since each country offers too little protection to foreign firms, a NT policy that leaves domestic protections unchanged essentially increases overall patent protection thereby alleviating the inefficiency of aggregate under-protection in the global economy.

While there is under-protection of patent protection in our model as well, what our analysis highlights is that a move towards increasing patent protection to foreigners driven by NT does not occur in isolation since each country simultaneously lowers the

[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. We can show that holding constant the patent protection of one country at a non-discriminatory level, unilateral violation of NT by the other country can indeed lower overall patent protection and welfare. This implies that the strategic substitutability of patent policies across countries is key to understanding Proposition 3 (*ii*).

protection it grants to domestic firms. In fact, such changes in patent protection granted to domestic firms as a result of NT offsets 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.

4 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 when trade is subject to barriers arising from the existence of trade costs and/or trade policy restrictions. We now address this issue and show that when trade barriers exist, NT induces incomplete offsetting of patent protection across countries and actually ends up *lowering* the effective level of global patent protection.

4.1 Trade liberalization and discrimination

Before deriving the effect of trade barriers on the incentives for discrimination in patent protection, we make three simple observations. First, trade barriers raise the local prices of imported goods in each market and therefore reduce the surplus consumers derive from them. Second, by making it costlier for firms to export, trade barriers lower export profits of firms (while having no effect on their domestic profits). Third, trade barriers do not affect the consumer surplus derived from goods whose patents have expired since such goods are not traded and are imitated and produced locally in each market.

Denote the degree of trade openness or liberalization between countries by θ, where $0 \leq \theta \leq 1$ and $\theta = 1$ represents free trade while $\theta = 0$ indicates prohibitive trade barriers. 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 $\theta\pi$. It is important to note that this parsimonious formulation of trade barriers (i.e. as being captured by a single parameter θ) is adopted purely for expositional simplicity.[17] Our results below hold as long as both consumer surplus and export profits decrease with trade barriers even if they do so at very different rates.

It is worth noting that in the context of patent protection, a world with prohibitive trade frictions ($\theta = 0$) is not the same as an autarkic economy that is shut off from the world in every way. If technology transfer does not depend on trade (i.e. if trade in ideas can occur without trade in goods – see Rivera-Batiz and Romer, 1991), then even when trade barriers are prohibitive (i.e. $\theta = 0$) a country is free to imitate foreign goods. As a result, one would expect a country to have less incentive to protect intellectual property under $\theta = 0$ 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 $\theta M_j \Omega_{ji} \pi$ 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 government 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 thus the profit firms make in their domestic markets. A country's marginal benefit of domestic protection,

[17] Suppose $h(x) = \zeta^{1/\varepsilon} \frac{\varepsilon}{\varepsilon-1} x^{\frac{\varepsilon-1}{\varepsilon}}$ where $\varepsilon > 1$ and $\zeta > 0$. This utility function yields a constant elasticity demand curve of the form $x(p) = \zeta p^{-\varepsilon}$ for each differentiated good. If, in addition, trade barriers are assumed to be 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. The ice-berg formulation of trade barriers has also recently been used to good effect by Ossa (2011) in his theory of international trade policy negotiations. 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.

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

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

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 trade openness (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

$$C_c-C_m-\pi=\frac{\gamma M_i}{M_i\Omega_{ii}+\theta M_j\Omega_{ji}}[(C_m-C_c)\Omega_{ii}+C_c\overline{T}] \tag{12}$$

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 decreases with trade liberalization (θ).

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

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

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 with trade openness (θ).

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

$$C_c-\theta C_m=\frac{\gamma\theta M_i}{\theta M_i\Omega_{ij}+M_j\Omega_{jj}}[(\theta C_m-C_c)\Omega_{ij}+C_c\overline{T}] \tag{13}$$

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

Proposition 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, bilateral trade liberalization increases the degree of effective global patent protection in both countries, i.e., $\frac{\partial P^*_i(\theta)}{\partial \theta} > 0$ where $P^*_i(\theta) = M_i\Omega^*_{ii}(\theta) + \theta M_j \Omega^*_{ji}(\theta)$.*

Proposition 4 shows that the *trade liberalization reduces the incentive to discriminate against foreign firms*. It follows then that an international discipline such as NT would be less objectionable to each country when trade frictions are lowered between them. This finding resonates well with the fact that multilateral negotiations over intellectual property were preceded by eight rounds of trade negotiations that were successful in lowering trade frictions through-out the world. Our model suggests that these multiple rounds of trade negotiations may have helped lowered the resistance among governments to multilateral disciplines on intellectual property.

It is worth noting that Proposition 4 addresses *bilateral* trade liberalization. One might also be interested in the effects of *unilateral* trade liberalization. Suppose θ_i denote the trade openness of country i. Then, we can show that holding the trade barriers of the other country constant, unilateral trade liberalization by country i (i.e. an increase in θ_i) induces it to strengthen its patent protection toward country j's firms (Ω_{ij}) while having no effect on the protection it grants to local firms (Ω_{ii}). Thus, the key driving force behind the positive effect of bilateral trade liberalization on global patent protection is the effect such trade liberalization has on the patent protection granted by each country to foreign firms.

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.[18]

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 details:

$$\begin{aligned} C_c - (\mu_i + \theta\mu_j)C_m - \pi \;=\;& \frac{\gamma M_i \mu_i}{M_i\Omega_i + \theta M_j \Omega_j}[(C_m - C_c)\Omega_i + C_c\overline{T}] \\ &+ \frac{\gamma\theta M_i \mu_j}{\theta M_i \Omega_i + M_j\Omega_j}[(\theta C_m - C_c)\Omega_i + C_c\overline{T}] \end{aligned} \tag{14}$$

To investigate the efficiency impact of NT, we now introduce the assumption that countries are symmetric in all respects ($M_i = M$, $K_i = K$ and $a_i = a$). This is a 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, analytical solutions under NT are difficult to calculate when countries are asymmetric. As a result, we use numerical examples to study the case of asymmetry and show that our results do not require countries to be symmetric.

