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Intellectual Property Rights and International R&D Competition

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Abstract

This paper examines a country's incentives for intellectual property rights (IPR) protection in a global trading environment. There is a time inconsistency problem intrinsic to IPR protection: ex ante strong protection is warranted to promote innovation, but once discovery takes place there is an incentive to lower protection. The sub optimal but time consistent policy involves an insufficient level of protection and, therefore, of innovation. In more technologically advanced economies reputational considerations may be sufficient to maintain strong protection. Otherwise a commitment mechanism, such as participation in the World Trade Organization, or, more controversially, some form of bilateral punishment, may be used.

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I. Introduction

In recent years, the protection of Intellectual Property Rights (IPRs) has been one of the most contentious areas of dispute in the international arena. In industrialized countries there already exists a system of patents, copyrights and trademarks that reward innovators for their efforts. With the increased globalization of trade and the increased pace of technological change there has been a growing demand to have this sort of protection extended throughout the rest of the world, in particular to the growing import markets of developing countries, where IPR protection has been notoriously weak or altogether absent.

A first success in the direction of global harmonization of IPR protection has been the TRIPs agreement (the agreement on trade related aspects of intellectual property rights), negotiated during the Uruguay Round and in effect since 1995. For members of the World Trade Organization (WTO), the TRIPs agreement sets minimum standards of protection and enforcement guidelines, and provides for a dispute settlement mechanism regarding the respect of TRIP obligations. It is important to note that even in countries where IPR protection has been in place for some time, legal protection and enforcement can be far from perfect.

The debate regarding the international protection of IPRs has often taken the following form. On the one hand, industrialized countries contend that weak IPR protection creates a disincentive for R&D by lowering the profits that accrue to successful innovation, with negative effects on growth and welfare not only for innovating countries but also for their trading partners. On the other hand, developing countries argue that IPR protection creates monopoly power, keeping them from becoming competitive in the more technological, and often more profitable, sectors. Furthermore, the monopoly power implicit in IPR protection drives up the price of goods, and in less developed countries availability of cheap imitated products often far outweighs the benefits of promoting R&D. Developing countries are often wary of enforcing laws against domestic imitation that not only would transfer profits abroad but would also raise domestic prices of consumption and intermediate goods.

This paper seeks to shed light on this debate by considering more closely the incentives for IPR protection in developing countries. The standard view of IPR protection in an international environment is tied to a vision of the world divided between industrialized, innovating countries on one side and developing, imitating countries on the other. It is assumed that countries that imitate do so because they do not have the technology to innovate. In the literature, this is reflected in the fact that trade related issues of IPR protection are traditionally examined in a North-South framework: purely innovating North, purely imitating South. In reality many imitating countries, and the ones that have been the subject of the bulk of accusations regarding IPR infringement, are in fact middle income countries where innovative activities are increasingly taking place. This is the case of China, Singapore, Korea, Taiwan Province of China, Mexico, Chile, Argentina, and Brazil, to name a few. Even if the greater part of total innovation continues to take place in industrialized countries, and the majority of patents continue to belong to these countries, there exists a non negligible number of competitive firms in developing countries now undertaking innovative activity, at a steadily increasing rate. It is often argued that stronger IPR protection might promote domestic economic growth by encouraging inflows of foreign technology and an increase in local innovation. It is therefore not clear why these countries continue to maintain and advocate weak IPR protection: apparently the trade-off between innovation and imitation is not the same for all countries.

One reason why the government may decide to permit weak IPR protection has to do with the uncertain nature of research. Firms race to be the first to discover a new product or technology: all firms pay the cost of research but only one firm, the "winner", makes positive profits. The government's problem is to decide whether and how much to promote innovation, taking into account that if innovation occurs abroad no profits will accrue domestically. Innovation, wherever it occurs, is desirable because it increases consumer surplus, either through the introduction of new and better products or by lowering consumer prices. Furthermore, innovation that occurs locally is desirable for its positive externalities (for example, there may be positive spillovers to other firms or industries, or domestic innovation may cater to local tastes). Strong protection promotes innovation and increases the probability of local discovery. Weak protection is a disincentive to local innovation, but permits the country, through imitation, to capture at least in part the benefits of foreign innovation. In this scenario, imitation can serve as a form of "insurance", allowing a country to reap at least some profits in the case domestic innovation is unsuccessful.

Secondly, there is a time inconsistency problem inherent in the government's policy decision. IPR policy influences firms' R&D decisions *before* discovery, but is enforced only *after* discovery. The government therefore may wish to impose strong protection *ex ante* to promote innovation, however once discovery takes place there is an incentive to weaken protection if innovation occurs abroad. If the change of policy is a surprise it will have the effect of increasing welfare, however in the long run the government will not be able to systematically surprise the private sector.

If commitment to an optimal but time inconsistent patent policy is not credible, a time consistent policy will obtain where R&D decisions incorporate expectations of patent policy, irrespective of government announcements, and the government will fulfill these expectations with a socially insufficient level of protection. In this framework weak IPR protection is therefore not a result of lobbying pressures or other political concerns, but a consequence of a government's inability to commit to policies that *ex post* it would not find optimal to pursue.

