A Strategic Model of Intellectual Property Protection Across Nations

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Abstract

In a two-country framework we study the strategic interacation between the governments regarding the choice of optimal patent policies and show that there always exist patent agreements that increase the welfare of each country. We then examine whether, in an optimal agreement, patent protection within each country will be discriminatory or uniform. On the assumption that countries are identical, we have shown that if cross-border imitation is perfect, the maximum welfare attainable under either regime is exactly equal. The positive marginal social gain from a uniformity clause arises only when imitation is imperfect.

Keywords: Intellectual property rights; uniform protection; discriminatory protection; research and development.

JEL classifications: O31; O34; O38.

1 Introduction

The issue of protecting intellectual property across national boundaries has received wide attention lately.[1] After much controversy, a TRIPs (Trade Related Aspects of Intellectual Property) accord was incorporated in the recently concluded Uruguay Round of the GATT. It requires member countries to give patent protection to all new innovations, irrespective of their country of origin.[2] The minimum duration of protection has been set at 20 years for most products. The TRIPs proposal, supported by industrialized nations, particularly USA, the leading innovating country, nevertheless met strong resistance from most of the developing world. Opponents argued that it would create substantial distortion in their domestic markets, and lead to increased prices for such essential items as pharmaceuticals.

Proponents of such an agreement often put forward a *pragmatic* argument for an integrated, common patenting system (as opposed to the indignant view that it is *ethically* unjust to steal rents from innovators). It is argued that wider protection of intellectual property will lead to a *Pareto improvement*. Even countries which are forced to extend protection to foreign firms will eventually gain in net terms from the increased flow of innovations that such a system will bring about. Obviously, making this argument is walking a very thin line—its validity depends on a proper weighing of the benefits (access to more new products and processes) against the ills (greater market distortion). This paper critically examines the issue.

There is a large literature on optimal patent policy, but mainly in the context of a closed economy. These works have analysed the problem of choosing different policy instruments, such as patent length, breadth and such practices as compulsory licensing.[3] We extend the analysis to a two-country framework, where the products developed in one country can be copied by producers in another. This leads to payoff externalities and strategic interaction between research firms as well as policy making authorities

[1] For conceptual issues one may look at Benko (1987), Maskus (1990), Maskus and Penubari (1994) and Subramanian (1990, 1991).

[2] Article 27.1 of the TRIPs Agreement reads, ".... patents shall be available and patent rights enjoyable without discrimination as to the place of innovation, the field of technology and whether products are imported or locally produced."

[3] See, for instance, Nordhaus (1969), Tandon (1982), Gilbert and Shapiro (1990), Klemperer (1990), Gallini (1992) and Boldrin and Levine (2002).

across the two countries. For simplicity of analysis, we focus on only one instrument of policy—the choice of patent length. We take as the benchmark case the situation where governments in the two countries independently frame their patent laws. This is contrasted with the outcomes that would be possible if countries could voluntarily sign binding patent agreements at the outset. Such agreements could specify the *duration* of protection to be provided by each country, as well as the *coverage* (i.e, which firms are to be protected—domestic or foreign?). We analyse the structure of optimal agreements as well as their welfare effects.

It is shown in a very generalized setting that there are always patent agreements which increase the welfare in each country. The reason is easy to see—due to the presence of positive externalities from extending protection (encouragement of research in one country benefits consumers in another, but this is not internalized by the former government), the patent length in each country tends to be too short when policies are chosen independently. We focus, however, on the suitable choice of regime—in an optimal agreement, should patent protection within each country be *discriminating* (i.e, only domestic innovations are protected) or *uniform* (i.e, both domestic and foreign firms are provided protection on the same terms)? This relates directly to the recent controversy over the GATT proposals.

We show that when countries are identical, a striking *equivalence* result holds—if cross-border imitation is perfect and research costs are not too high, the maximum symmetric welfare attainable under uniform protection is exactly equal to that obtainable under discriminating protection (assuming that the agreement sets patent length optimally in each case). The wider market distortion created by uniform protection is *exactly* offset by the benefits from the extra research activity that it generates. There are positive marginal social gains from an uniformity clause only when, and to the extent, imitation is imperfect (either in the form of higher cost of production for imitators, or lower quality) across countries. This result somewhat undermines the cause for *global* protection of intellectual property. While our analysis is conducted ignoring *implementation costs*, it is reasonable to posit that such costs will be much higher under an uniform protection system.[4] Thus, for products that can be imitated at very low cost, it may be efficient merely to strengthen patent protection *within* each country

[4] This is due to the absence of proper dispute settlement mechanisms if an innovating firm from one country brings charges of breach of agreement against the government in another country.

(to reap the externalities of such protection) instead of trying to implement a messy system of globally integrated patents.

The literature that talks about protection of intellectual properties in the international context is also quite vast.[5] The paper which is closely related to our work is by Aoki and Prusa (1993). In an interaction between two firms across borders Aoki and Prusa examine the effect of alternative standards for intellectual property protection. In particular, the paper studies the effect of discriminatory protection vis-a-vis uniform protection on the domestic R&D and shows that discriminatory protection may not increase domestic R&D. But it does not deal with the question of whether patent protection should be discriminatory or non-discriminatory, because it does not provide any welfare analysis. Our concern in the present paper is to examine whether uniform protection or discriminatory protection leads to a higher welfare in each country. We show that while inventive R&D under uniform protection will be strictly larger, welfare will be larger only when imitation is imperfect. In Aoki and Prusa, the firms compete in a single market and so the issue of spillovers in R&D has been overlooked. In contrary, we have considered interaction of firms in all the markets and therefore the imitation parameter plays a crucial role in determining the policy choice.