Denote the symmetric Nash equilibrium level of patent protection in each country 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 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:

$$P^{NT}(\theta) = M(1+\theta)\Omega^*(\theta) < P^*(\theta) = M(\Omega^*_d(\theta) + \theta\Omega^*_f(\theta))$$

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

(ii) The gap between the degree of effective patent protection under discrimination and NT decreases with trade liberalization (i.e. $P^*(\theta) - P^{NT}(\theta)$ falls 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 barriers 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, equilibrium effective protection is lower under NT. 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 barriers 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 5 can also be understood by examining the marginal benefit and marginal cost of strengthening patent protection. Suppose that $P^{NT}(\theta) \leq P^*(\theta)$. Then from the right-hand sides of (A6) and (A7) in the Appendix, we can see that the marginal benefit of raising effective patent protection is larger under discrimination for both countries. Moreover, it is larger than the marginal cost of patent protection so that each country would want to extend its total patent protection to eliminate the cost-benefit gap. This implies that $P^{NT}(\theta) = P^*(\theta)$ cannot be sustained as a Nash equilibrium. As a result we must have $P^*(\theta) > P^{NT}(\theta)$.

4.2 Jointly optimal policies under trade frictions

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}). The jointly optimal policies solve

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

We show in the appendix that

$$\frac{\partial WW^D(\theta)}{\partial \Omega_{ii}} - \frac{1}{\theta}\frac{\partial WW^D(\theta)}{\partial \Omega_{ji}} = \frac{\phi_i^D M_i(1-\theta)C_c}{\theta} > 0 \text{ for all } 0 < \theta < 1 \tag{15}$$

i.e. 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. Using this key relationship, we prove the following result:

Proposition 6: *In the presence of trade frictions (i.e. $0 < \theta < 1$), social optimality calls for each country to discriminate against foreign firms, i.e. $\Omega^w_{ij} < \Omega^w_{ii}$ for $i, j = H, F$.*[19] *Furthermore, if it is optimal to offer firms less protection in their domestic markets than the useful lifetime of products (i.e. $\Omega^w_{ii} < \overline{T}$), then it is optimal to give them no patent protection in their export markets (i.e. $\Omega^w_{ji} = 0$).*[20]

The central point of Proposition 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, not only the level of protection but also its composition matters. In contrast, Grossman and Lai (2004) show that under free trade efficiency depends on the level of total protection but not the compositional feature. In our model, this is easily verified by taking $\theta = 1$ in (15), so that domestic and foreign protections have equal net benefit.

Proposition 6 shows that, in the realm of patent protection, discriminatory policies are desirable even when beggar-thy-neighbor incentives are completely missing (as they are when countries maximize joint welfare). Bond (2005) has shown that it can be socially efficient to internationally discriminate with respect to patent protection if the elasticity of innovation with respect to patent protection differs across countries. Our results imply that this is not necessary for discrimination to be desirable since we allow the elasticity of innovation with respect to patent protection to be the same across

[19] 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: $\frac{\partial \Omega^w_{ii}}{\partial (M_j/M_i)} > 0$.

[20] 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 $\overline{T}$. Even so, the rationale for discrimination would remain since such enforcement costs would persumably also apply to foreign protection, and might even be higher than those for domestic protection.

countries.[21]

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 larger 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 the North's foreign protection may exceed the South's domestic protection. This is because the larger country tends to discriminate less while the smaller country free rides more. Notably, even though the South may be "sheltered" by the North, Proposition 6 indicates that this is not justified from an efficiency point of view.

It is also useful to consider the socially optimal protection levels assuming that NT must be followed. If countries must abide by NT while choosing jointly optimal policies, the common protection level in each country solves:

$$\underset{\Omega_i,\,\Omega_j}{Max}\; WW^{NT}(\theta) \text{ where } WW^{NT}(\theta) = \sum_i W_i^{NT}(\theta)$$

It is straightforward that world welfare cannot be higher under NT as additional constraints are imposed on the same maximization problem. Then the natural question would be whether NT yields strictly lower world welfare. Proposition 6 implies that this is indeed the case as long as there exist interior solutions under NT. The reason is straightforward: by maintaining the level of total patent protections under NT, efficiency can be improved by substituting domestic protection for foreign, which necessarily creates discrimination. Thus we arrive at the following:

[21] An interesting implication of the presence of trade frictions is that discrimination could be more desirable for goods that are harder to trade. Specifically, in an extreme case where goods are non-tradable (i.e. $\theta = 0$), there would be no reason to protect foreign firms as their innovation incentives are unresponsive to patent protection granted by countries other than their own. As a result, when $\theta = 0$ protecting foreign innovation only delays domestic consumption by the duration of the patent without affecting the rate of innovation.

Proposition 7: *Suppose interior solutions are obtained under NT. Then the imposition of a NT constraint on the social planner lowers welfare:* $WW^{NT}(\theta) < WW^{D}(\theta)$.

5 Further analysis

In what follows, we address two important issues. First, 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. Second, we extend our model to a three-country setting in order to assess the effects that the formation of a free trade agreement (FTA) has on equilibrium patent policies and welfare. In this setting, we also examine how the coordination of patent protection between two countries affects the rest of the world. The motivation behind this analysis is to determine whether preferential trade relationships (that are a clear violation of the MFN principle) create incentives for preferential relationships in the realm of intellectual property and, if so, how this feedback affects excluded countries.