Reputational considerations may be sufficient to induce the government to maintain high protection, but only in the case of countries that are highly successful at innovation. In other innovating countries two other solutions are possible. International agreements that involve commitment to a strong IPR regime, such as TRIPs agreement, may be sufficient to solve the time inconsistency problem. Alternatively, unilateral retaliation from the country's trade partners may help keep the offender in check and serve to maintain strong protection.

The latter option is more controversial in that unilateral retaliation is in general frowned upon in the international community.

It should be noted that this argument does not apply to the least developed countries, where conditions are such that even *ex ante* there is no incentive for strong IPR protection. One can imagine that the time inconsistency of IPR protection is an issue that countries face at a certain stage of development, when they move from being developing countries with no need for strong IPR protection, but before becoming sufficiently technologically advanced so that reputational considerations are sufficient to maintain optimal levels of IPR protection.

This paper builds on the extensive literature on patent races: Loury (1979), Lee and Wilde (1980), Reinganum (1981), and Dixit (1988a and b), among others. The seminal work on innovation and imitation in a North-South environment, also based on the patent race literature, is Grossman and Helpman (1991). This paper is also tied to the literature on trade related issues of intellectual protection: Aoki and Prusa (1991) consider the effect of discriminatory IPR protection, Jensen and Thursby (1996) deal with the effects of product standards (an indirect form of intellectual protection), Diwan and Rodrik (1991) examine the issue of IPR protection in a world where tastes differ between the North and South. Helpman (1993) considers the welfare effect of increased IPR protection in an North-South environment, and finds that it always hurt the South, and does not necessarily benefit the North. Lastly, the paper is related to the literature on the time inconsistency of trade policies, as in Eaton and Grossman (1985) and Staiger and Tabellini (1987).

This paper differs from previous literature by assuming innovative activity also in the South. While the time inconsistency aspect of IPR protection has been examined in a closed economy, it has not been examined in an international trading environment. This changes the trade-off faced by the government in choosing its IPR regime: the benefits of imitation must be weighed against the costs of discouraging research in domestic firms.

This paper focuses on a specific form of innovation, quality enhancing R&D. This specification applies to many types of research, and moreover is equivalent to cost-reducing innovation. However there are many aspects of innovation to which this specification does not apply, and that are not considered in this paper. In particular, this paper does not deal with issues tied to differing consumer preferences or different income levels or income distributions across countries. Furthermore, it considers imitation goods that are perfect copies of the originals, and therefore does not deal with the trade-off tied to consuming a lower priced yet imperfect counterfeit instead of the higher priced original. Lastly, it assumes a positive domestic spillover effect tied to local innovation, to embody the idea that innovation is always a good thing but local innovation is better.

This paper focuses on the interaction between a particular pair of countries: an industrialized country, with a well-developed patent protection system, and another less developed country, where some innovation takes place but IPR protection is weak or absent. Less developed countries where no innovation takes place are not considered. The focus of the paper is on developing countries with growing innovative sectors, because such countries have largely been ignored by the literature on international IPR protection and empirically represent the majority of countries targeted for IPR infringement.

IPR protection in the industrialized country is assumed perfect by definition. This result could be derived from the setup of the paper, conditions in the industrialized country being such that reputational considerations would always be sufficient to insure high protection. This step is excluded to simplify the exposition and to focus on incentives in the developing country.

The rest of this paper is structured as follows. In Section 2, a model of repeated patent races conducted along a continuum of product lines is presented. Section 3 develops how the government intervenes in the matter of IPR protection both in the short and in the long run. Commitment, reputation and unilateral punishment are then considered as solutions to the time inconsistency problem. Lastly, some concluding remarks are presented.

II. The Model

Assume two countries, Home and Foreign, and two types of goods, a high-tech good and a traditional good. Both countries engage in two activities: production of goods and research to discover better goods in the high tech sector. Time is discrete, and in each period new discoveries are made.

A. Innovation

Each product *j* in the high tech sector potentially can be produced in an unlimited number of vertically differentiated varieties, or qualities, as in the Grossman and Helpman (1991) "quality ladders" model. Denote $q_m(j)$ the quality of the *m*-th generation of product *j*. Assume that each generation provides exactly λ times as many services as the previous one:

$$q_m(j) = \lambda q_{m-1}(j) \quad \forall j, m \tag{1}$$

Assume λ to be exogenous, constant, greater than 1, and common to all product lines.

Suppose there are *X* domestic and *Y* foreign firms conducting research, where *X* and *Y* as continuous variables. For notation purposes, small *x* (*y*) will denote the individual firm, while large case *X* (*Y*) will denote the number of firms in each country. In each period, individual firms in each country race to discover a new innovation along a continuum of identical product lines, $j \in [0,1]$.[2]

[2] The idea here is that individual firms do not "put all their eggs in one basket" when it comes to R&D, and usually are active in several research projects simultaneously. Alternatively, one can imagine a continuum of different industries, with a continuum of firms conducting research in each one.