It may be mentioned that before the TRIPs resolution comes into force, international patent rules were governed by the Paris Convention which did never oblige member countries to prohibit, in their domestic legislation, the discrimination of patents as to the place of invention, the field of technology or whether products were imported or locally produced. As long as these sorts of discrimination are applied to both nationals and foreigners, the general principle of national treatment was respected. But under the TRIPs accord, member countries are obliged to ensure equal treatment of nationals and foreigners. The adoption of such a clause, in fact, has forced Canada to eliminate differential treatment for inventions practised in the country with regard to compulsory licenses. Section 104 of the US Patents Act, which imposed a discriminatory burden on foreign inventors, has been subsequently ammended and has extended the right to establish priority with respect to an invention not only in NAFTA countries, but in

[5] A subgroup of the literature includes Chin and Grossman (1991), Deardorff (1990, 1992), Diwan and Rodrik (1991), Aoki and Prusa (1993), Helpman (1993), Taylor (1994), Vishwasrao (1994), Grinols and Lin (1997), Yang (1998), Lai (1998), Marjit and Beladi (1998), Kabiraj (2000), Sakakibara and Branstetter (2001), Kabiraj and Banerjee (2002), and Glass and Saggi (2002).

any WTO member.

The lay out of the paper is the following. The second section provides the model of discriminating protection and uniform protection in two subsections, and in a general term we show that there always exist patent agreements that will lead to higher welfare for each country. Then we have solved the global planner's problem in section 3 and examine whether uniform patent protection generates larger R&D incentives and larger welfare compared to non-uniform protection. We have extended this section to study the effect of lobbies on the policy choices. Finally, section 4 provides a summary of the results.

2 The Model

2.1 Description

We construct a model of strategic interaction between two countries. In each country, there are two decision-making parties whose interests do not coincide completely—a government which maximizes social welfare and an R&D firm which maximizes expected profit from its research activity. Taking any representative country, we assume that its market demand conditions are given and stationary over time. Assume that the product in question, if developed by research laboratories, can be produced at a constant marginal cost of c per unit. Then, we can define the following scalars: let $\alpha_i \Pi$ denote the flow rent or profit a monopolist operating in this market would earn, whereas $\alpha_i C$ is the flow of consumers' surplus when the market is served by a monopolist. Further, let $\alpha_i S$ denote the total social surplus (which would be entirely in the form of consumers' surplus) that would arise per period if the market was competitive, operating by the marginal cost pricing rule. In the above expressions, α_i is a country specific factor which represents the market size of the country concerned. Without any loss of generality, we can normalize α_1 to be unity. Due to the familiar deadweight loss created in monopolistic markets, it must be true that $S > C + \Pi$.

The model is set in continuous time, with r as the rate of time discount, taken to be the same for everyone. The government in country i (where $i = 1, 2$) chooses a patent length T_i, to which it commits by passing a patent law. The innovating firm, if successful in creating the product, has exclusive right to market it and earn monopoly profits for a period of length T_i, after which the patent expires and the technology becomes freely available to other competing firms. Due to Bertrand competition, profits of all firms drops to zero from that point onwards.

We assume that the outcome of a research venture is probabilistic—the research may end up either in successful development of the product, or in failure. The research activity, however, requires costly resources, and it is natural to assume that application of more resources into research leads to a higher probability of success. We can represent the R&D firm's choice as effectively a choice of the probability of success, p, which carries with it a resource cost given by the cost function $\beta_i R(p)$, where β_i is a "research efficiency" parameter that may vary from one country to another. The following assumptions are made about this function:

Assumption: *The function $R(p)$ is twice continuously differentiable, with the following properties: $R^{'}(.) \geq 0, R^{''}(.) > 0, R(0) = 0, R^{'}(0) = 0$ and $R^{'}(1) = \infty$.*

The above assumptions are fairly innocuous. The positive second derivative captures diminishing returns in R&D activity, while the familiar Inada-type end point conditions are imposed to ensure interior solutions.

Depending on the governments' choice of patent policy at the outset, various regimes may ensue. The patent law formulated by any government has two different dimensions to it—the length of the patent, and its scope or coverage. The former refers to the time interval over which a patent holder is entitled to monopoly power; the latter concerns who can obtain a patent in the country in question. We shall analyze and compare two kinds of patent regimes: one in which countries provide *discriminating protection*, i.e, only domestic innovations are covered, while no provision is made to discourage immitation of products developed abroad, and another in which patent protection is *uniform*, i.e, innovating firms, irrespective of their country of origin, can hold a patent in any country. Governments can potentially enter into patent agreements with one another; such an agreement may involve clauses relating either to the patent length, or the coverage (whether it is discriminatory or uniform), or both. Thus, individual countries may agree to curb or extend the length of their respective patents, and may also agree to extend protection to foreign innovators.[6] We take as

[6]It is assumed that any patent agreement is treated as binding. Reputational considerations can, once again, justify such an assumption imposed on sovereign nations.

the benchmark case, however, the regime where governments offer discriminating protection, and choose their respective patent lengths unilaterally. The main purpose of the paper is to examine under what situations there exist patent agreements which, whether through coordinated control of individual country's patent lengths, and/or extending more uniform protection, increase global welfare.

2.2 Discriminating Protection

Let us first outline the benchmark case. This pertains to a regime of discriminating patent protection. The decision making processes essentially constitute a two stage game—in the first stage, the governments simultaneously and independently choose their respective patent lengths, while in the second stage, the research firms in the two countries simultaneously allocate resources to R& D. We solve for the subgame perfect equilibrium of this game, which gives each country's "reservation utility". Since either country has veto power over any patent agreement, any such deal must guarantee each nation at least this minimum level of welfare.