5.1 NT in a North-South setting

The WTO is comprised of countries with markedly different economies and it is important to determine how NT operates in such an environment. To address this, we consider a North-South world where Home is taken as the North, i.e. $M_H > M_F$, $K_H > K_F$.[22] We illustrate the effects of NT in such a setting by employing a constant elasticity demand function ($x = p^{-\varepsilon}$ where $\varepsilon = 1.5$). With this specific demand function it can be shown that $C_m = \pi \approx 0.2Cc$. Also, the following values are assigned to the fundamental parameters of the model: $\alpha = 0.67$, $\gamma = 3$, $C_c = 5$ and $\overline{T} = 20$. These parameter values ensure interior solutions under discrimination and NT and our results are robust to variations in their values. To normalize away any level effects, we fix the total world market size ($M_H + M_F$) and the stock of human capital ($K_H + K_F$).

[22] We set $\rho = 1$ and $a_H = a_F$ for simplicity.

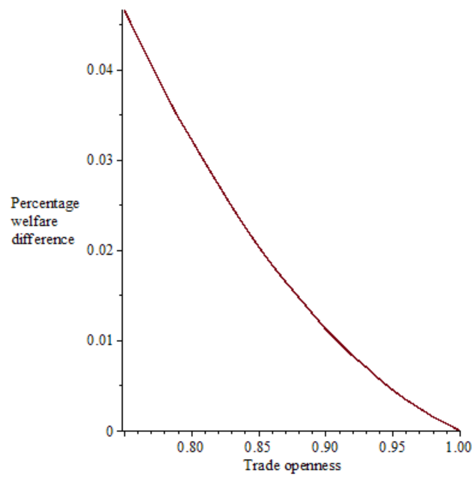

Figure 1: Discrimination versus NT when market size differs

Figure 1 shows how the welfare difference between discrimination and NT, i.e. $(WW^D - WW^{NT})/WW^{NT}$, varies with trade frictions θ, given $M_H = 10$, $M_F = 5$, $K_H = 2$ and $K_F = 1$. 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 analytical findings under symmetry. Moreover, as trade frictions fall (i.e. θ increases), the welfare differential between the two regimes converges to zero.

To see how the welfare gap is affected by the degree of asymmetry, we study the effects of variations in market size by assuming human capital stock to be equal across countries. In particular, we reduced the gap between M_H and M_F in the above experiment to 0, fixing their sum (at 20). Also we set $K_H = K_F = 1$ and $\theta = 0.75$. *Figure 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 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.

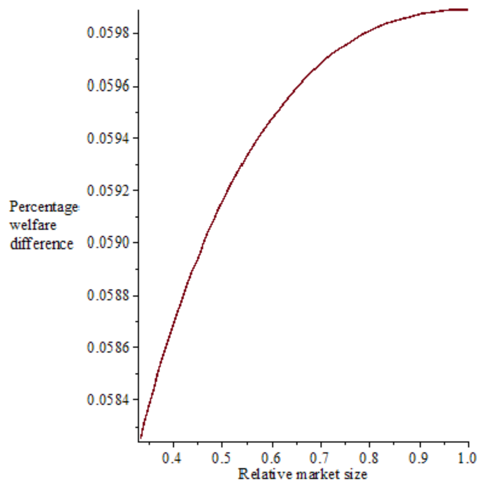

Figure 2: Comparison when market size differs

Finally, we illustrate the effect of asymmetric human capital stocks. To this end, we equalize market size across countries by setting $M_H = M_F = 7.5$ and bring K_H and K_F closer to 1.5 from 2 and 1 respectively. Again, we see in Figure 3 that NT generates a smaller welfare loss when human capital stocks are more unequal. 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. To see what drives our results, note that Home chooses stronger patent protection under NT (i.e. Ω_H^{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, Home firms will receive more total protection as its major component is Ω_H^{NT} and the increase in Ω_H^{NT} is not discounted by trade frictions θ. As a result, the country with more human capital 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).

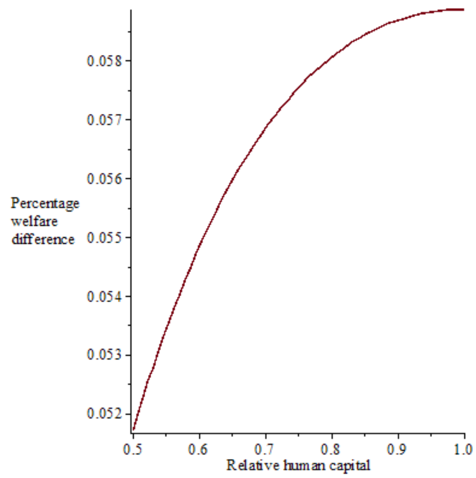

Figure 3: Welfare difference with asymmetric human capital stocks

5.2 Patent policies and preferential trade liberalization

As we noted earlier, non-discrimination within TRIPS manifests itself in two different forms: NT and MFN. Our analysis thus far has focused on NT and not addressed the issue of why countries might be tempted to violate MFN in the context of patent protection and what the consequences of such a violation might be for all concerned. In principle, while there can be many reasons for discriminating across one's trading partners, we focus on differences in trade policy barriers. The reason to do so is simple: the number of preferential trade agreements (PTAs) have risen sharply in recent decades.[23] By definition, PTA members grant trade policy concessions to each other that they do not extend to others. Our interest lies in determining the consequences of such non-discriminatory trade liberalization for equilibrium patent policies.