Consider the situation at Home (the situation in Foreign is symmetric). To participate in the innovation race firms must pay a fixed cost $K(x)$ at the beginning of each period, which differs between firms. Firms are ranked in order of increasing cost such that $K'(x) > 0$, $K''(x) \geq 0$ and $K(x)$ is continuous and differentiable.[3] Assume furthermore that $K'(x) < M$, where M is a finite number: in this way we avoid the cost of innovation "exploding" for some firms.

At the beginning of each period a race takes place in each product line. In each one the firm with the best result wins, capturing for itself the ability to produce the next generation of new goods. R&D is not an uncertain enterprise in this setup, innovation will always occur, the only uncertainty is who wins the race. *Ex ante* each project is equally likely to succeed, so the probability of success of an individual firm in a particular product line is $1/(X+Y)$. The product remains "new" for the duration of the period, at the beginning of the subsequent period a new good is discovered in each product line. Thus both the length of the race and the effort expended by each participant are exogenous. Furthermore, research undertaken to develop one generation of new goods has no effect on the success of research devoted to a subsequent generation: in this way the race is exactly the same in each period.

For the winner of the innovation race, denote the expected payoff from winning the race as Π_W (for winner). The payoff from conducting research for the individual domestic firm x is

$$P(x) = \frac{\Pi_W}{X+Y} - K(x) \tag{2}$$

For a foreign firm y it will be[4]

$$P^*(y) = \frac{\Pi_W}{X+Y} - K^*(y) \tag{3}$$

The equilibrium number of firms will be X and Y that solve $P(X) = 0$ and $P^*(Y) = 0$ simultaneously. Firms don't act strategically but take the number of both domestic and foreign firms as given. For $K(x)$ or $K(y)$ very large, solutions may obtain where X or Y equal zero, but we shall ignore these outcomes and concentrate on equilibria where both countries innovate.

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[3] Therefore X (Y) denotes both the total number of firms *and* the marginal firm in each country.

[4] Throughout this paper, asterisks will be used to denote foreign variables.

For each individual firm, innovation along each single product line is stochastic; however, since R&D takes place along a continuum of research projects, in the aggregate total innovation will be deterministic. The number of innovations that occur domestically in each period will be $X/(X+Y)$, while the number of Foreign innovations will be $Y/(X+Y)$. While the individual probability of winning the innovation race decreases with X (this is the "common pool" negative externality), the probability of innovation occurring domestically, and therefore aggregate domestic innovation, increases with X.

This setup differs from traditional patent race models in that innovation occurs for sure each period. Qualitative results, however remain the same. Although all firms have equal probabilities of success, the cost of participating differs across firms and across countries. In a traditional patent race, the more research undertaken the greater the rate of innovation. Here an increase in research effort *may* affect the distribution of innovations between countries, but not the total amount of innovations (which is constant each period). The social benefit of innovation is represented by a spillover effect, which will be introduced shortly.

B. Preferences

Households' intertemporal utility function is separable in the two types of goods:

$$U_t = \sum_{t=0}^{\infty} \beta^t \left[\log D(t) + \log C(t)\right] dt \tag{4}$$

$C(t)$ denotes the traditional good, while instantaneous utility from consumption of the high tech good, $D(t)$, is

$$\log D(t) = \int_0^1 \log\left[\sum_m q_m(j) d_{mt}(j)\right] dj \tag{5}$$

This specification of the utility function corresponds to that of Grossman and Helpman (1991). Note that $d_{mt}(j)$ denotes consumption of quality m in product line j at time t. The summation extends over a set of qualities that coincides with the set of past time periods: progress is exogenous, so each period t is associated with a new quality. The highest available quality in each case is the state of the art. Units are chosen such that the lowest quality of each product (the one available at time $t = 0$) offers one unit of service, i.e., $q_0(j)=1$. From equation (1), this implies that $q_t(j)= \lambda^j = \lambda^t$.

This utility specification has the property that different qualities of each good substitute perfectly for one another, once adjustment is made for quality differences. Goods of different product lines enter utility symmetrically, so households maximize static utility by spreading expenditure evenly across product lines, and by purchasing the good $m_t(j)$ that carries the lowest price per unit of quality. This yields the following demand functions

$$d_{mt}(j) = \frac{E(t)}{p_{mt}(j)} \tag{6}$$

where $E(t)$ denotes per period expenditure and $p_{mt}(j)$ is the price of quality m of product j at time t. The same is true in the Foreign country, with $d^*_{mt}(j) = E^*(t) / p^*_{mt}(j)$.

C. Production

For simplicity, assume identical production technologies across all product lines j and all qualities q. Assuming labor as the only factor of production, one can choose units so that one unit of each producible good requires one unit of labor input, this way the marginal cost of every good is equal to the wage rate w.

