Mutual Recognition in the International Protection of Intellectual Property

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Abstract

This paper shows that implementing the principle of mutual recognition (MR) in the international protection of intellectual property (IP) can yield inefficiently high levels of IP protection. Nevertheless, MR can improve welfare if (*i*) innovation is sufficiently responsive to IP protection and (*ii*) international trade frictions are sufficiently low. These results provide insight into circumstances under which the implementation of MR in IP protection can be a welfare improving policy reform.

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1 Introduction

The last three decades have witnessed a surge in global patenting activity: during 1990-2019, the number of global patent applications more than tripled, having increased from 997,500 to 3,224,200.[1] Meanwhile, the explosion in patent applications has caused growing patent backlogs across national patent offices, a problem that is likely to aggravate in coming years if not addressed through some type of international policy coordination over the granting of intellectual property (IP).[2] Delays in patent processing can be costly for society if they end up having an adverse effect on innovation incentives.

One practical avenue for reducing patent pendency is the international acceptance of the principle of mutual recognition (MR) of patent rights.[3] If two countries follow MR of patent rights with respect to one another, they agree to officially "recognize" each other's patent policies in the sense that the conferral of a patent on an innovator by one country automatically results in the granting of an equivalent patent by the other country. Given that a fair share of global patent applications are filed in multiple jurisdictions, MR can potentially reduce patent backlogs by cutting down redundant patent applications and their examination by multiple national offices.[4]

While the benefits of eliminating redundancy seem clear, a proper evaluation of the principle of MR entails studying its effects in a setting where patent protection policies are endogenously determined. Evaluating the effects of MR without allowing national patent policies to adjust can potentially lead to erroneous policy conclusions. With this insight as a guiding principle, we examine two key questions: (i) How does the adoption of the principle of MR between a pair of countries affect their incentives for patent

[1] These statistics regarding global patent applications were obtained from the database of the World Intellectual Property Organization.

[2] As per one estimate in 2010, the overall backlog at seven major national patent offices was anticipated to increase from 35 months of backlog to 48 months over the next five years (London Economics, 2010).

[3] MR is a principle commonly adopted in international agreements on product standards. A leading example is the EU's approach to technical standards which features MR as a core principle. See http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex:31985Y0604(01).

[4] While multilateral coordination over IP at the WTO has been governed by the national treatment clause (i.e., non-discrimination between foreign and domestic innovators), the principle of MR in IP has been implemented bilaterally between a number of countries and regions. For example, Austria has a MR-based agreement on patent and trademark rights with Chinese Taipei, and the latter also implements MR of rights on patents and utility models with Germany. Besides, the Buenos Aires Convention – a multilateral copyright treaty – provides MR of copyrights among eighteen countries in the Americas.

protection? And (*ii*) how does it affect global innovation and welfare? A careful analysis of these fundamental questions is important for properly evaluating the economic case for MR in international patent protection. To the best of our knowledge, the present paper is the first to provide such an analysis. We establish two major results. First, in contrast to alternative IP regimes such as national treatment that yield inadequate IP protection relative to the social optimum, MR can lead countries to offer too much patent protection under free trade. Second, we derive a pair of simple conditions under which MR necessarily improves welfare: (*i*) innovation is sufficiently responsive to IP protection and (*ii*) trade frictions between countries are sufficiently low.

To address our central questions, we build upon Grossman and Lai's (2004) open-economy multi-country model of innovation. Though this model focuses on patent protection, its findings also apply to other forms of IP rights such as copyrights and trademarks. In the model, firms engage in variety-expansion R&D and each country chooses the level of patent protection granted to domestic and foreign firms which is assumed to be the same due to the principle of national treatment (NT) that requires countries to treat domestic and foreign firms symmetrically. The model captures the classic trade-off between dynamic welfare gains and the static deadweight losses that result from IP protection, as first highlighted by Nordhaus (1969). On one hand, stronger patent protection raises firms' incentives for conducting R&D. On the other, it reduces the flow of consumer surplus by increasing the monopoly power of firms. The optimal patent policy balances these conflicting welfare effects of patent protection.

To identify the impact of MR, we compare innovation and welfare under two alternative patent policy regimes. In the first regime, countries follow MR under which the level of patent protection each country grants foreign firms equals the protection those firms receive in their own countries. In the second regime, countries independently choose their patent protection levels towards domestic and foreign firms. We call this latter policy regime *discrimination*, as previous analysis has shown that when facing no institutional constraints countries choose to grant weaker patent protection to foreign firms relative to domestic ones (Geng and Saggi, 2015, 2022). Moreover, to fully understand the efficiency implications of MR in patent protection, we also compare MR with the globally optimal levels of patent protection.

We first show that, under free trade, the equilibrium level of patent protection under MR exceeds the globally optimal level. This result is in sharp contrast to previous findings that patent protection under NT as well as discrimination tends to be insufficient

(Grossman and Lai, 2004; Geng and Saggi, 2015). The key reason for this contrast lies in the nature of externalities generated by a country's patent protection towards local and foreign firms. Under NT and discrimination, patent protection granted by a country to foreign firms generates positive externalities for foreign consumers (who benefit from innovation) as well as foreign firms (who earn greater monopoly profits). By contrast, patent protection decisions under MR can yield *negative international externalities*: as a country raises its own patent protection, MR mandates that its firms be also granted the same level of protection abroad, which increases their monopoly power in foreign markets and thus lowers foreign consumer surplus. While choosing its patent protection policy, each country ignores the negative international impact of the matching increase in patent protection instituted by its trading partners required under the principle of MR. As a result, Nash equilibrium patent policies under MR exhibit over-protection of patents, as opposed to under-protection that typically arises under NT and discrimination. We believe this result highlights a key conceptual distinction between MR and other major types of policy regimes governing international patent protection.