The most commonly occurring PTAs are free trade agreements (FTAs) such as the North American Free Trade Agreement between Canada, Mexico, and the US. In some of these FTAs, particularly those involving the US, member countries have also attempted to coordinate their policies with respect to intellectual property protection.[24]

[23] As per the WTO's web-site, as of 15 January 2012, 511 notifications of PTAs had been received by the WTO. Of these notifications, 319 PTAs are already in force while others are scheduled for implementation in the near future. Intra-PTA trade represented about 35 per cent of total world merchandise trade in 2008, compared with 18 per cent in 1990 (World Trade Report, 2011).

[24] Strictly speaking, under such FTAs, the smaller countries (such as Chile, Jordan, and Singapore) negotiating FTAs with the US agreed to strengthen the level of protection that they granted to intel-

Accordingly, in what follows, we first assess the implications of the formation of an FTA between two countries on patent policies in the global economy. Next, we describe the consequences of coordination over patent policies between FTA members.

Suppose the world economy comprises three countries: Home, Foreign, and a third country we call the Rest of the World (ROW) that is denoted by R. For simplicity and to isolate the effects of differences in trade barriers across countries, through-out this section we continue to assume that countries are symmetric with respect to market size and human capital. Let trade openness between Home and Foreign be denoted by $\lambda\theta$ while that between Home and the ROW (as well as between Foreign and the ROW) be given by θ, where $\lambda \geq 1$ measures the degree to which Home and Foreign firms enjoy preferential access to each other's markets. An increase in λ (starting at $\lambda = 1$) is equivalent to the formation of an FTA between Home and Foreign under which they reduce trade barriers on each other while holding trade barriers with respect to the ROW constant.[25] Our interest is in determining the impact of the formation of such a FTA on equilibrium patent policies.

To begin, suppose Home and Foreign are small in the sense that their patent policies do not affect policies in the ROW. Let the patent protection granted by the ROW to Home and Foreign be denoted by Ω_R and that to its own firms by Ω_{RR}. Following earlier derivations, the first order conditions determining patent policies of an FTA member country (denoted by $i, j = H, F$) can be written as follows:

$$\frac{\partial W_i(\theta,\lambda)}{\partial \Omega_{ii}} = 0 \Leftrightarrow C_c - C_m - \pi = \frac{\gamma}{\Omega_{ii} + \theta\lambda\Omega_{ji} + \theta\Omega_R}[(C_m - C_c)\Omega_{ii} + C_c\overline{T}],$$

$$\frac{\partial W_i(\theta,\lambda)}{\partial \Omega_{ij}} = 0 \Leftrightarrow C_c - \theta\lambda C_m = \frac{\gamma\theta\lambda}{\theta\lambda\Omega_{ij} + \Omega_{jj} + \theta\Omega_R}[(\theta\lambda C_m - C_c)\Omega_{ij} + C_c\overline{T}]$$

and

$$\frac{\partial W_i(\theta,\lambda)}{\partial \Omega_{iR}} = C_c - \theta C_m = \frac{\gamma\theta}{\theta\Omega_{iR} + \theta\Omega_{jR} + \Omega_{RR}}[(\theta C_m - C_c)\Omega_{iR} + C_c\overline{T}]$$

lectual property in return for improved and preferential access to the US market relative to the rest of the world.

[25] In our model, coordinating countries have an incentive to push liberalization as far as possible but note that θ captures policy barriers to trade (such as tariffs), transportation costs, as well as all other factors that may lower the profitability of exports and the consumer surplus derived from imports. Therefore, even if countries adopt perfectly liberal trade policies, they may be unable to eliminate all frictions that impede trade.

Denote equilibrium protection levels chosen by FTA members by $\Omega^*_{ii} = \Omega^*_{jj}$, $\Omega^*_{ij} = \Omega^*_{ji}$, and $\Omega^*_{iR} = \Omega^*_{jR}$. The degree of effective global patent protection received by an FTA country then equals

$$P^*(\theta, \lambda) = [\Omega^*_{ii}(\theta, \lambda) + \theta\lambda\Omega^*_{ji}(\theta, \lambda) + \theta\Omega_R(\theta, \lambda)]M$$

while that by the ROW equals

$$P^*_R(\theta, \lambda) = [\theta\Omega^*_{iR}(\theta, \lambda) + \theta\Omega^*_{jR}(\theta, \lambda) + \Omega^*_{RR}(\theta, \lambda)]M$$

Using the first order conditions listed above, we can prove the following result:

Proposition 8: *(i) The formation of an FTA between two countries increases the effective global patent protection enjoyed by their firms while having no effect on the protection available to firms from ROW:* $\frac{\partial P^*(\theta,\lambda)}{\partial \lambda} > 0$ and $\frac{\partial P^*_R(\theta,\lambda)}{\partial \lambda} = 0$.
(ii) If patent policies of the ROW are endogenous, part (i) continues to hold even though the ROW reduces its patent protection toward FTA *members (i.e.* $\frac{\partial \Omega_R(\theta,\lambda)}{\partial \lambda} < 0$*).*

The important point about Proposition 8 is that *preferential trade liberalization creates incentives for preferential patent protection*: the ROW ends up facing relatively unfavorable discrimination in patent protection due to mutual trade liberalization between FTA members. Such discrimination is clearly a violation of the MFN principle, a key clause of the TRIPS agreement. But Proposition 8 argues that ruling out discrimination based on preferential trade liberalization is counter-productive since it lowers overall patent protection and therefore aggregate welfare in the global economy. This is because the additional innovation induced in FTA member countries as a result of stronger protection enjoyed by FTA members benefits not just them, but also the ROW. Part (*ii*) of Proposition 8 follows from the general substitutability of patent policies across countries: as FTA members increase their patent protection to each other, the ROW can reduce the protection it grants FTA members without compromising innovation incentives.