All firms engage in Bertrand price competition. A winning firm, as long as it has not been imitated, has exclusive knowledge of how to produce the new product. Consider the competition between the firm producing the state of the art product and one able to manufacture the product one step behind on the quality ladder (the "follower" firm). The follower charges price w, the lowest price consistent with nonnegative profits. The highest price the state of the art firm can charge is λw, in fact at this price consumers are indifferent between the older good and the state of the art, the latter being more expensive but offering greater services. By charging a price a shade below λw the state of the art firm captures the entire market: therefore in every period only the state of the art good is produced and consumed. The price λw yields sales of $E/\lambda w$ in Home and $E^*/\lambda w$ in Foreign. Monopoly profits to the state of the art firm in each period, Π_M in the Home market and Π^*_M in Foreign, will be

$$\begin{aligned} \Pi_M &= \left(1 - \frac{1}{\lambda}\right)E \\ \Pi^*_M &= \left(1 - \frac{1}{\lambda}\right)E^* \end{aligned} \tag{7}$$

D. Spillovers

Empirical evidence shows that technological advance in one industry often has positive effects on other industrial sectors of the economy.[5] In the traditional sector the homogeneous good $C(t)$ is produced under perfect competition, constant returns to scale and no distortions, according to the production function

[5] See Los and Vespargen (2000) for a recent review.

$$C(t) = F[A(t)L(t)] \tag{8}$$

where

$$\frac{dA}{dt} = f(X)\ f'>0 \tag{9}$$

Productivity in the homogenous good industry therefore increases with domestic innovation but not with foreign innovation. (In truth foreign spillovers are also present but are typically of smaller magnitude than domestic ones, therefore they can be ignored and the same qualitative results obtained.[6])

E. Imitation

Assume for simplicity that the Foreign country has perfect patent protection, i.e., imitation by Foreign firms is impossible. Implicitly, the model reflects the case of trade between an industrialized country, historically more committed to strong IPR protection, and a middle income country that has yet to establish IPR legislation. Home firms that are unsuccessful at innovation in a particular product line become potential imitators. Imitation is completely costless, although success at imitation depends in part on imitation technology, and in part on government enforcement of intellectual property rights. IPR protection is not discriminatory: both local and foreign state of the art firms face the same risk of imitation. Ignoring the problem of imitation technology, assume that imitation depends entirely on how well IPRs are enforced: imitation will be a decreasing function of IPR protection. Markets are segmented: no imitation occurs in Foreign and imitated Home products cannot be sold abroad (in this sense protection in the Foreign market is truly perfect).

Denote α the index of IPR protection. One can interpret α as the probability of a winning firm actually receiving monopoly profits Π_M (the winning firm always receives Π^*_M, since protection is perfect in the Foreign country). $\alpha \in [0,1]$, with $\alpha = 1$ corresponding to perfect IPR protection and $\alpha = 0$ to complete lack of protection ($\alpha^*=1$ in Foreign always). $(1-\alpha)$ is the probability of imitation occurring. When imitation takes place, Bertrand competition drives profits to zero for all producing firms, consumers however will gain from lower prices. The expected payoff from winning the race, Π_W, is therefore

$$\Pi_W = \Pi^*_M + \alpha\Pi_M \tag{10}$$

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[6] An empirical analysis of this effect can be found in Eaton and Kortum (1997).

The increase in consumer welfare due to imitation will be *E*logλ, given that prices will be driven down to w for all producing firms. Note that this is equal to the increase in consumer welfare due to the discovery of a new good.

F. Welfare

Consider now the social welfare that accrues in the Home country from each individual innovation in each period. Welfare that accrues from a *domestic* innovation, W_{HD}, is comprised of four components: (1) an increase in consumer surplus due to the availability of higher quality goods ($E\log\lambda$), (2) spillover effects from innovation ($f(X)$),(3) innovation profits $\left(\Pi^*_M + \alpha\Pi_M\right)$, and 4) any increase in consumer surplus due to imitation ($E\log\lambda$). Therefore

$$\begin{aligned} W_{HD} &= E\log\lambda + f(X) + \Pi^*_M + \alpha\Pi_M + (1-\alpha)E\log\lambda \\ &= (2-\alpha)E\log\lambda + f(X) + \Pi^*_M + \alpha\Pi_M \end{aligned} \tag{11}$$

with $dW_{HD}/d\alpha < 0$ (see appendix for all mathematical derivations).

Domestic social welfare from a *foreign* discovery, W_{FD}, has only two components: (1) the increase in consumer surplus due to innovation, (2) any extra increase in consumer surplus due to imitation.

$$\begin{aligned} W_{FD} &= E\log\lambda + (1-\alpha)E\log\lambda \\ &= (2-\alpha)E\log\lambda \end{aligned} \tag{12}$$

with $dW_{FD}/d\alpha < 0$.[7] It is apparent that $W_{HD} > W_{FD}$, and note also that $\left|dW_{HD}/d\alpha\right| < \left|dW_{FD}/d\alpha\right|$, i.e., the gains from imitation are greater in the case of foreign versus local innovation. Total welfare each period, W_{Tot}, will be given by

$$W_{Tot} = \frac{X}{X+Y}W_{HD} + \frac{Y}{X+Y}W_{FD} - \int_0^X K(x)dx \tag{13}$$

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[7] Note that if imitation has occurred in a previous period, in the current period there will be no increase in consumer surplus due to innovation. Derivatives will be the same however, i.e., today's incentives for imitation will not change.