We also show that, although MR does not induce the globally optimal level of patent protection, its adoption can still yield higher welfare relative to discrimination if the elasticity of innovation with respect to patent protection is sufficiently high. Intuitively, as innovation becomes more responsive to patent protection, an increase in patent protection generates greater dynamic gains. This makes patent over-protection relatively less problematic from a welfare perspective relative to under-protection. As a result, MR can induce higher world welfare than discrimination if innovation is sufficiently responsive to patent protection. Thus, the first condition for MR of IP to yield welfare gains relative no coordination is that the adopting countries be sufficiently innovative.

Next, we show that the presence of trade frictions can drastically alter the welfare implications of MR. In particular, the effects of MR can be reversed for large enough trade frictions such that imposing MR can lower effective patent protection, innovation and world welfare.[5] This is because MR makes countries enforce a high level of foreign patent protection by mandating it to equal the domestic protection of other countries. When trade frictions exist, however, foreign patent protection is less effective for incentivizing innovation as firms do not profit as much from their exports. In such a situation, social optimality entails limiting foreign patent protection and incentivizing innovation

[5] We formally define effective patent protection in section 2. Roughly speaking, effective patent protection is what actually determines firms' profits and innovation incentives. It can be less than nominal patent protection if export profits are diluted by trade frictions.

primarily through domestic patent protection. This result leads to a second condition for MR to be welfare-enhancing: i.e. the adopting countries should have sufficiently low trade barriers amongst themselves.

Our paper contributes to the literature that examines strategic setting of national IP policies in the global economy (Lai and Qiu, 2003; Grossman and Lai, 2004; Lai and Yan 2013; Geng and Saggi, 2015, 2022). These papers yield the insight that strategic incentives can give rise to under-protection of IP under discrimination as well as national treatment. We show that this result can be reversed if the international IP regime is based on MR as opposed to discrimination or NT. Furthermore, we identify intuitive conditions under which imposing MR can be welfare-improving.

This paper also broadly relates to the literature on MR of alternative policy instruments such as product standards. The European Union, for example, adopts MR as a fundamental rule for its approach to regulatory standards. The welfare implications of MR of product standards have been analyzed in various studies (Costinot, 2008; Edwards, 2012; Toulemonde, 2013; Geng, 2019; Grossman et al., 2021). Unlike these studies, our paper provides the first formal economic analysis of MR in the context of international IP protection.

The paper is structured as follows. Section 2 describes the set-up of the model. Section 3 examines the implications of MR under free trade, and section 4 investigates how these implications are affected by the existence of trade frictions. Section 5 concludes.

2 Baseline model

Our analysis builds on the open-economy model of innovation developed in Grossman and Lai (2004). The baseline model considers a world comprising two countries: Home (H) and Foreign (F), although the analysis extends readily to an n-country case, where $n \geq 3$. Each country has two sectors: one producing a homogeneous good and the other producing a variety of differentiated goods. A representative consumer in each country maximizes her lifetime utility as

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

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

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

where $y(z)$ and $x(s,z)$ represent respectively the consumption of the homogeneous good and the sth differentiated good at time z, $n(z)$ denotes the variety of differentiated goods that exist at time z, and $h(\cdot)$ is consumer's utility derived from each differentiated good at time z.[6] There are M_i consumers in country i, where $i = H, F$.

On the supply side, differentiated goods are invented through research and development (R&D) which requires a combination of labor (L) and human capital (K) as inputs. For ease of exposition, we assume country i's aggregate R&D technology takes the Cobb-Douglas form

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

where $\phi_i(z)$ is the measure of newly invented differentiated goods 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. Our major results also hold under the CES R&D technology but the exposition is cleaner under the Cobb-Douglas case. Once invented, each differentiated good has a finite life span ($\overline{\tau}$) so that it yields positive utility to consumers over $\overline{\tau}$ prior to becoming obsolete and exiting the market.

In country i, a_i units of labor are needed to produce one unit of either the homogeneous or the differentiated goods. The homogeneous good is assumed to be the numeraire and is sold on a perfectly competitive market. We assume L_i to be sufficiently large so that in equilibrium each country always produces a positive amount of the homogeneous good. This implies that the wage rate in country i equals the marginal product of labor in the homogeneous sector: i.e. $w_i = 1/a_i$. Finally, labor is mobile between sectors but not across countries.

At each time period z, $\phi_H(z) + \phi_F(z)$ differentiated goods are invented and enter country i's market, where $\phi_H(z)$ and $\phi_F(z)$ are determined by (3). In the meantime, $\phi_H(z-\overline{\tau}) + \phi_F(z-\overline{\tau})$ differentiated products invented at $z - \overline{\tau}$ become obsolete. As a result, the growth in the variety of differentiated goods in country i at a given point in time is

$$\dot{n}_i(z) = \phi_H(z) - \phi_H(z-\overline{\tau}) + \phi_H(z) - \phi_F(z-\overline{\tau}) \tag{4}$$

We focus on the steady state where $\dot{n}_i(z) = 0$.