In a discriminating regime, the expected payoff to country i's research firm depends only on the length of the patent in that country, and can be written as

$$\begin{aligned}\phi_i^d(p_i, T_i) &= p_i \int_0^{T_i} e^{-rt} \alpha_i \Pi dt - \beta_i R(p_i) \\ &= p_i(1 - e^{-rT_i}) \frac{\alpha_i \Pi}{r} - \beta_i R(p_i) \qquad (1)\end{aligned}$$

where p_i is the firm's research intensity, chosen so as to maximize the above expected return function. The assumptions on $R(.)$ guarantee that for all positive values of T_i, the objective function is strictly concave and the maximizing problem has a unique and interior solution. Throughout, we shall assume that both firms and governments are risk neutral.

To economize on notation later, we shall introduce the following substitution: let $\lambda_i = 1 - e^{-rT_i}$. The first order condition to this maximization problem is then

$$\lambda_i \frac{\alpha_i \Pi}{r} = \beta_i R'(p_i) \qquad (2)$$

where p_i is the optimal choice. The solution to the above equation then generates a well defined "response function" $p_i = p_i^d(\lambda_i)$, which denotes the firm's choice of p_i in response to any arbitrary patent length λ_i.

It is easy to see, and is intuitively fairly obvious, that the response function is monotonically increasing in T_i. Longer patent protection means a larger accumulation of rents if discovery is made, thereby increasing the marginal value of increasing p_i. This can be formally checked by differentiating the first order condition, and obtaining the following:

$$\frac{dp_i^d}{d\lambda_i} = \frac{\alpha_i \Pi}{r\beta_i R''(p_i)} > 0 \tag{3}$$

Notice that it is normally impossible to say anything about the curvature of this response function, but it is certainly concave if $R''' \geq 0$. We shall assume, in the rest of the analysis that the response function is strictly concave, although none of the results crucially hinge on this assmption.

Next, we turn to the first stage of the game, in which the two governments simultaneously choose their respective patent lengths. Each government's problem can then be formulated as follows:

$$\begin{aligned}\max_{\lambda_i, p_i} W_i^d(\lambda_i, p_i; \lambda_j, p_j) &= \left[p_i \lambda_i \frac{\alpha_i \Pi}{r} - \beta_i R(p_i)\right] + p_i \left[\lambda_i \frac{\alpha_i C}{r} + (1-\lambda_i)\frac{\alpha_i S}{r}\right] \\ &\quad + p_j(1-p_i)\frac{\theta_i \alpha_i S}{r} \end{aligned} \tag{4}$$

subject to the constraint $p_i = p_i^d(\lambda_i)$. In the above expression, which represents an utilitarian social welfare function with equal weights on producers' and consumers' surplus, λ_j represents the patent length in the other country, and $p_j = p_j^d(\lambda_j)$. Further, $\theta_i \in [0, 1]$ is an imitation parameter. Imitation of a product developed abroad may be costly, either in the form of a higher cost of production than the original innovator, or a reduction in quality of the good, or in the form of a cost of "learning" about the technology. We do not explicitly model the imitation process at this stage. All imitation costs are captured in the parameter θ_i; thus, a fraction $(1-\theta_i)$ of the potential social surplus from an innovation is lost due to cost of imitation across border. $\theta_i = 1$ is the case of perfect (i.e, costless) imitation.

The first expression within square brackets in the social welfare function represents expected producers' surplus. The second expression represents present discounted value of expected consumers' surplus, in the event that the innovation arises at home (which happens with probability p_i). The last term represents expected producers' surplus in the event that an innovation is produced only abroad, and not by the domestic firm. This event arises with probability $p_j(1-p_i)$, which explains the attached weight.

A word about the specification of payoffs in the imperfect imitation case ($\theta_i < 1$) is in order. We assume that an innovating firm can earn no rent abroad in the absence of protection in the foreign market. This is a strong assumption. In a later section, we relax this by modeling an unprotected foreign market as a contested monopoly for the innovator. The assumption maintained in this section can nevertheless be justified on the following grounds. An innovating firm, in order to compete with imitating rivals in an unprotected foreign market (who have, say, a higher marginal cost of production), will be forced to reduce its price there. This may open up arbitrage opportunities for consumers in the domestic market.[7] If imitation is close to perfect, so that the required price reduction is large, the firm will do better by not serving the foreign market and thereby preventing arbitrage.

The solution to the above maximization exercise yields a pair of reaction functions in the game between the two governments. These are of the form: $\lambda_i = \lambda_i^d(\lambda_j)$, where $i = 1, 2; j \neq i$. The solution to this pair of equations yields the subgame perfect equilibrium of the whole game.

2.3 Uniform Protection

A patent agreement may require each government to extend protection to a foreign innovator on the same terms as to a domestic innovator. We first analyze the game between the R&D firms induced by such a regime. Each firm chooses a best response to its opponent's choice by solving the following exercise:

[7]This is especially true for products which can be easily shipped back to the exporting country, e.g, software. While import restrictions can be, and often are used to shut off illegitimate foreign brands from the market, such regulations can hardly prevent the re-routing of a brand whose sale is legal within the country.

$$\max_{p_i} \phi_i^u(p_i; p_j, \lambda_i, \lambda_j) = p_i \left(1 - \frac{1}{2}p_j\right) \left(\lambda_i \frac{\alpha_i \Pi}{r} + \lambda_j \frac{\alpha_j \Pi}{r}\right) - \beta_i R(p_i) \tag{5}$$

The first order condition to this problem is:

$$\left(1 - \frac{1}{2}p_j\right) \left(\lambda_i \frac{\alpha_i \Pi}{r} + \lambda_j \frac{\alpha_j \Pi}{r}\right) = \beta_i R^{'}(p_i) \tag{6}$$

This defines a pair of response functions in p_i and p_j. Given any λ_1, λ_2, the solution to this pair of equations defines the equilibrium in the subgame where firms make their choices. Let us denote these values by $p_i^u(\lambda_i, \lambda_j)$, where $i = 1, 2; j \neq i$.