III. Government Intervention

The timing of events is as follows. Time is discrete, and in each period innovation takes place in each product line. Each period is divided into three separate stages. In stage one, the government announces a level of intellectual protection. In stage two, firms make their individual investment decisions, i.e., decide whether to participate or not in the innovation race. In stage three, innovation takes place and IPR protection is enforced. Since policy is announced in stage one but only enforced in stage three, if the government is not committed to its announcement it will be able to change its policy.

Given the sequence of events, there is a time consistency problem inherent in the government's IPR policy decision. At the beginning of the period, the government announces its IPR regime, i.e., a value for α. Firms make their investment decision based on this α. In particular, since the payoff from successful innovation increases with protection so will the number of firms conducting R&D: $dX/d\alpha > 0$ and $dY/d\alpha > 0$. Enforcement doesn't take place until after discovery: at this point the welfare function of the government is different since investment decisions have already been made, i.e. X and Y are fixed.

A. Optimal IPR Policy in a One Shot Patent Race

Assume for now that the R&D race occurs only once in time. A policy that maximizes welfare at the beginning of the race is time inconsistent in that the government has an incentive to lower protection whenever domestic innovation is unsuccessful. Low protection will give higher instantaneous profits, but will also lower the number of domestic firms engaging in research. This will lower the amount of domestic innovation, and therefore the associated social benefits. More innovators will operate in the Home country if the government is forced to commit to its IPR regime.

One must distinguish the government's problem *before* and *after* discovery, i.e., in stage one and in stage three. At the beginning of the race, i.e., in stage one, the government's problem is to maximize $W_{Tot,s1}$

$$\max_{\alpha} W_{Tot,s1} = \frac{X(\alpha)}{X(\alpha)+Y(\alpha)} W_{HD} + \frac{Y(\alpha)}{X(\alpha)+Y(\alpha)} W_{FD} - \int_0^{X(\alpha)} K(x)dx \tag{14}$$

Note that $W_{Tot,s1}$ is increasing in the level of protection, as long as $f(X)$ is sufficiently large (and as long as $K(x)$ doesn't explode), which we shall assume hereon.[8] (See Appendix)

[8] It should be mentioned that for a less developed country $f(X)$ may be quite small, and there will be no *ex ante* incentive for strong IPR protection. But, as noted earlier in the paper, the focus will be on middle income countries.

Once discovery is made, i.e., in stage three, the government's problem becomes that of maximizing $W_{Tot,s3}$:

$$W_{Tot,s3} = \frac{X}{X+Y} W_{HD} + \frac{Y}{X+Y} W_{FD} \tag{15}$$

where X and Y are fixed.

Proposition 1: *(The pre-commitment optimal IPR policy). With full commitment, the optimal IPR policy is maximum protection, $\alpha = 1$.*

This follows directly from $dW_{Tot,s1}/d\alpha > 0$. With full commitment, the government does not have the option of reneging in stage three, and its problem is only that of maximizing $W_{Tot,s1}$ in stage one, the solution of which is $\alpha = 1$. This policy maximizes the number of domestic firms participating in innovation, given that $dX/d\alpha > 0$: $X = X_{\max}$.

Proposition 2: *(The non commitment IPR policy). In the absence of a commitment mechanism, maximum protection is not time consistent. The time consistent IPR policy consists of minimum protection and a socially inefficient number of domestic firms conducting R&D.*

Proof. This can be proved by backwards induction. In stage three, the government maximizes $W_{Tot,s3}$, the solution of which will be $\alpha = 0$, given that $dW_{Tot,s3}/d\alpha < 0$ since $dW_{HD}/d\alpha < 0$ and $dW_{FD}/d\alpha < 0$. In stage two firms make their investment decisions, and being rational they know that if the government cannot pre-commit to its announced policy in stage three it will impose $\alpha = 0$. Therefore they decide whether or not to participate in the innovation race taking into account $\alpha = 0$, regardless of the announced policy. The equilibrium number of firms participating in the innovation will be the X that solves:

$$P(X) = \frac{\Pi_W(\alpha = 0)}{X+Y} - K(X) = 0 \tag{16}$$

Given $dX/d\alpha > 0$, this will be the minimum number of innovating firms possible (we have excluded the case of no firms operating): $X = X_{min}$. The same will be true in the Foreign country, with $Y = Y_{min}$.

In stage one, the government announces its IPR policy. If firms could be "fooled" into believing that the government will maintain its announced IPR regime, it would announce maximum protection. Since firms are rational the government solves the problem:

$$\max_{\alpha}\left[\frac{X_{\min}}{X_{\min}+Y_{\min}}W_{HD}+\frac{Y_{\min}}{X_{\min}+Y_{\min}}W_{FD}\right] \tag{17}$$

The solution is $\alpha = 0$, i.e., the optimal policy is to announce the policy that firms are expecting.