[6] As with Grossman and Lai (2004), the utility function $h(\cdot)$ is assumed to satisfy the following regularity conditions: (i) $h' > 0$ and $h'' < 0$; (ii) every variety of differentiated goods is purchased in equilibrium (i.e. $h'(0) = \infty$); and (iii) optimal monopoly price of each differentiated good is finite (i.e. $-xh''/h' < 1$).

To incentivize innovation, each country's government affords patent protection to firms that successfully invent differentiated goods. As in Grossman and Lai (2004), patent protection has two dimensions: the length τ and the degree of enforcement ω where $\omega \in [0, 1]$. These two dimensions can be captured by a composite patent index $\Omega = \omega(1 - e^{-\rho\tau})/\rho$. Intuitively, Ω reflects the present value of a 1 dollar flow over the term of the patent τ. Also let $\overline{T} = \omega(1 - e^{-\rho\overline{\tau}})/\rho$ denote the present value of a 1 dollar flow over the entire product life of a differentiated good. While a patent is in force, the protected firm can charge monopoly price and earn the associated monopoly profit π. After the patent expires, the market for the good becomes competitive where all incumbents earn zero profits. It follows that the present value of the expected per capita profits from a patented good equals $\Omega\pi$.

Our objective is to investigate the implications of MR of patent protection. To this end, we compare a patent regime based on MR with one featuring no institutional constraints whatsoever. We term the latter patent regime discrimination since when countries can freely choose their patent protection, they end up discriminating in favor of domestic firms by granting them stronger protection. Let Ω_{ii}^{R} and Ω_{ij}^{R} denote country i's patent protection for domestic and foreign firms under regime R, where $R = MR$ or D (i.e. discrimination). Under MR, each country's patent protection for foreign firms equals what these firms receive in their home country, that is, $\Omega_{ij}^{MR} = \Omega_{jj}^{MR}$. Thus country i only determines its domestic patent protection, Ω_{ii}^{MR}. By contrast, country i sets both Ω_{ii}^{D} and Ω_{ij}^{D} under discrimination.

Under patent regime R, a patenting firm from country i expects to earn the present value of an aggregate profit $M_i\Omega_{ii}^{R}\pi$ in the home market and $M_j\Omega_{ji}^{R}\pi$ overseas. Thus, the value of a patenting firm from country i equals $v_i^R = (M_i\Omega_{ii}^{R} + M_j\Omega_{ji}^{R})\pi$. As will be useful, we denote $P_i^R = M_i\Omega_{ii}^{R} + M_j\Omega_{ji}^{R}$ as the *effective* global patent protection received by the firms from country i. We call P_i^R effective protection received by firms from country i as it is what determines firm profits and their R&D incentives. Also note that profit maximization implies that the marginal value of labor input in R&D equals the wage rate in equilibrium: $v_i^R \partial F_i(L_{Ii}, K_i)/\partial L_{Ii} = w_i$, which pins down the amount of labor allocated to R&D activity.

Let C_m and C_c be the instantaneous per capita consumer surplus derived from each differentiated good with and without patent protection. In particular, $C_m = h(x_m) - p_m x_m$ and $C_c = h(x_c) - p_c x_c$ where (p_m, x_m) and (p_c, x_c) are the combinations of price and per capita consumption of each differentiated product with and without patent protection. It follows that $C_m < C_c$, that is, consumer surplus is higher after a patent expires as the price of the good drops. The present value of per capita consumer surplus derived from each domestic differentiated good equals $C_m\Omega_{ii}^R + C_c(\overline{T} - \Omega_{ii}^R)$ whereas that from each foreign good is $C_m\Omega_{ij}^R + C_c(\overline{T} - \Omega_{ij}^R)$.

Let Λ_0 denote the welfare yielded by all the goods invented prior to the implementation of patent policies. Then country i's national welfare under patent regime R can be written as the sum of the aggregate consumer surplus and firm's global profits

$$\begin{aligned} W_i^R &= \Lambda_{i0} + \frac{w_i}{\rho}(L_i - L_{Ii}^R) + \frac{M_i\phi_i^R}{\rho}[C_m\Omega_{ii}^R + C_c(\overline{T} - \Omega_{ii}^R)] \qquad (5) \\ &+ \frac{M_i\phi_j^R}{\rho}[C_m\Omega_{ij}^R + C_c(\overline{T} - \Omega_{ij}^R)] + \frac{\pi\phi_i^R}{\rho}(M_i\Omega_{ii}^R + M_j\Omega_{ji}^R) \quad \text{for } i, j = H, F \text{ and } i \neq j. \end{aligned}$$

Moreover, define world welfare as the sum of each country's national welfare:

$$WW^R = W_H^R + W_F^R. \qquad (6)$$

3 MR under free trade

In this section, we investigate the implications of adopting MR in patent policies when trade between countries is frictionless.

3.1 Equilibrium patent protection under MR

Suppose countries non-cooperatively and simultaneously choose their patent protection policies except that they agree to follow the principle of MR. Each country's objective is to maximize its national welfare. The impact of MR can then be identified by comparing Nash equilibria under MR and discrimination (i.e. the regime in the absence of MR).