Using these response functions, we can define the equilibrium of the game between the governments in the first stage. The government in country i solves the following problem:

$$\begin{aligned} \max_{\lambda_i, p_i} W_i^u(\lambda_i, p_i; \lambda_j, p_j) &= p_i \left[\left(1 - \frac{1}{2}p_j\right) \left(\lambda_i \frac{\alpha_i \Pi}{r} + \lambda_j \frac{\alpha_j \Pi}{r}\right)\right] - \beta_i R(p_i) \\ &\quad + (p_i + p_j - p_i p_j) \left[\lambda_i \frac{\alpha_i C}{r} + (1 - \lambda_i) \frac{\alpha_i S_i}{r}\right] \end{aligned} \tag{7}$$

subject to the constraints $p_i = p_i^u(\lambda_1, \lambda_2)$ and $p_j = p_j^u(\lambda_1, \lambda_2)$. This defines, as in the discriminating protection case, a pair of reaction functions, which we denote as follows: $\lambda_i = \lambda_i^u(\lambda_j)$ (where i = 1, 2, and $j \neq i$) and the subgame perfect equilibrium for the overall game is obtained by solving for the point of intersection of these reaction functions.

A feature of the equilibrium under either kind of patent protection (discriminating or uniform) becomes immediately apparent. There are always positive spillovers in the game between the policy making authorities. This is because part of the benefits of encouraging research in country i accrues to consumers in country j. This benefit is not internalized by the government in i. Thus, the choice of patent lengths tend to be "too short" for efficiency. Let $\hat{\lambda}_i^k$ ($i = 1, 2; k = u, d$) denote the equilibrium values, and $\hat{W}_i^k$ denote the associated welfare levels. The following result is then straightforward:

PROPOSITION **1** *Under either regime (discriminating or unform), an equilibrium is always (constrained) Pareto inefficient. More specifically, there exist* $\lambda_i^k > \hat{\lambda}_i^k$ *(*$i = 1, 2$*,* $k = u, d$*), and associated welfare levels* W_i^k *such that* $W_i^k > \hat{W}_i^k$ $\forall i, k$.

PROOF: With slight abuse of notation, incorporate the firms' response functions into the objective functions of the governments. Now, in any equilibrium of the game, each government's choice must be a best response, which implies $dW_i^k/d\lambda_i = 0$ (It can be easily checked that the solution is always interior). Pareto optimality, on the other hand, requires that $dW_i^k/d\lambda_i + dW_j^k/d\lambda_i = 0$. However, notice from the payoff functions that $dW_j^k/d\lambda_i > 0 \; \forall \lambda_i$. This establishes the result. $\square$

The above Proposition clearly establishes a case for an international patent agreement. Welfare in *each* country can be enhanced by departing from the equilibrium and appropriately increasing the patent length in both countries through a binding contract signed by the respective governments. However, the issue of choice of regime remains unsettled. Should an optimal patenting system provide for uniform treatment of all innovators, domestic and foreign? In the next section, we deal with this issue in the simplified setup where the countries are *ex ante* identical.

3 The Case of Identical Countries

In this section, we restrict attention to the case where the two countries are identical in all respect, specifically in their research efficiency, market size and imitation capacity. Thus, we introduce some harmless notation and normalization, and let $\beta_1 = \beta_2 = \beta$, $\theta_1 = \theta_2 = \theta$ and $\alpha_1 = \alpha_2 = 1$. In this setup, we first characterize the nature of equilibrium choices under the two different patent regimes, borrowing on our analysis of the general case from the previous section. Next, we analyse a (global) social planner's choice of the patent lengths in each country, designed to maximize the symmetric welfare function. This is followed by a welfare comparison of the various cases, and an evaluation of the welfare effects of uniform protection.

3.1 Coordinated Choice of Patent Length

Suppose a global social planner were to choose the patent length in each country so as to maximize symmetric welfare. Such a planner can be interpreted as an international body like the GATT which forges a patent agreement between the countries. Will the planner choose to impose uniform protection? For this purpose, we look at the maximum welfare the planner can attain in each regime (by controlling the patent length) and compare the two.

Under discriminating protection, the planner's problem is as follows:

$$\max_{\lambda,p} W_d(\lambda,p) = \left[p\lambda\frac{\Pi}{r} - \beta R(p)\right] + p\left[\lambda\frac{C}{r} + (1-\lambda)\frac{S}{r}\right] + p(1-p)\frac{\theta S}{r} \tag{8}$$

subject to the constraint $p = p_d(\lambda)$, where $p_d(\lambda)$ is given by the first order condition of the firm's problem:

$$\lambda\frac{\Pi}{r} = \beta R^{'}(p) \tag{9}$$

The government's objective function above is obtained straight away from (4) by incorporating the simplifications of this section, and by imposing the symmetry condition: $\lambda_i = \lambda_j = \lambda$ and hence $p_i = p_j = p$. Let λ_d^* denote the optimal choice, and W_d^* the maximum value. λ_d^* is obtained from the following first-order condition:

$$p.\frac{\Pi + C - S}{r} + \frac{\partial W_d}{\partial p}.\frac{dp_d}{d\lambda} = 0 \tag{10}$$

We now turn to the planner's problem under an uniform protection system. This can be described as follows:

$$\max_{\lambda,p} W_u(\lambda,p) = \left[p(2-p)\lambda\frac{\Pi}{r} - \beta R(p)\right] + p(2-p)\left[\lambda\frac{C}{r} + (1-\lambda)\frac{S}{r}\right] \tag{11}$$

subject to the constraint $p = p^u(\lambda)$, where $p^u(\lambda)$ is obtained from the following condition:

$$(2-p)\lambda\frac{\Pi}{r} = \beta R^{'}(p) \tag{12}$$

The objective function is obtained by imposing symmetry on (7). Equation (12) above is the firm's first order condition in a symmetric equilibrium of the firms' subgame (refer to (6)). Since, given patent lengths, the optimal choice of p_i is inversely related to p_j (i.e, they are strategic substitutes), it is easy to see that there always exists an unique symmetric equilibrium of this subgame.