Since $X_{min} < X_{max}$, there is a socially insufficient number of firms operating in the economy. Furthermore, since $dW_{Tot}/dX > 0$ in general, welfare is lower than in the commitment case.

B. Repercussions in the Foreign Country

Given the assumption of segmented markets Foreign consumers do not benefit from lower prices due to imitation, therefore the only effect of imitation is a loss of profits from sales in Home. Welfare in the Foreign country from a discovery that takes place in Foreign is

$$W^*_{FD} = E^*\log\lambda + f(X^*) + \alpha\Pi_M + \Pi^*_M \tag{18}$$

while the welfare from a discovery that takes place in the Home country is

$$W^*_{HD} = E^*\log\lambda \tag{19}$$

Total welfare at the end of each period is:

$$W^*_{Tot} = \frac{X}{X+Y}W^*_{HD} + \frac{Y}{X+Y}W^*_{FD} - \int_0^Y K(y)dy \tag{20}$$

It is apparent that, since $dW^*_{FD}/d\alpha > 0$, a decrease in protection in the Home country has a negative effect on welfare in the Foreign country. For the same reason we see that optimal Home protection, for the Foreign country, is $\alpha = 1$.

C. Optimal IPR Policy in the Infinite Horizon

Consider now the case where patent races are repeated infinitely through time. For simplicity, the Home government can impose only two levels of protection: high (α_H) and low (α_L).[9] We shall see in this case that a country can get stuck in a weak IPR regime even with a non negligible amount of innovation occurring domestically.

Note that $W_{Tot}(\alpha_L) > W_{Tot}(\alpha_H)$ *for fixed X and Y*. If the government were consistently able to fool firms into believing its announcements, the optimal policy would be to announce strong protection in stage one each period and to then enforce weak protection in stage three, i.e., once discovery takes place. However, if firms are rational this will not take place. Once low protection is in place, it tends to persist as firms will always act as if protection is low and the government's best response therefore will be to impose low protection. In the one shot race the only time consistent policy is low protection, however a policy of high protection may become credible if reputational considerations make a deviation from it costly enough.

The first dynamic game considered is simply the static game of the previous section, infinitely repeated, and played as follows. Time is made up of a discrete sequence of periods, $t = 1,2,3,...$ In the first stage of each period, the government announces a policy regime, i.e., chooses either α_H or α_L as the level of domestic IPR protection. In the second stage, firms make their investment decisions. Firms behave in the following way: if in the previous period the policy announcement was respected, firms will make their investment on the basis of the policy announcement. If in the previous period the government reneged on its announcement, firms will expect it to follow a low protection regime forever in the future (i.e., the system reverts to the one-shot no commitment solution). We assume this reversion to the one-shot equilibrium lasts forever. Foreign government plays no role in this game, since it has already committed to a high level of protection.[10]

An equilibrium will be credible if the incentive to deviate from it, the "temptation", is not greater than the "punishment" (or "enforcement"), i.e. the cost of a deviation. To simplify notation, define $X_H = X(\alpha_H)$ and $Y_H = Y(\alpha_H)$, i.e. the number of firms operating with high IPR protection, and $X_L = X(\alpha_L)$ and $Y_L = Y(\alpha_L)$.

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[9] Given that $W_{tot,s1}$ is increasing in the level of IPR protection, the case of continuous protection would be identical.

[10] An alternative setup would have both countries choosing an optimal level of IPR protection in an infinitely repeated game. This paper concentrates on a game more consistent with the situation witnessed presently in the world: developed countries already committed to high IPR protection, urging developing countries to increase their levels of IPR protection.

Let

$$\Phi(\alpha)=\frac{Y}{X_H+Y}\left[W_{FD}(\alpha_L)-W_{FD}(\alpha_H)\right]+\frac{X_H}{X_H+Y}\left[W_{HD}(\alpha_L)-W_{HD}(\alpha_H)\right] \qquad (21)$$

represent the static gains from reneging high protection, i.e. the "temptation". Note that it is always true that

$$W_{FD}(\alpha_L)-W_{FD}(\alpha_H)>W_{HD}(\alpha_L)-W_{HD}(\alpha_H) \qquad (22)$$

i.e., there is more to gain from imitation in the case of foreign innovation: imitation in the case of local discovery constitutes in part a redistribution of welfare within the country.

The "punishment" will be given by the difference between present discounted values of welfare under high and low protection:

$$\Psi(\alpha)=\frac{\beta}{1-\beta}\left[W_{Tot}(\alpha_H)-W_{Tot}(\alpha_L)\right] \qquad (23)$$

Proposition 3: *High IPR protection is a time consistent policy if and only if*

$$\Phi(\alpha)<\Psi(\alpha) \qquad (24)$$

otherwise, the only time consistent policy is low IPR protection.

The Home government's incentive to renege on its policy of high IPR protection will be lower the less efficient its trading partner is at research (the smaller Y), the larger the social and private benefits of domestic innovation (i.e., if W_{HD} is large), and the more reactive X is to IPR protection (for example, if Π_M is large). If this is the case, an international equilibrium can ensue where both countries impose maximum IPR protection.