Finally, we consider the case where two FTA member countries also coordinate their patent policies. More specifically, we consider a scenario where Home and Foreign form an FTA under which they eliminate mutual trade barriers (i.e. set $\lambda\theta = 1$) and agree to grant NT to (only) each other while retaining their barriers with the ROW (at θ).

The trade barriers with respect to the ROW are held constant. Let the protection that FTA members grant to each other be denoted by Ω_M while that they grant to the non-member (or the ROW) be denoted by Ω_R. Under coordination, FTA members jointly choose Ω_M and Ω_R to solve

$$\underset{\Omega_M,\, \Omega_R}{Max} \sum_{i=H,F} W_i^{NT}$$

Denote the solution to this problem by $(\Omega_M^C(\theta), \Omega_R^C(\theta))$. The degree of effective global patent protection received by firms from an FTA country under coordination then equals

$$P^C(\theta) = [\Omega_M^C(\theta) + \theta\lambda\Omega_M^C(\theta) + \theta\Omega_R^C(\theta)]M$$

while that available to the ROW be given by

$$P_R^C(\theta, \lambda) = [\Omega_N^C(\theta) + \theta\Omega_N^C(\theta) + \Omega_{RR}^C(\theta)]M.$$

We prove the following result in the appendix:

Proposition 9: *Suppose two countries form an FTA and choose their patent policies to maximize joint welfare. Then the following hold:*
(i) Holding constant the patent policies of the ROW, coordination between FTA members increases effective global patent protection available to firms from all countries: $P^C(\theta, \lambda) > P^*(\theta, \lambda)$ and $P_R^C(\theta, \lambda) > P_R^*(\theta, \lambda)$.
(ii) If patent policies of the ROW are endogenous, part (i) continues to hold even though the ROW reduces its patent protection for local firms (i.e. $\Omega_{RR}^C < \Omega_{RR}^*$*).*

The noteworthy part of the above result is that even though FTA members do not account for the welfare of the ROW, they find it optimal to increase protection not just to each other's firms but also to firms from the ROW. The logic is easy: in the absence of coordination, each FTA member ignores the benefits of its own protection on the welfare of the partner country and this is true also for the level of protection each extends to the ROW. As a result, coordination calls for them to increase protection to not only each other but also the ROW. Finally, as in the two country model, an increase in effective global patent protection raises global welfare.

Thus, our analysis above shows that a violation of MFN in the context of patent protection can actually be in the interest of even those that are discriminated against.

This result contrasts sharply with models of trade policy where MFN applies to trade in goods: in such models, eliminating discrimination in trade policy makes the country that is discriminated against generally better off. As is clear from above, in the context of endogenous innovation, international discrimination in patent protection does not create harmful welfare effects so long as it is in the direction of increasing patent protection above the Nash equilibrium level.[26] In other words, discrimination does not take the form of lowering patent protection for one country while holding everything else constant.

The key point is that, in our model, discrimination in patent protection motivated by a reduction in trade barriers between two countries results in an increase in the degree of effective global patent protection and the benefits of enhanced innovation spill across national boundaries. Of course, this is not to say that discriminatory trade liberalization is necessarily first-best, even non-discriminatory or MFN consistent liberalization would have the effect of encouraging innovation. Rather the point is to note that the rest of the world benefits from the trade liberalization and/or patent policy coordination between a pair of countries even when its interests are not taken into account by those countries.

6 Conclusion

The TRIPS agreement was controversial from the start. Developing countries fought hard against the inclusion of any multilateral rules on intellectual property, just as major developed countries put their considerable weight behind the opposite position. In addition to raising intellectual property protection in developing countries, TRIPS made it illegal for WTO members to discriminate against as well as across foreign nationals via the NT and MFN principles respectively.

At first glance, the inclusion of these principles in TRIPS hardly seems worthy of comment. After all, the idea of non-discrimination is the very foundation of today's multilateral trading system. Yet, our analysis has shown that the desirable properties of NT and MFN in the context of policy instruments that affect trade in goods (or market access) do not extend automatically to the domain of policies that determine

[26] We should also note that, in our model, the volume of a country's trade has no affect on its ability to innovate or imitate. If trade were to be an important channel of knowledge transmission, then it is conceivable that by causing trade diversion an FTA could lower the welfare of an excluded country even if it increases innovation within member countries.

the protection 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 fully compensated by what they gain at home. But when access to foreign markets is imperfect, the case for non-discrimination in intellectual property 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 firms a higher level of effective patent protection because exports are relatively 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 reducing the volume of trade). As a result, in our model, imposing a NT constraint on national governments actually reduces welfare in the presence of trade frictions.

We also show that preferential trade liberalization that results from the formation of a free trade agreement (FTA) between two countries induces them to raise their patent protection towards each other while having no effect on their policies toward the rest of the world. While such discrimination in patent protection violates the MFN principle, it actually makes all countries better off. This result is driven by the fact that the Nash equilibrium patent protection is too low in our model: the extra innovation induced in FTA member countries benefits consumers worldwide, including those in the non-member country.

Of course, these results do not imply that MFN based trade liberalization is undesirable. Rather, our point here is that changes in trade policies that increase innovation by raising overall patent protection can increase welfare even if they violate MFN. Overall, our analysis shows that time tested multilateral principles of NT and MFN are on relatively weaker turf in the realm of intellectual property.