First consider the Nash equilibrium under MR. Recall that a country only needs to choose the patent protection for its own firms taking account of the fact that the other country grants its firms the same level of protection by virtue of MR. There are two benefits from raising a country's own protection Ω_{ii}^{MR}. The first is the gain in consumer surplus derived from more varieties invented by domestic firms, which is

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

where $\frac{\partial \phi_i^{MR}}{\partial \Omega_{ii}} = \frac{\partial \phi_i^{MR}}{\partial v_i^{MR}} \times \frac{\partial v_i^{MR}}{\partial \Omega_{ii}}$ represents the increased number of differentiated good due to a marginal strengthening of own patent protection. Importantly, since MR implies $\Omega_{ii}^{MR} = \Omega_{ji}^{MR}$, we have $v_i^{MR} = (M_i + M_j)\Omega_{ii}^{MR}\pi$ which indicates that

$$\frac{\partial v_i^{MR}}{\partial \Omega_{ii}^{MR}} = (M_i + M_j)\pi.$$

That is, under MR an increase in country i's own patent protection raises the value of its firms in both markets because country j equally raises its protection for country i's firms. One can further show that $\frac{\partial \phi_i^{MR}}{\partial v_i^{MR}} = \frac{\gamma \phi_i^{MR}}{v_i^{MR}}$ where $\gamma = \frac{\alpha}{1-\alpha}$ represents the elasticity of innovation in response to changes in patent protection. Hence, the first benefit of raising Ω_{ii}^{MR} can be simplified as

$$\frac{M_i}{\rho} \frac{\gamma \phi_i^{MR}}{\Omega_{ii}^{MR}} [(C_m - C_c)\Omega_{ii}^{MR} + C_c \overline{T}].$$

The second benefit from strengthening Ω_{ii}^{MR} enjoyed by a country is the total increase in profits accruing to its firms from exports of all existing varieties

$$\frac{M_j \phi_i^{MR}}{\rho} \pi.$$

On the other hand, the marginal cost of raising Ω_{ii}^{MR} is the fall in country i's consumer surplus from the existing varieties sold by domestic firms

$$\frac{M_i \phi_i^{MR}}{\rho} (C_c - C_m - \pi),$$

The first-order conditions (FOCs) for Home and Foreign equate the marginal benefits with the marginal cost of increasing own patent protection. These conditions can be simplified as

$$C_c - C_m - (1 + \frac{M_F}{M_H})\pi = \frac{\gamma}{\Omega_{HH}^{MR}} [(C_m - C_c)\Omega_{HH}^{MR} + C_c \overline{T}] \tag{7}$$

and

$$C_c - C_m - (1 + \frac{M_H}{M_F})\pi = \frac{\gamma}{\Omega_{FF}^{MR}} [(C_m - C_c)\Omega_{FF}^{MR} + C_c \overline{T}]. \tag{8}$$

An important observation is that each country's FOC under MR depends only on its own patent protection. Hence, under MR the equilibrium patent policies of individual countries are *independent* across countries. This property differs from that under discrimination or NT where patent policies are *interdependent* (i.e. strategic substitutes) across countries (Geng and Saggi, 2015; Grossman and Lai, 2004). The intuition behind this contrast is the following. Under MR, each country's own protection determines the protection its firms receive at home as well as abroad. Thus, MR allows each country to essentially set the effective global patent protection for its firms. Such, however, is not the case under discrimination or NT where the level of patent protection that firms receive abroad is determined by the foreign government. As countries care about the global patent protection received by firms, each country's patent protection ends up depending on the level chosen by its trading partner.

Before proceeding, it is important to note that under MR, an increase in a country's domestic patent protection can generate a *negative* welfare externality on the other country. To see why, note that when country i raises own patent protection, MR requires country j to grant stronger protection to country i's firms, which leads to a static loss in country j's consumer surplus. Notably, such a negative cross-border externality does not arise under discrimination or NT, as a country's strengthening of its domestic protection does not mandate a matching increase in the protection for its firms by foreign countries. As we will show below, this contrast plays a key role in shaping the efficiency implications of MR.

3.2 Comparing MR and discrimination

We now compare equilibrium outcomes under MR and discrimination. To this end, we present country i's FOCs with respect to its own and foreign patent protections (i.e. Ω_{ii}^D and Ω_{ij}^D) under discrimination:

$$C_c - C_m - \pi = \frac{\gamma M_i}{P_i^D}[(C_m - C_c)\Omega_{ii}^D + C_c\overline{T}], \tag{9}$$

and

$$C_c - C_m = \frac{\gamma M_i}{P_j^D}[(C_m - C_c)\Omega_{ij}^D + C_c\overline{T}].^{7} \tag{10}$$

It can be shown that $\Omega_{ii}^{D*} > \Omega_{ij}^{D*}$, that is, under discrimination countries indeed extend stronger patent protection to their firms relative to foreign ones. This occurs because the cost of protecting domestic firms is partly offset by their increased monopoly profits, whereas the profits arising from protecting foreign firms accrue to the foreign country.

Comparing (7) and (9), we have $\Omega_{ii}^{MR*} > \Omega_{ii}^{D*}$, i.e. firms receive higher domestic patent protection under MR than under discrimination. Analogously, we can also show that $\Omega_{ji}^{MR*} > \Omega_{ji}^{D*}$, i.e. firms also receive higher foreign protection under MR. It follows that MR induces stronger effective global protection than discrimination. Hence we can state following proposition:

Proposition 1: *Relative to discrimination, firms receive higher patent protection from both countries under MR:* $\Omega_{ii}^{MR*} > \Omega_{ii}^{D*}$ *and* $\Omega_{ji}^{MR*} > \Omega_{ji}^{D*}$ *for* $i, j = H, F$. *As a result, the adoption of MR raises the degree of effective global patent protection available to firms:* $P_i^{MR*} > P_i^{D*}$ *for* $i, j = H, F$.