D. Retaliation

If equation (24) does not hold, enforcement by a super national organization or action by a trade partner can serve to maintain strong protection. For example, if both countries are members of the WTO and must make a binding commitment to high protection, the high protection outcome is sustainable. However, not all countries most criticized for their IPR regimes belong to the WTO (see for example the case of China, in the process of accessing) or have been granted a "grace period" before enforcing stronger IPR legislation.[11] In these cases the Foreign country often decides to coerce the Home country into imposing higher protection through different forms of unilateral retaliation. These different forms of retaliation can serve to strengthen the "punishment mechanism" and reverse the inequality in Proposition 3, i.e., make a high protection outcome sustainable.

Retaliation can take the form of any type of trade restriction that serves to reduce welfare in the Home country. The Foreign country chooses a level of retaliation $\delta \in [0, \infty)$. Assume for simplicity retaliation has no effect on the Foreign country's welfare, and reduces Home welfare by δ.

With retaliation, the dynamic game includes Foreign government as a player. In the first stage of each period, the Home government chooses a level of IPR protection $\alpha \in \{\alpha_H, \alpha_L\}$. In stage two, firms make their investment decisions, as specified above. In stage three, IPR protection at Home is enforced and the Foreign country chooses a level of trade retaliation $\delta \in [0, \infty)$. The Foreign country adopts the following strategy: if Home enforces high IPR protection, α_H, the Foreign country chooses $\delta = 0$. If the Home country chooses low IPR protection, α_L, the Foreign country imposes retaliation $\delta > 0$. Retaliation is maintained as long as the Home country enforces low protection.

Proposition 4: *The country with weak IPR protection can be induced to maintain strong protection through sufficiently large trade retaliation by its trading partner.*

For high IPR protection to be sustainable the Home country must no longer have an incentive to defect to low protection: retaliation must be large enough that the temptation to deviate, $\Phi(\alpha)$,must be less than the sum of the future cost of deviation, $\Psi(\alpha)$, plus the retaliation imposed by the Foreign country:

$$\Phi(\alpha) < \Psi(\alpha) + \delta \qquad (25)$$

Retaliation may take the form of punitive measures in other sectors of the economy, for example a tariff on Home's exports of goods in other sectors, or by repealing concessions in other areas. An obvious example was the U.S. threat in the mid 1990s to impose punitive tariffs on China for its continued violation of American IPRs, particularly in the fields of compact discs, videos and software. Retaliation wasn't aimed at the sectors in question, instead important Chinese export industries, such as textiles, footwear, apparel and

[11] A "grace period" for developing countries is part of the TRIPs agreement, for all but the least developed countries this grace period expired in 2000.

electronics, were targeted.[12] In the U.S., the instrument to enact this type of "punishment" is provided through the Section 301 provision. This type of "lump sum" punishment is in fact very effective for it is not limited by the size of the market for imitated goods, nor by the relative size of the two markets in the industry in question. If the level of retaliation chosen by the Foreign country is large enough the Home country's optimal policy will be to maintain high IPR protection, i.e., choose α_H, in every period.

In the best of scenarios, the threat is sufficient, retaliation need in fact never be imposed, and therefore its consequences never dealt with. The mere threat is enough to induce the first best solution for both countries. If however retaliation is imposed, one must drop the simplistic assumption that retaliation will have no effect on the imposing country: in the above example, one needs to consider the effect on importers of the effected goods. In the worst case scenario, retaliation can lead to a trade war, with welfare reducing effects on all agents involved.

IV. Concluding Remarks

This paper uses a model of repeated patent races to examine the incentives for intellectual property rights protection, and the effects of such protection both locally and on a country's trading partners. A partial equilibrium analysis is conducted in the context of international R&D competition between two countries both sufficiently technologically advanced to engage in innovative activities. The idea is to capture the situation of a middle income country competing in an innovation race with an industrialized country where strong IPR protection is already in place.

This paper demonstrates that weak IPRs are maintained in some countries not because imitation is a more desirable activity than innovation, as is often believed, but because of the time inconsistency problem intrinsic in IPR protection. While *ex ante* a government has an incentive to impose strong protection to promote innovation, protection is only enforced *ex post*, after discovery is made. At this point the government has an incentive to weaken protection to maximize profits in those product lines where local innovation has been unsuccessful. Given that firms are rational, they will make their investment decisions based on these expectations, and the equilibrium that will ensue will be one with weak IPR protection, fewer local firms innovating, and relatively lower welfare. Low protection will also lower welfare for the country's trading partner.

One way this problem may be solved is through country participation in a super national international organization, such as WTO, that forces governments to commit to

[12] Since the signing of a bilateral U.S. – China agreement on IPR protection, China has been taken off the U.S. trade representatives' Special 301 watch list, indicating progress in implementing stronger IPR regulations. Each year the Special 301 Report examines the effectiveness of IPR protection in the U.S.'s trading partners.

strong protection. The commitment equilibrium will be one of strong protection, maximum number of innovating firms and maximized welfare. Commitment will also increase welfare in the country's trading partner. In the absence of a super national commitment system, unilateral punishment may serve as an efficient enforcement mechanism for the country's trading partner. While effective, unilateral reaction often proves quite costly, and is in general frowned upon by the international community in that it can degenerate into mutually detrimental trade wars.