The first order condition for the above maximization problem is as follows:

$$p(2-p).\frac{\Pi + C - S}{r} + \frac{\partial W_u}{\partial p}.\frac{dp_u}{d\lambda} = 0 \tag{13}$$

which defines the socially optimal patent length λ_u^* and the maximized welfare W_u^* under uniform protection.

Our aim is to compare the maximum attainable welfare in the two regimes, i.e, the values W_d^* and W_u^*. Before launching into a formal analysis, it is useful to review the various economic forces that come into play when countries are forced to extend patent protection to foreign firms. The *direct* effect of this on welfare is negative when imitation is close to being perfect, since greater product market distortion is created in the process.[8] There is a transfer of consumers' surplus in the recipient country to producer's surplus in the innovating country (in the symmetric case, *ex ante*, each country has equal chance of adopting either role), but the transfer is not one-to-one, since it is obtained through monopolistic distortion. A dollar's worth of consumers' surplus gets translated into less than a dollar's worth of profits. This can be formally checked by observing:

$$W_u(\lambda, p) - W_d(\lambda, p) = p(1-p)\left[\lambda.\frac{\Pi + C - S}{r} + (1-\theta)\frac{S}{r}\right] \tag{14}$$

which is negative for values of θ close to 1.

The effect of uniform protection on research incentives, however, is not neutral. This creates a second, more indirect effect, which interacts with the first and makes the ultimate impact on welfare less than obvious. Proponents claim that uniform protection will encourage more research (for a given patent length), and the positive benefits of this will outweigh the negative effect of increased product market distortion. While the second part of this claim is more tenuous (and the analysis will soon turn to that issue), it is easy to see that the first part is indeed true under the assumptions of the present model. This is stated in the following result:

PROPOSITION **2** *Assume countries are identical. Then, $p_u(\lambda) > p_d(\lambda)$, $\forall \lambda \in (0, 1]$. In other words, for any (symmetric) patent length in the two countries, firms invest more in research under uniform protection than under discriminating protection.*

PROOF: Fix λ. Let p_u denote the equilibrium choice of firms if protection were uniform, and p_d the corresponding value if protection were discriminatory. p_u satisfies the first

[8] When cross-border imitation is highly inefficient, even the direct welfare effect may be positive. Fetching the doctor, even at a price, may be better than indulging in cheap quacks and charlatans. Since this is not the interesting case, however, we focus on instances where imitators are reasonably efficient.

order condition in (12) while p_d is obtained from (9). Thus, on dividing the two sides of the first equation by those of the second, we obtain:

$$2 - p_u = \frac{R'(p_u)}{R'(p_d)} \tag{15}$$

Since, due to the end point condition, $p_u < 1$ and because $R''(p) > 0$, it follows that $p_u > p_d$. □

The intuition behind this research enhancement result is as follows. As we switch from a discriminating to a uniform protection regime, there are two opposing effects on the firms' expected revenue, and hence on the marginal returns to p. The first we call the *market expansion effect*; it arises from the fact that each successful innovator, if he manages to procure a patent, can now capture rents from two markets instead of one. The negative effect arises from the fact that R&D firms are exposed to rivalry in an uniform protection regime—they contest for the same common market instead of trying to capture their own domestic niches. For any given research intensity, this reduces their probability of actually winning the "prize", since there is some chance that there may be a joint discovery, in which case the firm may lose out in the toss-up. We call this the *rivalry effect*. We show above that in the symmetric case, the rivalry effect is always strictly dominated by the market expansion effect. The reason is quite simple: when countries are identical, uniform protection doubles the size of the potential market. However, for any given level of research, the probability of actually capturing the market is reduced by a factor of less than 2. This is because conditional on an individual firm's discovery, the probability of a tie is less than one, and it is only in half of these *tied* cases that an innovator loses through toss.

It is important to note that this research enhancement result rests crucially on a number of assumptions: (i) that market sizes are equal (ii) that firms are risk neutral, and that (iii) in the case of joint discovery, *one* firm is guaranteed patent protection in both markets. The importance of (i) is obvious from the argument above. If (ii) were not valid so that firms were risk averse, then the rivalry effect could be large enough to swap the market expansion effect. This is because uniform protection brings in an element of extra risk into the research process: for a given level of expenditure, the prize is larger but the probability of winning smaller. Assumption (iii) could be violated, for example, if we assume that in the case of joint discovery, *both* firms are allowed market access instead of a randomly selected one.[9] Bertrand competition will then dissipate all rents. Whether research will be encouraged or depressed in this case will depend on the probability of a tie (more specifically on whether the original value of p is less than or greater than 1/2). However, (iii) seems to be a reasonable assumption in the current context, particularly if one remembers that the research process in this model is meant to represent simplistically that in a more general model where success comes stochastically at some point in time, so that the toss is merely a proxy for the random outcome of who makes an *earlier* breakthrough.