The intuition behind Proposition 1 is clear. MR gives each country a stronger incentive to raise patent protection since some of the cost of incentivizing innovation is shifted to the foreign country who has to offer its firms the same level of protection. This does not occur under discrimination where patent protection only yields positive cross-border externalities which in turn mute national incentives for providing such protection. Importantly, Proposition 1 suggests that MR can potentially alleviate the well-known problem of under-protection of patent that arises under discrimination and NT.

3.3 Welfare implications of MR

We now compare MR with the global optimum. To this end, we first solve for globally optimal patent protection that maximizes world welfare given in (5). The FOCs for this problem are:

$$C_c - C_m - \pi = \frac{\gamma}{P_i^{SO}}[(C_m - C_c)P_i^{SO} + (M_i + M_j)C_c\overline{T}] \quad \text{for } i, j = H, F \tag{11}$$

The left-hand side of (11) is the marginal social cost of protecting country i's firms on a per capita and per variety basis. Similarly, the right-hand side represents the marginal social benefit of protecting country i's firms. As the right-hand side is monotonically decreasing in P_i^{SO}, there exists a unique level of globally optimal patent protection, P_i^{SO*}. Importantly, (11) indicates that innovation and welfare under free trade depend on the level of P_i^{SO} rather than its composition, i.e. how much protection is granted by each country. This is because when trade is costless, each unit of domestic or foreign patent protection (e.g. Ω_{ii} or Ω_{ji}) is equally effective in incentivizing innovation and thus has the same cost and benefit effects.[8]

Next, let us solve for the effective global protection under MR, i.e. P_i^{MR}. To this end, multiplying the right-hand side of (7) by the world market size $M_i + M_j$ to obtain the condition that pins down equilibrium P_i^{MR}

$$C_c - C_m - (1 + \frac{M_j}{M_i})\pi = \frac{\gamma}{P_i^{MR}}[(C_m - C_c)P_i^{MR} + (M_i + M_j)C_c\overline{T}]. \tag{12}$$

Comparing (11) and (12), one can show that $P_i^{MR*} > P_i^{SO*}$, i.e. effective global patent protection under MR exceeds the globally optimal level. Hence we have the following proposition:

Proposition 2: *(i) The equilibrium level of effective global patent protection under MR exceeds the socially optimal level, i.e.* $P_i^{MR*} > P_i^{SO*}$ *for* $i = H, F$.
(ii) World welfare under MR is lower than the globally optimal level.

The intuition for Proposition 2 is the following. Raising own patent protection under MR generates both a positive and a negative externality on the foreign country. Nevertheless, it turns out that the negative externality dominates. To see this, note that the positive externality of raising Ω_{ii}, which is the gain in country j's consumer surplus due to a larger variety of goods invented by country i's firms, can be written as

$$\frac{M_j}{\rho}\frac{\gamma\phi_i^{MR}}{\Omega_{ii}^{MR}}[(C_m - C_c)\Omega_{ii}^{MR} + C_c\overline{T}].$$

On the other hand, the negative cross-border externality of raising Ω_{ii} is the fall in country j's consumer surplus from existing goods imported from country i, due to the matching increase in Ω_{ji}:

$$\frac{M_j\phi_i^{MR}}{\rho}(C_c - C_m).$$

Given country i's FOC under MR, (7), it is easily seen that $C_c - C_m > \frac{\gamma}{\Omega_{ii}^{MR*}}[(C_m - C_c)\Omega_{ii}^{MR*} + C_c\overline{T}]$, which implies that the negative externality of increasing Ω_{ii} must be larger in magnitude. Hence, raising own patent protection under MR generates a *net* negative externality on the foreign country. This, in turn, induces countries to choose suboptimally high levels of patent protection.

[8] In particular, it can be shown that the FOCs for maximizing global welfare with respect to Ω_{ii} and Ω_{ji} are identical. This, however, is not the case under trade frictions – something we address in greater detail below.

Given that neither MR nor discrimination induces the globally optimal outcome, it is important to ask whether MR welfare-dominates discrimination under certain circumstances.[9] The following proposition states the answer:

Proposition 3: *A regime of MR in patent protection yields higher welfare than discrimination provided innovation is sufficiently responsive to patent protection, i.e. the elasticity of innovation γ is sufficiently large.*[10]

Proof: see the appendix.

As innovation becomes more responsive, the dynamic gains from patent protection increase relative to its static efficiency losses. This makes over-protection of patents less costly relative to under-protection so that imposing MR increases world welfare.[11] Interestingly, Proposition 3 suggests that the case for MR maybe stronger when it is applied to industries in which the rate of innovation is highly responsive to the degree of patent protection. A case in point might be the pharmaceutical industry where relatively ineffective patent protection can slow down innovation substantially.[12] Thus, it could be welfare-improving to apply MR of patent protection in the pharmaceutical industry.[13]

4 MR under trade frictions

In this section, we examine how trade frictions such as transportation costs or trade policy restrictions may affect the welfare implications of MR. Two central findings emerge from the analysis. First, although MR induces over-protection of patents under free

[9]MR or discrimination may induce the globally optimal outcome if innovation is highly responsive to patent protection (e.g. γ is very large). In this case, both Nash and globally optimal outcomes may involve maximum patent protection (e.g. $\overline{T}$) and therefore coincide. We rule out this uninteresting case by focusing on interior solutions of patent protection.

[10]Since discrimination and NT have the same welfare implications under free trade as shown in Geng and Saggi (2015), it follows that the results of Proposition 2 and 3 also hold when one compares MR and NT.