This paper has concentrated on the interaction between a middle income country (a country with non negligible innovative potential) and a more developed economy already committed to strong IPR protection. One could extend the analysis to the more general case of two countries, both without a commitment mechanism, and examine the incentives for IPR protection. Qualitatively the results would not change. Given different characteristics of the two countries, outcomes could obtain where reputational considerations are sufficient for both to maintain strong protection, or where instead a commitment mechanism is necessary in one or both countries. Alternatively a system of bilateral retaliation could serve as a double enforcement mechanism to maintain strong IPR protection in the global economy.

MATHEMATICAL DERIVATIONS

The effect of IPR protection on Home welfare:

$$\frac{dW_{HD}}{d\alpha} = \Pi_M - E\log\lambda$$
$$= \left(1 - \frac{1}{\lambda}\right)E - E\log\lambda$$

Furthermore, since

$$\frac{\lambda}{\lambda - 1}\log\lambda > 1$$

for $\lambda > 1$, which is true by definition, it follows that $dW_{HD}/d\alpha < 0$.
Social welfare from a *foreign* discovery, W_{FD}, is

$$\frac{dW_{FD}}{d\alpha} = -E\log\lambda < 0$$

It is apparent that $W_{HD} > W_{FD}$, and note also that $\left|dW_{HD}/d\alpha\right| < \left|dW_{FD}/d\alpha\right|$. Total welfare *at the end of* each period, i.e., in stage three, is also always decreasing in α.

$$W_{Tot,s3} = \frac{X}{X+Y}W_{HD} + \frac{Y}{X+Y}W_{FD} - \int_0^X K(x)dx$$

$$\frac{dW_{Tot,s3}}{d\alpha} = \frac{X}{X+Y}\frac{dW_{HD}}{d\alpha} + \frac{X}{X+Y}\frac{dW_{FD}}{d\alpha} - \frac{dK}{dX}\frac{dX}{d\alpha}$$

Instead total welfare at the beginning of each period, $W_{Tot,s1}$, is increasing in α, for given conditions.

$$\frac{dW_{Tot,s1}}{d\alpha} = \frac{\left(\frac{dX}{d\alpha}Y - \frac{dY}{d\alpha}X\right)}{(X+Y)^2}\left[f(X) + \Pi_M^* + \alpha\Pi_M\right] +$$

$$+\frac{X}{X+Y}\left(\Pi_M + \frac{df(X)}{dX}\frac{dX}{d\alpha}\right) - E\log\lambda - K(X)\frac{dX}{d\alpha}$$

Note that $\frac{df(X)}{dX} > 0$ by the definition of spillovers, and furthermore

$$\frac{dX}{d\alpha}Y - \frac{dY}{d\alpha}X > 0$$

given that $Y > X$ and $K''(x) \geq 0$ and $K^{*}{''}(y) \geq 0$. Given the constraints on $K(X)$, for $f(X)$ large enough $\frac{dW_{Tot,s1}}{d\alpha} > 0$.

Consider now the effect of Home protection on Foreign welfare. Welfare from a discovery that takes place in Foreign is

$$W_{FD}^* = E^* \log\lambda + f(X^*) + \alpha\Pi_M + \Pi_M^*$$

$$\frac{dW_{FD}^*}{d\alpha} = \Pi_M > 0$$

while the welfare from a discovery that takes place in the Home country is

$$W_{HD}^* = E^* \log\lambda$$

$$\frac{dW_{HD}^*}{d\alpha} = 0$$

Total welfare at the end of each period is:

$$W^*_{Tot} = \frac{X}{X+Y} W^*_{HD} + \frac{Y}{X+Y} W^*_{FD} - \int_0^Y K(y)dy$$

$$\frac{dW^*_{Tot}}{d\alpha} > 0$$

The effect of IPR protection on the number of innovating firms:

To derive $dX / d\alpha$ use the implicit function theorem

$$\frac{dX}{d\alpha} = -\frac{P_\alpha}{P_X}$$

$$P_X = -\frac{\Pi_W}{(X+Y)^2} - \frac{dK(X)}{dX} < 0$$

$$P_\alpha = \frac{\Pi_W}{X+Y} > 0$$

Therefore $dX / d\alpha > 0$. The same is true in Foreign, so $dY / d\alpha > 0$.

As for the effect of the number of innovating firms on Home welfare:

$$\frac{dW_{Tot}}{dX} = \frac{Y}{(X+Y)^2}\left[W_{HD} - W_{FD}\right] + \frac{X}{X+Y}\frac{df(X)}{dX} - K(X)$$

This will always be positive as long as $K(x)$ behaves well, i.e., doesn't explode after a certain value of x.

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