7 Appendix

7.1 Supporting calculations

Here we show that

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

Note that $\frac{\partial \phi_i}{\partial \Omega_i^i} = \frac{\partial \phi_i}{\partial v_i} \times \frac{\partial v_i}{\partial \Omega_i^i}$. Hence, $\frac{\partial \phi_i}{\partial v_i} = \frac{\partial \phi_i}{\partial L_{Ii}} \frac{\partial L_{Ii}}{\partial v_i} = F_L^i \times \frac{\partial L_{Ii}}{\partial v_i}$. Differentiating the firm's FOC $v_i F_L^i = w_i$ w.r.t v_i we obtain $F_L^i + v_i F_{LL}^i \frac{\partial L_{Ii}}{\partial v_i} = 0$. This implies $\frac{\partial L_{Ii}}{\partial v_i} = -\frac{F_L^i}{v_i F_{LL}^i}$. Therefore, $\frac{\partial \phi_i}{\partial v_i} = -\frac{F_L^{i2}}{v_i F_{LL}^i} = -\frac{F_L^{i2}}{v_i F_{LL}^i \phi_i} \times \phi_i = \frac{\gamma}{v_i} \phi_i$ where $\gamma \equiv -\frac{F_L^{i2}}{F_{LL}^i \phi_i}$. Also note that $\frac{\partial v_i}{\partial \Omega_{ii}} = M_i \pi$. As a result, $\frac{\partial \phi_i}{\partial \Omega_{ii}} = \frac{\gamma}{v_i} \phi_i \times M_i \pi = \frac{\gamma \phi_i M_i}{M_i \Omega_{ii} + M_j \Omega_{ji}}$.

7.2 Proof of Proposition 1

We prove Proposition 1 under the more general CES research technology with $\beta \leq 0$. The generalization brings about the essential feature that responsiveness of innovation to patent protection may differ across countries, i.e. $\gamma_H \neq \gamma_F$. Taking account of this feature, we can modify (9) and (10) as follows

$$C_c - C_m - \pi = \frac{\gamma_i M_i}{M_i \Omega_{ii} + M_j \Omega_{ji}} [(C_m - C_c)\Omega_{ii} + C_c \overline{T}] \tag{A1}$$

$$C_c - C_m = \frac{\gamma_j M_i}{M_i \Omega_{ij} + M_j \Omega_{jj}} [(C_m - C_c)\Omega_{ij} + C_c \overline{T}] \tag{A2}$$

where γ is no longer a constant. We may then add up (A1) for country i and (A2) for country j to get

$$2(C_c - C_m) - \pi = \frac{\gamma_i}{M_i \Omega_{ii} + M_j \Omega_{ji}} [(C_m - C_c)(M_i \Omega_{ii} + M_j \Omega_{ji}) + (M_i + M_j) C_c \overline{T}] \tag{A3}$$

$$2(C_c - C_m) - \pi = \frac{\gamma_j}{M_j \Omega_{jj} + M_i \Omega_{ij}} [C_m - C_c)(M_j \Omega_{jj} + M_i \Omega_{ij}) + (M_i + M_j) C_c \overline{T}]. \tag{A4}$$

It is easy to see that the right-hand sides of (A3) and (A4) are respectively monotonic functions of total protections $M_i \Omega_{ii} + M_j \Omega_{ji}$ and $M_j \Omega_{jj} + M_i \Omega_{ij}$. And they must also be equal to each other. It follows that we must have $M_i \Omega_{ii}^* + M_j \Omega_{ji}^* = M_i \Omega_{ii}^* + M_j \Omega_{ji}^*$ and $\gamma_i = \gamma_j = \gamma^*$. Hence (A3) and (A4) immediately imply that $\Omega_{ii}^* > \Omega_{ij}^*$ for $i, j = H, F$.

7.3 Proof of Proposition 3

We first show (ii). Adding up the first-order conditions for Ω_i and Ω_j under NT yields

$$2(C_c - C_m) - \pi = \frac{\gamma}{M_i\Omega_i + M_j\Omega_j}[(C_m - C_c)(M_i\Omega_i + M_j\Omega_j) + (M_i + M_j)C_c\overline{T}]. \quad \text{(A5)}$$

Comparing (A5) with either (A3) or (A4) yields that $\gamma_i = \gamma_j = \gamma = \gamma^*$ and

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

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 $\frac{\gamma^* M_i}{P^*}[(C_m - C_c)\Omega_{ii}^* + C_c\overline{T}] < \frac{\gamma^* M_i}{P^{NT}}[(C_m - C_c)\Omega_i^{NT} + C_c\overline{T}] < \gamma^*\frac{M_i}{P^*}[(C_m - C_c)\Omega_{ij}^* + C_c\overline{T}]$ due to the first-order conditions for Ω_{ii}, Ω_i and Ω_{ij}. This implies

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

which is the desired result.

Finally, when countries are symmetric we may focus on the symmetric equilibria such that $\Omega_{ii}^* = \Omega_{jj}^*$, $\Omega_{ij}^* = \Omega_{ji}^*$ under discrimination and $\Omega_i^{NT} = \Omega_j^{NT}$ under NT. Then (A3) and (A5) together imply that

$$\frac{1}{(\Omega_{ii}^* + \Omega_{ij}^*)}[(C_m - C_c)(\Omega_{ii}^* + \Omega_{ij}^*) + 2C_c\overline{T}] = \frac{1}{2\Omega_i^{NT}}[(C_m - C_c)2\Omega_i^{NT} + 2C_c\overline{T}],\ i, j = H, F$$

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

7.4 Proof of Proposition 4

We prove this claim under the Cobb-Douglas technology, noting that it is easy to generalize under the assumption of CES. Again one can obtain the first-order conditions for country j by reversing i and j in (12) and (13). It is easy to show that