Going back to the original question of the impact on social welfare, we find that one has to weigh the extra deadweight loss created by uniform protection against the social value of the increased research that it generates. The result of this comparison is summarised in the following Proposition.

PROPOSITION **3** *Assume the two countries are identical. If $\theta = 1$ and $\beta \leq \bar{\beta}$ (where $\bar{\beta}$ is some threshold value described later), $W_d^* = W_u^*$. For all $\theta < 1$ (or if $\theta < 1$ but $\beta > \bar{\beta}$), $W_u^* > W_d^*$. In other words, the maximum welfare attainable under uniform protection is strictly greater than that obtained under discriminating protection if imitation is imperfect. In the case of perfect imitation, the two regimes yield equal maximal welfare, provided research costs are not too high.*

PROOF: Let us define a new problem, which is a convex combination of the two problems described above. For this purpose, introduce a new variable, μ, which denotes the *fraction* of each country's market on which uniform protection is practiced. In the remaining fraction $(1-\mu)$, protection is discriminatory. The maximization problems described above, then, correspond to the special cases where the value of μ is either 0 or 1. It is not necessary to ascribe any economic meaning to intermediate values of μ; they can be seen merely as mathematical constructs.

We now define the following optimization problem:

$$\max_{\lambda,\mu,p} W(\lambda,\mu,p) = \left[p(1-\mu)\lambda\tfrac{\Pi}{r} + \mu(2-p)\lambda\tfrac{\Pi}{r} - \beta R(p)\right] +$$

$$(1-\mu)\left[p\left\{\lambda\frac{C}{r} + (1-\lambda)\frac{S}{r}\right\} + p(1-p)\frac{\theta S}{r}\right] + \mu p(2-p)\left[\lambda\frac{C}{r} + (1-\lambda)\frac{S}{r}\right] \quad (16)$$

[9] One may be reminded of the practice in academic journals of publishing identical but simultaneous and independent research.

subject to the constraint $p = p(\lambda, \mu)$ as defined by the first-order condition that must hold in any symmetric equilibrium of the subgame in which firms choose their research intensity. This is as follows:

$$(1-\mu)\lambda\frac{\Pi}{r} + \mu(2-p)\lambda\frac{\Pi}{r} = \beta R^{'}(p) \tag{17}$$

Interpretation of the objective function and the constraint is straightforward, given the interpretation of μ as a weight across the two pure cases. On simplification, the objective function can be written as follows:

$$W(\lambda, \mu, p) = p\lambda[1+\mu(1-p)]\frac{\Pi + C - S}{r} + p[1+(1-p)\{\theta+(1-\theta)\mu\}]\frac{S}{r} - \beta R(p) \tag{18}$$

while the constraint simplifies to

$$\lambda[1+\mu(1-p)]\frac{\Pi}{r} = \beta R^{'}(p) \tag{19}$$

On differentiating the above equation with respect to λ and μ, we obtain

$$\frac{dp}{d\lambda} = \frac{[1+\mu(1-p)].\Pi/r}{\lambda\mu.\Pi/r + \beta R''(p)} \tag{20}$$

$$\frac{dp}{d\mu} = \frac{\lambda(1-p).\Pi/r}{\lambda\mu.\Pi/r + \beta R''(p)} \tag{21}$$

Let (λ^*, μ^*, p^*) denote a solution to the problem, where $p^* = p(\lambda^*, \mu^*)$. The following Kuhn-Tucker conditions should then be satisfied at these optimum values (again, with slight abuse of notation, treat p in the objective function as a function of λ and μ, instead of an independent variable).

$$\frac{\partial W}{\partial \lambda} = p^*[1+\mu^*(1-p^*)]\frac{\Pi + C - S}{r} + \frac{\partial W}{\partial p}.\frac{dp}{d\lambda} = 0 \tag{22}$$

$$\frac{\partial W}{\partial \mu} = \lambda p(1-p)\frac{\Pi + C - S}{r} + p(1-p)(1-\theta)\frac{S}{r} + \frac{\partial W}{\partial p}.\frac{dp}{d\mu} \geq=\leq 0$$

$$\text{according as } \mu^* = 1, \mu^* \in (0,1), \text{ or } \mu^* = 0 \text{ respectively.} \tag{23}$$

Now, substituting the expression for $dp/d\lambda$ from (20) into (22) above, and simplifying, we have

$$[1 + \mu^*(1 - p^*)] \left[p^*.\frac{\Pi + C - S}{r} + \frac{\partial W}{\partial p}.\frac{\Pi/r}{\lambda^*\mu^*.\Pi/r + \beta R''(p^*)} \right] = 0 \tag{24}$$

which implies

$$p^*.\frac{\Pi + C - S}{r} + \frac{\partial W}{\partial p}.\frac{\Pi/r}{\lambda^*\mu^*.\Pi/r + \beta R''(p^*)} = 0 \tag{25}$$

Now, on substituting (21) into (23), we have

$$\frac{\partial W}{\partial \mu} = \lambda^*(1 - p^*) \left[p^*.\frac{\Pi + C - S}{r} + \frac{\partial W}{\partial p}.\frac{\Pi/r}{\lambda^*\mu^*.\Pi/r + \beta R''(p^*)} \right] + p^*(1 - p^*)(1 - \theta)\frac{S}{r} \tag{26}$$

Using (25), the first term on the right hand side vanishes, which implies that at the optimum

$$\frac{\partial W}{\partial \mu} = p^*(1 - p^*)(1 - \theta)\frac{S}{r} \tag{27}$$