[11]Note that although γ has to be sufficiently high for Proposition 3 to hold, numerical results show that moderate values of γ may ensure that MR yields higher world welfare than discrimination. We provide such an illustration in the appendix.

[12]For example, see Budish et al. (2015) who show that new drugs that require long-term research projects may be under-provided due to short-termism and the fixed patent term for all industries.

[13]This finding is relevant for certain real-world IP agreements (such as that between Japan and Chinese Taiwan) regarding the deposit of biological materials for the purpose of patent procedures.

trade, it can lead to *insufficient* patent protection when trade frictions are large enough. Second, imposing MR *lowers* welfare when trade frictions are high.

Denote the inverse of the level of trade frictions between countries by θ where $0 \leq \theta \leq 1$.[14] A lower θ implies higher trade frictions, with $\theta = 0$ and $\theta = 1$ indicating prohibitively high trade frictions and free trade respectively. We make two intuitive assumptions about the effects of trade frictions. First, trade frictions reduce the consumer surplus derived from foreign patented goods. Particularly, per capita consumer surplus derived from each foreign good can be written as $(\theta C_m - C_c)\Omega_{ji}^R + C_c\overline{T}$. Second, trade frictions lower firms' export profits. In this case, the value of country i's firms becomes $v_i^R(\theta) = P_i^R(\theta)\pi$ with $P_i^R(\theta) = M_i\Omega_{ii}^R + \theta M_j\Omega_{ji}^R$.

Now consider Nash equilibrium under MR. With trade frictions, the marginal benefit for country i from raising own patent protection Ω_{ii}^{MR} becomes

$$\frac{M_i}{\rho}\frac{\gamma\phi_i^{MR}(\theta)(M_i + \theta M_j)\pi}{v_i}[(C_m - C_c)\Omega_{ii}^{MR} + C_c\overline{T}] + \frac{M_j\phi_i^{MR}(\theta)}{\rho}\theta\pi.$$

Both terms in the above expression increase in θ, implying that trade frictions reduce the marginal benefit of Ω_{ii}^{MR}. In particular, the first term increases in θ as trade frictions undermine the effectiveness of foreign patent protection in incentivizing domestic innovation; the second term increases because trade frictions lower export profits of domestic firms.

Next, the marginal cost of strengthening Ω_{ii}^{MR} can be written as

$$\frac{M_i\phi_i^{MR}(\theta)}{\rho}(C_c - C_m - \pi).$$

The marginal cost also rises in θ because trade frictions reduce innovation incentives and decrease the variety of differentiated goods, which in turn reduces the total losses in consumer surplus. Equating the above marginal benefit to the marginal cost yields country i's FOC with respect to Ω_{ii}^{MR}

$$C_c - C_m - (1 + \theta\frac{M_j}{M_i})\pi = \frac{\gamma}{\Omega_{ii}^{MR}}[(C_m - C_c)\Omega_{ii}^{MR} + C_c\overline{T}]. \tag{13}$$

The left-hand side of (13) decreases in θ while the right-hand side is independent of it. It follows that higher trade frictions reduce country i's equilibrium own protection $\Omega_{ii}^{MR*}(\theta)$.

[14] Thus, we implicitly assume that trade frictions are symmetric between countries. One could alternatively assume asymmetric trade frictions such that $\theta_{ij} \neq \theta_{ji}$, where θ_{ij} (and θ_{ji}) is the trade frictions country j (and i) faces when exporting to country i (and j). Our results would carry over to this generalized case.

Moreover, given $P_i^{MR}(\theta) = (M_i + \theta M_j)\Omega_{ii}^{MR}(\theta)$, effective global patent protection under MR also decreases in θ. Hence, we have the following lemma:

Lemma 1: *Under MR, trade frictions lower each country's patent protection and the effective global patent protection available to firms, i.e.* $\partial\Omega_{ii}^{MR*}(\theta)/\partial\theta > 0$ *and* $\partial P_i^{MR*}(\theta)/\partial\theta > 0$.

We now compare MR with the global optimum. It can be shown that globally optimal patent protection under trade frictions satisfies the following condition

$$C_c - C_m - \pi = \frac{\gamma}{P_i^{SO*}}[(C_m - C_c)P_i^{SO*} + (M_i + M_j)C_c\overline{T}] \tag{14}$$

with $P_i^{SO*} = M_i\Omega_{ii}^{SO*}$. A key observation is that in the presence of trade frictions optimality requires countries to grant no protection for foreign firms, i.e. $\Omega_{ji}^{SO*}(\theta) = 0$. This is because trade frictions reduce the net social benefit generated by foreign patent protection relative to domestic protection, so that innovation is more efficiently incentivized through the latter.

Next, (13) implies that effective global protection under MR must satisfy the following condition

$$C_c - C_m - (1 + \theta\frac{M_j}{M_i})\pi = \frac{\gamma}{P_i^{MR}(\theta)}[(C_m - C_c)P_i^{MR}(\theta) + (M_i + \theta M_j)C_c\overline{T}]. \tag{15}$$

Now compare (14) and (15). It is useful to first consider prohibitive trade frictions such that $\theta = 0$. In this case, we must have $P_i^{MR*}(\theta) < P_i^{SO*}$, i.e. MR induces lower effective global protection than the globally optimal level. Moreover, since $P_i^{MR*}(\theta)$ is continuously increasing in θ while P_i^{SO*} is invariant to θ, we must have $P_i^{MR*}(\theta) < P_i^{SO*}$ for all θ close to 0. Hence, as opposed to the case of free trade, MR gives rise to suboptimally low effective global patent protection for sufficiently high trade frictions. Furthermore, there must exist some level of trade frictions $0 < \theta < 1$ such that $P_i^{MR*}(\theta) = P_i^{SO*}$, that is, MR induces the optimal level of effective global patent protection. However, it is important to note that equilibrium welfare under MR remains suboptimal in this case. The reason is that MR induces positive levels of foreign protection whereas global optimum under trade frictions entails providing no patent protection to foreign firms.