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

and

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

where $\eta = M_j/M_i$. It follows that $\Omega^*_{ii}(\theta)$ decreases in θ since $\frac{\eta\theta(C_c - C_m - \pi)}{(C_c - yC_m)}$ 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

$$P^*_i(\theta) = M_i\Omega^*_{ii}(\theta) + \theta M_j\Omega^*_{ji}(\theta) = \frac{\gamma C_c\overline{T}}{(2+\gamma)(C_c - C_m) - \pi}\left[M_i + M_j\frac{\theta(C_c - C_m)}{(C_c - \theta C_m)}\right]$$

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

7.5 Proof of Proposition 5

We know that $\Omega^*(\theta)$ satisfies the following first-order condition:

$$2C_c - (1+\theta)C_m - \pi = \frac{\gamma}{(1+\theta)\Omega^*(\theta)}[(C_m - C_c)(1+\theta)\Omega^*(\theta) + (1+\theta)C_c\overline{T} - (1-\theta)\theta C_m\Omega^*(\theta)]. \tag{A6}$$

Similarly, $\Omega^*_d(\theta)$ and $\Omega^*_f(\theta)$ respectively satisfy the following first order conditions:

$$C_c - C_m - \pi = \frac{\gamma}{\Omega^*_d(\theta) + \theta\Omega^*_f(\theta)}[(C_m - C_c)\Omega^*_d(\theta) + C_c\overline{T}]$$

and

$$C_c - \theta C_m = \frac{\gamma\theta}{\Omega^*_d(\theta) + \theta\Omega^*_f(\theta)}[(\theta C_m - C_c)\Omega^*_f(\theta) + C_c\overline{T}]$$

Adding up the last two equations we obtain

$$2C_c - (1+\theta)C_m - \pi = \gamma\left[\frac{1}{\Omega^*_d(\theta) + \theta\Omega^*_f(\theta)}[(C_m - C_c)(\Omega^*_d(\theta) + \theta\Omega^*_f(\theta)) + (1+\theta)C_c\overline{T} - (1-\theta)\theta C_m\Omega^*_f(\theta)\right] \tag{A7}$$

Moreover, it can be shown that $\Omega^*(\theta) > \Omega^*_f(\theta)$, which further implies that $(1-\theta)\theta C_m\Omega^*(\theta) > (1-\theta)\theta C_m\Omega^*_f(\theta)$.[27] Since the right-hand sides of (A6) and (A7) 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

$$\Omega^*_d(\theta) + \theta\Omega^*_f(\theta) > (1+\theta)\Omega^*(\theta)$$

[27] Note that $\Omega^*_d(\theta) > \Omega^*_f(\theta)$ in any interior equilibrium. Further, if $\Omega^*_f(\theta) \geq \Omega^*(\theta)$, then $\Omega^*_d(\theta) > \Omega^*_f(\theta) \geq \Omega^*(\theta)$ and this implies $\Omega^*_d(\theta) + \theta\Omega^*_f(\theta) > (1+\theta)\Omega^*(\theta)$. One can use the latter inequality to show that (A6) and (A7) cannot hold simultaneously. As a result, we must have $\Omega^*(\theta) > \Omega^*_f(\theta)$ in equilibrium.

Multiplying both sides by the common market size M, we get

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

■

7.6 Proof of Proposition 6

We first show that

$$\frac{\partial WW^D(\theta)}{\partial \Omega_{ii}} - \frac{1}{\theta}\frac{\partial WW^D(\theta)}{\partial \Omega_{ji}} = \frac{\phi_i M_i}{\rho}\frac{(1-\theta)C_c}{\theta} > 0 \text{ for all } \theta < 1$$

We have

$$\frac{\partial WW^D(\theta)}{\partial \Omega_{ii}} = \frac{\phi_i M_i}{\rho}[\frac{\gamma}{P_i(\theta)}[(C_m - C_c)P_i(\theta) + (M_i + M_j)C_C\overline{T} - (1-\theta)M_jC_c\Omega_{ji}] - (C_c - C_m - \pi)] \tag{A8}$$

and

$$\begin{aligned}\frac{1}{\theta}\frac{\partial WW^D(\theta)}{\partial \Omega_{ji}} \quad = \quad & \frac{\phi_i M_i}{\rho}[\frac{\gamma}{P_i(\theta)}[(C_m - C_c)P_i(\theta) + (M_i + M_j)C_C\overline{T} - (1-\theta)M_jC_c\Omega_{ji}] \\ & -(C_c - C_m - \pi) - \frac{(1-\theta)}{\theta}C_c] \end{aligned} \tag{A9}$$

Subtracting the second equation from the first yields the desired result.

First order conditions (A8) and (A9) simply say that for any country the net marginal benefit of domestic protection is higher than that of protection received from abroad. It follows that global efficiency requires each country to be protected through its domestic market whenever possible. Foreign protection may be needed (which depends on model parameters such as γ) when domestic protection has hit the boundary $\overline{T}$. Assuming foreign protection is always interior (i.e. γ cannot be too large), we have $\Omega_{ji}^w < \Omega_{ii}^w$. In particular, $\Omega_{ji}^w = 0$ whenever Ω_{ii}^w is an interior solution.

To show that each country necessarily practices discrimination (i.e. $\Omega_{ij}^w < \Omega_{ii}^w$), let us differentiate several cases. First, the conclusion is obvious if both Ω_{ii}^w and Ω_{jj}^w are interior solutions. Second, when $\Omega_{ii}^w = \Omega_{jj}^w = \overline{T}$ discrimination must exist as foreign protection is not at the same corner. Finally, suppose $\Omega_{ii}^w = \overline{T}$ and $\Omega_{jj}^w < \overline{T}$, so that $\Omega_{ji}^w \geq 0$. Suppose $\Omega_{ji}^w > 0$ (otherwise we are done). To show that $\Omega_{jj}^w > \Omega_{ji}^w$, note that under

CES technology with $\beta \leq 0$, we must have $P_i^*(\theta) \leq P_j^*(\theta)$ because country i resorts to foreign protection that is more costly. This implies $M_i\Omega_{ii}^w + M_j\Omega_{ji}^w \leq M_j\Omega_{jj}^w + M_i\Omega_{ij}^w$, which is reduced to $M_i\Omega_{ii}^w + M_j\Omega_{ji}^w \leq M_j\Omega_{jj}^w$ (as $\Omega_{ij}^w = 0$). It follows that we must have $\Omega_{ji}^w < \Omega_{jj}^w$ for the inequality to hold.