Now clearly for $\theta < 1$, $\partial W/\partial \mu > 0$, which implies from (23) that $\mu^* = 1$, i.e, uniform protection is the unique optimum in such cases. However, if $\theta = 1$, $\partial W/\partial \mu = 0$, which means any combination of μ and λ which make both derivatives of $W(\lambda, \mu)$ vanish can be optimal. For suitable parametric conditions, the set of optimum combinations may span both extreme values of μ. □

While the above proof is not very illuminating, the following argument may be useful in gaining understanding. Notice that both expected marginal (and total) revenue of firms (see (19)) and the first term in the social welfare function (equivalently, consumers' surplus) in (18) depends *directly*[10] on the policy parameters λ and μ by the *same* factor of proportionality $\lambda[1 + \mu(1 - p)]$. The second term in the social welfare function (see the right hand side of (18)), viz. the term $p[1+(1-p)\{\theta+(1-\theta)\mu\}]\frac{S}{r}$ is independent of λ but is inceasing in μ unless $\theta = 1$, in which case it is an independent term. Now suppose λ^* and $\mu^* < 1$ is an optimum, with $p = p^* = p(\lambda^*, \mu^*)$. Consider

[10] λ and μ also affect social welfare *indirectly* through their effect on p, but this can be ignored in the present argument because, as the reader will see, we shall vary λ and μ in such a way as to keep p constant.

any $\lambda^{'}, \mu^{'}$ with $\mu^{'} > \mu^{*}$ and $\lambda^{'}[1 + \mu^{'}(1 - p^{*})] = \lambda^{*}[1 + \mu^{*}(1 - p^{*})]$. Since marginal revenue of firms is unchanged at the initial choice of p, p^{*} is still the optimum choice. The first term in social welfare is also unaffected. However, the second term is higher, unless $\theta = 1$, in which case it is unchanged. This proves that $\mu < 1$ cannot be an optimum when $\theta < 1$.

Now turn to the case where $\theta = 1$. Clearly $\mu = 1$ is one optimum. Let $\lambda = \lambda_u^{*}$ be the optimum patent length associated with this value, and let p^{*} be the induced value of p. Define $\bar{\lambda}_d$ as follows: $\bar{\lambda}_d = \lambda_u^{*}(2 - p^{*})$ (the right hand side is obtained by putting $\mu = 1$ in the above factor of proportionality). Clearly, if $\bar{\lambda}_d \leq 1$, the pair $\lambda = \bar{\lambda}_d, \mu = 0$ is also an optimum. If $\bar{\lambda}_d > 1$, then clearly the optimum *feasible* value of λ under discriminating protection is 1 (infinitely long patent), but this yields strictly lower welfare relative to the choice $(\lambda_u^{*}, 1)$. Now, the optimum patent length in each regime is strictly increasing in β. This proves the existence of the threshold $\bar{\beta}$ mentioned in the Proposition.

The welfare possibilities of the two regimes are depicted in the two panels of Figure 1 (corresponding to the cases of perfect and imperfect imitation). The curve $W_d(\lambda)$ denotes welfare in each country corresponding to a patent length of λ, assuming protection is discriminatory. $W_u(\lambda)$ is the corresponding value for uniform protection. Typically, both curves will be single peaked, with $W_u(\lambda)$ achieving its peak for a lower value of λ. In panel 1(a) (the case in which $\theta = 1$), the two peaks have the same height, while in panel 1(b) ($\theta < 1$), the curve $W_u(\lambda)$ achieves a strictly higher peak.

3.2 The Effect of Lobbies

In the preceeding section, it was assumed that consumers' and producers' surplus is weighed equally by policy making authorities. In many situations, it may be reasonable to assume that government decision making is influenced by lobbies. This factor can be incorporated by introducing different weights on firms' profits and consumers' surplus in the government's objective function. The results of the last section are surprisingly robust to small perturbations in the weights away from the equal weight case.

To see this, suppose the government attaches a weight of δ on firms' profits, and a weight $(1-\delta)$ on consumers' surplus. In addition, suppose that $\delta < (S-C)/(S-C+\Pi)$, which implies that $\delta\Pi + (1 - \delta)(C - S) < 0$. The analysis of this case is exactly like that in the previous section, except that the expression $(\Pi + C - S)$ in equations (22) through (26) is to be replaced by $\delta\Pi + (1-\delta)(C-S)$. As long as this latter expression is negative, the equivalence result holds for $\theta = 1$ (and low research costs) for exactly the same reasons, i.e, governments will be indifferent between either regime provided the patent length can be optimally set in each. If $\theta < 1$, the unfiform regime is strictly preferred. The equivalence of the two regimes with perfect imitation breaks down, however, when $\delta\Pi + (1-\delta)(C-S) > 0$. The reader can easily check that the optimal λ in each regime is 1 (infinitely long patent) in this case, since producers' profits are valued too highly for an interior solution to exist. By appropriately modifying (14) to fit this case, we can see that *even for a fixed* p, social welfare is higher under uniform protection. Since, by Proposition 2, the choice of p is also higher (leading to greater profits as well as consumers' surplus), uniform protection yields strictly higher welfare on the whole.

More interestingly, the equivalence result holds even by the yardstick of the "true" social welfare function, even if we allow government behavior to be distorted by lobbying power in the manner described above. Suppose $\theta = 1$. In terms of Figure 1, the patent lengths chosen through common agreement will be off-peak under each regime. Still, corresponding to these *distorted choices*, both regimes will yield equal welfare. To see this, inspect the preceeding argument carefully. Notice that corresponding to the governments' optimal (cooperative) choice of λ in the two regimes, social welfare is the same for *each component*—both producers' and consumers' surplus. Hence, it does not matter if a separate set of weights is used to *evaluate* the two outcomes. Similar reasoning works for the $\theta < 1$ case.