Can MR improve welfare relative to discrimination when trade frictions exist? Absent MR, the FOCs with respect to each country's own patent protection Ω_{ii}^D is

$$C_c - C_m - \pi = \frac{\gamma M_i}{P_i^D(\theta)}[(C_m - C_c)\Omega_{ii}^D + C_c\overline{T}] \tag{16}$$

Consider again $\theta = 0$. It can be seen that (13) becomes identical to (16) due to $P_i^D(\theta) = M_i\Omega_{ii}^D$. Therefore, we must have $\Omega_{ii}^{MR*}(\theta = 0) = \Omega_{ii}^{D*}(\theta = 0)$ which implies that a country would choose the same domestic protection under MR and discrimination when trade frictions are prohibitively high. Intuitively, in the absence of trade, each country cannot improve its firms' foreign profits by raising own patent protection, so the marginal net benefits of own protection converge under MR and discrimination.

Moreover, it is readily seen that $P_i^{MR*}(\theta = 0) = P_i^{D*}(\theta = 0)$, that is, MR and discrimination induce the same level of effective global patent protection under prohibitively high trade frictions. Nevertheless, this does not imply that world welfare is the same under the two regimes. The reason is that under MR countries have to recognize each other's own protection so that they have to provide positive foreign protection, i.e. $\Omega_{ji}^{MR*}(\theta = 0) = \Omega_{ii}^{MR*}(\theta = 0) > 0$. But this only gives rise to a loss in country j's consumer surplus as when $\theta = 0$ country j's foreign patent protection does not stimulate any innovation by country i's firms. By contrast, each country under discrimination chooses zero foreign protection because the marginal benefit of Ω_{ji}^D vanishes. This implies that discrimination induces a more efficient composition of effective global patent protection relative to MR, and thus would yield a higher level of world welfare. By continuity of world welfare in patent protection, it follows that for sufficiently high trade frictions discrimination must always dominate MR from the welfare perspective. The above discussion yields:

Proposition 4: *If trade frictions are sufficiently high, imposing MR lowers effective patent protection as well as welfare relative to discrimination, regardless of the innovation responsiveness parameter γ.*

Propositions 3 and 4 together identify two key conditions for MR to improve world welfare: (i) innovation is sufficiently responsive to patent protection and (ii) trade frictions between countries are not too high. Importantly, this insight suggests that an MR-based approach to IP policy is likely to be globally desirable between innovative and open countries.

5 Conclusion

This paper analyzes the implications of MR in the context of IP, a principle that is a feature of various recent IP agreements but has received little attention in formal economic research. We show that MR can promote innovation and welfare provided two intuitive conditions are met: innovation is sufficiently responsive to IP protection and trade frictions between countries are not too high. Moreover, it is worth noting that MR based IP agreements may yield additional gains for the rest of the world as it would lead to more innovation by adopting countries, the benefits of which can spread to other countries. Overall, our paper suggests MR as a beneficial rule for international IP protection if implemented under the right circumstances.

There are several open directions for future work. First, it would be interesting to see whether our results carry over when innovation is quality-improving. The mechanisms underlying our model suggest that this should be the case but formal verification would be useful. Second, we have focused on the qualitative features of MR of IP and it would be valuable to quantify the welfare impacts of MR.

6 Appendix

6.1 Proof of Proposition 3

From (11), (12), (9) and (10) we can solve for the explicit expressions for the effective global patent protections as

$$P_i^{SO*}(\gamma) = \frac{\gamma(M_i + M_j)C_c\overline{T}}{(\gamma+1)(C_c - C_m) - \pi},$$

$$P_i^{MR*}(\gamma) = \frac{\gamma M_i(M_i + M_j)C_c\overline{T}}{M_i(\gamma+2)(C_c - C_m) - (M_i + M_j)\pi},$$

$$P_i^{D*}(\gamma) = \frac{\gamma(M_i + M_j)C_c\overline{T}}{(\gamma+2)(C_c - C_m) - \pi}.$$

It is easy to check that $P_i^{D*} < P_i^{SO*} < P_i^{MR*}$ and all the effective global protections increase in γ.

Let $\Delta P_i^{MR*} = P_i^{MR*} - P_i^{SO*}$ and $\Delta P_i^{D*} = P_i^{SO*} - P_i^{D*}$. We have

$$\Delta P_i^{MR*}(\gamma) = \frac{\gamma M_j(M_i + M_j)C_c\overline{T}\pi}{\{(\gamma+1)(C_c - C_m) - \pi\}\{M_i(\gamma+2)(C_c - C_m) - (M_i + M_j)\pi\}},$$

and

$$\Delta P_i^{D*}(\gamma) = \frac{\gamma(M_i + M_j)(C_c - C_m)C_c\overline{T}}{\{(\gamma+1)(C_c - C_m) - \pi\}\{(\gamma+2)(C_c - C_m) - \pi\}}.$$