■

7.7 Proof of Proposition 8

To prove part (i) we assume that the ROW's patent policies are fixed. One can derive the optimal patent policies for FTA countries from their first-order conditions. The effective protection for FTA countries can then be obtained by $P^*(\theta,\lambda) = [\Omega_{ii}^*(\theta,\lambda) + \theta\lambda\Omega_{ji}^*(\theta,\lambda) + \theta\Omega_R^*(\theta,\lambda)]M$. Straightforward calculations show that

$$\frac{\partial P^*(\theta,\lambda)}{\partial\lambda} = \frac{\gamma\theta C_c^2\overline{T}(C_c - C_m)}{[(2+\gamma)(C_c - C_m) - \pi](C_c - \theta\lambda C_m)^2} > 0$$

Moreover, the patent protection FTA countries offer to the ROW is

$$\Omega_{iR}^* = \frac{\theta\Omega_{RR}C_m - \Omega_{RR}C_c + \gamma\theta C_c\overline{T}}{\theta[(2+\gamma)(C_c - \theta C_m)]}$$

where Ω_{RR} is the ROW's patent protection for itself. Note that Ω_{RR} is fixed by assumption and Ω_{iR}^* does not depend on λ. Hence $\frac{\partial P_R^*(\theta,\lambda)}{\partial\lambda} = 0$. This completes the proof of part (i).

To prove part (ii), we allow the ROW's policies to be endogenous. This introduces the first-order conditions for the ROW's patent protections, which is familiar by now. It can be shown that

$$\frac{\partial P^*(\theta,\lambda)}{\partial\lambda} = \frac{\gamma\theta C_c^2\overline{T}(C_c - C_m)}{[(3+\gamma)(C_c - C_m) - \pi](C_c - \theta\lambda C_m)^2} > 0$$

Moreover, we have

$$\frac{\partial\Omega_R(\theta,\lambda)}{\partial\lambda} = -\frac{C_c^2\overline{T}(C_c - C_m)}{[(3+\gamma)(C_c - C_m) - \pi](C_c - \theta\lambda C_m)^2} < 0$$

which implies that ROW lowers its protection toward FTA members.

To prove part (ii), we allow the ROW's policies to be endogenous. This introduces the first-order conditions for the ROW's patent protections, which are familiar by now. It can be shown that

$$\frac{\partial P^*(\theta,\lambda)}{\partial \lambda} = \frac{\gamma\theta C_c^2 \overline{T}(C_c - C_m)}{[(3+\gamma)(C_c - C_m) - \pi](C_c - \theta\lambda C_m)^2} > 0$$

Moreover, we have

$$\Omega_{iR}^* = \frac{C_c\overline{T}[(\gamma\theta + \theta - 1)C_c - \gamma\theta C_m - \theta\pi]}{\theta[(3+\gamma)(C_c - C_m) - \pi](C_c - \theta\lambda C_m)}$$

Note that Ω_{iR}^* does not depend on λ and this completes the proof of part (ii). ■

7.8 Proof of Proposition 9

First assume the ROW's patent policies are fixed. One can calculate $P^C(\theta)$ and $P^*(\theta)$ by solving for the first-order conditions for the coordinating countries. It can then be shown that

$$P^C(\theta,\lambda) - P^*(\theta,\lambda) = \frac{\gamma\pi[\theta\Omega_{RR}(C_c - C_m) + 2C_c\overline{T}]}{[(2+\gamma)(C_c - C_m) - \pi][(2+\gamma)(C_c - C_m) - 2\pi]} > 0$$

Similarly, one can show that

$$P_R^C(\theta,\lambda) - P_R^*(\theta,\lambda) = \frac{\gamma[\Omega_{RR}(C_c - \theta C_m) + 2\theta C_c\overline{T}]}{(C_c - \theta C_m)(1+\gamma)(2+\gamma)} > 0$$

which is the desired result.

When the ROW's policies are endogenous, one can solve for the optimal patent policies for each country and show

$$P^C(\theta,\lambda) - P^*(\theta,\lambda) = \frac{\gamma\pi C_c\overline{T}[(2+\theta)C_c - 3\theta C_m]}{(C_c - \theta C_m)[(3+\gamma)(C_c - C_m) - \pi][(3+\gamma)(C_c - C_m) - 2\pi]} > 0$$

and

$$P_R^C(\theta,\lambda) - P_R^*(\theta,\lambda) = \frac{\gamma C_c\overline{T}(C_c - C_m)[(1+2\theta)C_c - 3\theta C_m]}{(C_c - \theta C_m)[(3+\gamma)(C_c - C_m) - \pi][(2+\gamma)(C_c - C_m) - \pi]} > 0$$

Finally, the change in ROW's domestic protection can be written as

$$\Omega_{RR}^C - \Omega_{RR}^* = -\frac{C_c\overline{T}(C_c - C_m - \pi)[(1+2\theta)C_c - 3\theta C_m]}{(C_c - \theta C_m)[(3+\gamma)(C_c - C_m) - \pi][(2+\gamma)(C_c - C_m) - \pi]} < 0.$$

■

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