4 Conclusion

We have considered a two-country framework and studied the strategic intercation between the governments regarding the choice of optimal patent policies; innovators interact in the second stage. Patent policies are either discriminatory (i.e., only domestic innovators are protected) or uniform (i.e., both domestic and foreign firms are provided protection on the same term). In either case, duration of protection to be provided by each country is chosen optimally.

First, in a general set-up we have shown that there always esist patent agreements that increase the welfare of each country. The presence of externalities means that under non-cooperative equilibrium the patent lengths tend to be too short in each country. Therefore, welfare in each country can be enhanced by appropriately increasing the patent length in both countries through a binding contract signed by the respective governments. This establishes a case for an international patent agreement.

Then we have addressed to the more debatable question, viz., whether the optimal patenting system will provide uniform treatment of all innovators, domestic and foreign. This directly addresses the problem of the global social planner like the GATT which forges a patent agreement between the countries. We have discussed this issue of regime choice under the assumption that both countries are identical in all respect. In our structure, uniform protection necessarily leads to higher R&D investment, but at the same time it involves the negative effect of an increased product market distortion. We have shown that the net effect of uniform protection vis-a-vis discriminatory protection depends on whether imitation is perfect or imperfect. The maximum welfare attainable under uniform protection is strictly greater than that attainable under discriminatory protection if imitation is imperfect. In the case of perfect imitation, however, the two regimes yield equal maximal welfare, provided that the imitation cost is not too large. So one implication of of our result could be that at least for the product that can be imitated at a very low cost, it is efficient merely to strengthen the patent protection within each country instead of trying to implement a messy system of globally integrated patents.

References

Aoki, R. and Prusa, T. J., 1993. “International Standards of Intellectual Property Protection and R&D Incentives”. *Journal of International Economics* 35, 251-73.

Benko, R. P., 1987. *Protecting Intellectual Property Rights*. American Enterprise Institute, Washington, DC.

Boldrin, M. and Levine, D., 2002. “The Case Against Intellectual Property”, *American Economic Review* 92, 209-212.

Chin, J. C. and Grossman, G. M., 1991. “Intellectual Property Rights and North-South Trade”, in R. Jones and A. Krueger (eds.), *The Political Economy of International Trade*. Cambridge, MA: Basil Blackwell.

Deardorff, A. V., 1992. “Welfare Effects of Global Patent Protection”. *Economica* 59, 35-51.

Deardorff, A. V., 1990. “Should Patent Protection Be Extended ro All Developing Countries?”, *World Economy* 13, 497-508.

Diwan, I. and Rodrik, D., 1991. “Patents, Appropriate Technology and North-South Trade”. *Journal of International Economics* 30, 27-47.

Gallini, N., 1992. “Patent Policy and Costly Imitation”, *Rand Journal of Economics* 23, 52-63.

Gilbert, R. and Shapiro, C., 1990. “Optimal Patent Length and Breadth”, *Rand Journal Of Economics* 21, 106-112.

Glass, A. and Saggi, K., 2002. ”Intellectual Property Rights and Foreign Direct Investment”. *Journal of International Economics* 56, 387-410.

Grinols, E. L. and Lin, H. C., 1997. ”Asymmetric Intellectual Property Rights Protection and North-South Welfare”. Office of Research Working Paper No. 98-0106, University of Illinois.

Helpman, E., 1993. “Innovation, Imitation, and Intellectual Property Rights”. *Econometrica* 61, 1247-80.

Kabiraj, T., 2000. “Providing Protection to Foreign-Owned Patents — A Strategic Decision”. *Keio Economic Studies* 37, 9-24.

Kabiraj, T. and Banerjee, K., 2002. “Will All Southern Countries Extend Patent Protection to Northern Innovations?” *Keio Economic Studies* 39, 87-98.

Klemperer, P., 1990. “How Broad Should the Scope of Patent Protection Be?”, *Rand*

Journal Of Economics 21, 113-130.
Lai, E., 1998. "International Intellectual Property Rights Protection and the Rate of Product Innovation". *Journal of Development Economics* 55, 133-153.
Maskus, K. E., 1990. "Normative Concerns in the International Protection of Intellectual Property Rights". *World Economy* 13, 387-409.
Maskus, K. E. and Penubari, M., 1994. "How Trade-related Are Intellectual Property Rights?" *mimeo*, Dept. of Econ., University of Colorado at Boulder.
Marjit, S. and Beladi, H., 1998. "Product versus Process Patents: A Theoretical Approach", *Journal of Policy Modelling* 20, 193-199.
Nordhaus, W.D., 1969. *Invention, Growth and Welfare: A Theoretical Treatment of Technological Change.* The MIT Press, Cambridge.
Sakakibara, M. and Branstetter, L., 2001. "Do Stronger Patents Induce More Innovation? Evidence from the 1988 Japanese Patent Law Reforms", *Rand Journal of Economics* 32, 77-100.
Subramanian, A., 1991. "The International Economics of Intellectual Property Right Protection: A Welfare-Theoretic Trade Policy Analysis", *World Development* 19, 945-956.
Subramanian, A., 1990. "TRIPs and the Paradigm of the GATT: A Tropical, Temperate View", *the World Economy* 13, 509-521.
Tandon, P., 1982. "Optimal Patents wirh Compulsory Licensing", *Journal of Political Economy* 90, 470-486.
Taylor, M. S., 1994. "TRIPs, Trade and Growth". *International Economic Review* 35, 361-81.
Vishwasrao, S., 1994. "Intellectual Property Rights and the Mode of Technology Transfer". *Journal of Development Economics* 44, 381-402.
Yang, Y., 1998. "Why do southern countries have little incentive to protect northern intellectual property rights?" *Canadian Journal of Economics* 31, 800-16.