As γ increases, both ΔP_i^{MR*} and ΔP_i^{D*} tend to 0 so that both P_i^{MR*} and P_i^{D*} converge to P_i^{SO*}. Now let $\Delta WW^{MR*}(\gamma)$ and $\Delta WW^{D*}(\gamma)$ be the welfare losses under MR and discrimination relative to the global optimum. For large enough γ such that P_i^{MR*} and P_i^{D*} are sufficiently close to P_i^{SO*}, we can write $\Delta WW^{MR*} \simeq |\frac{\partial WW}{\partial P_i}|_{P_i^{MR*}}| \cdot \Delta P_i^{MR*}$ and $\Delta WW^{D*} \simeq |\frac{\partial WW}{\partial P_i}|_{P_i^{D*}}| \cdot \Delta P_i^{D*}$. Hence we only need to show $\Delta WW^{MR*} < \Delta WW^{D*}$ for sufficiently high γ. This amounts to showing that $\frac{|\frac{\partial WW}{\partial P_i}|_{P_i^{MR*}}|}{|\frac{\partial WW}{\partial P_i}|_{P_i^{D*}}|} < \frac{\Delta P_i^{D*}}{\Delta P_i^{MR*}}$ for large enough γ.

Substituting P_i^{MR*} and P_i^{D*} into $|\frac{\partial WW}{\partial P_i}|$ to obtain

$$|\frac{\partial WW}{\partial P_i}|_{P_i^{MR*}}| = \frac{M_j \pi}{M_i} \cdot \phi_i|_{P_i^{MR*}},$$

and

$$|\frac{\partial WW}{\partial P_i}|_{P_i^{D*}}| = (C_c - C_m) \cdot \phi_i|_{P_i^{D*}}.$$

Since both $\phi_i|_{P_i^{MR*}}$ and $\phi_i|_{P_i^{D*}}$ converge to $\phi_i|_{P_i^{SO*}}$ as γ increases, we have $\frac{|\frac{\partial WW}{\partial P_i}|_{P_i^{MR*}}|}{|\frac{\partial WW}{\partial P_i}|_{P_i^{D*}}|}$ converges to $\frac{M_j \pi}{M_i(C_c - C_m)}$. Assuming interior solutions, the left-hand side of (12) must be positive, that is, $C_c - C_m - (1 + \frac{M_j}{M_i})\pi > 0$. This implies that $M_i(C_c - C_m) > M_i + M_j \pi > M_j \pi$. It follows that $\frac{|\frac{\partial WW}{\partial P_i}|_{P_i^{MR*}}|}{|\frac{\partial WW}{\partial P_i}|_{P_i^{D*}}|}$ converges to $\frac{M_j \pi}{M_i(C_c - C_m)} < 1$ which says that world welfare does not fall too fast at P_i^{MR*} relative to at P_i^{D*}. Finally, direct calculations show that $\frac{\Delta P_i^{D*}}{\Delta P_i^{MR*}}$ converges to $\frac{M_i(C_c - C_m)}{M_j \pi} > 1$ as γ increases. Thus, we must have $\frac{|\frac{\partial WW}{\partial P_i}|_{P_i^{MR*}}|}{|\frac{\partial WW}{\partial P_i}|_{P_i^{D*}}|} < \frac{\Delta P_i^{D*}}{\Delta P_i^{MR*}}$ for large enough γ.

6.2 A numerical example of the welfare effects of MR

This numerical example illustrates that MR can yield higher joint welfare than discrimination even for moderate values of γ. To this end, we consider a constant elasticity demand function $x = p^{-\varepsilon}$ where we set $\varepsilon = 1.5$. It can be then shown that $C_m = \pi \approx 0.2Cc$. Also, we set the following values for the key parameters of the model: $\alpha = 0.67$, $C_c = 5$,

$\overline{T} = 10$ and $\rho = 1$. Thus we have $\gamma = \frac{\alpha}{1-\alpha} \approx 2.03$. In their calibration analysis, Lai and Yan (2013) consider $\gamma = 4$ along with other values of γ. Hence 2.03 seems a moderate value for γ. For simplicity, let $M_H = 1$, $M_F = 1$, $H_H = 1$ and $H_F = 1$. The chosen parameter values ensure interior solutions under MR and discrimination. The qualitative results from the simulation are robust to alternative values of the parameters.

Table A1: Equilibrium patent protections and welfare under MR and discrimination

	P^{MR*}	P^{D*}	P^{SO*}	$WW^{MR} - WW^{D}$	$(WW^{MR} - WW^{D})/WW^{D}$
$\theta = 1$	39.38	26.52	36.01	11494.49	17.80%
$\theta = 0.8$	34.79	23.38	36.01	5438.34	10.62%
$\theta = 0.6$	30.37	20.52	36.01	-1299.59	-3.06%

Two main observations emerge from Table A1. First, MR may induce too much or too little effective patent protection depending on the level of trade frictions. When trade frictions are minimal, i.e. $\theta = 1$, we see MR induces suboptimally high protection, i.e. $P^{MR*} > P^{SO*}$. However, when $\theta = 0.6$ so that trade frictions are fairly high, MR leads to suboptimally low patent protection, i.e. $P^{MR*} < P^{SO*}$.

Second, the welfare gains from MR over discrimination decline with trade frictions. As column 5 and 6 show, this is true when the welfare difference between the two regimes is measured in both levels and percentages. Moreover, as trade frictions become relatively high, i.e. $\theta = 0.6$, welfare under MR falls below that under discrimination. This example illustrates that the level of trade frictions between countries is key in shaping the welfare implications of MR.

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