

## **INFORMATION TO USERS**

**This manuscript has been reproduced from the microfilm master. UMI films the text directly from the original or copy submitted. Thus, some thesis and dissertation copies are in typewriter face, while others may be from any type of computer printer.**

**The quality of this reproduction is dependent upon the quality of the copy submitted. Broken or indistinct print, colored or poor quality illustrations and photographs, print bleedthrough, substandard margins, and improper alignment can adversely affect reproduction.**

**In the unlikely event that the author did not send UMI a complete manuscript and there are missing pages, these will be noted. Also, if unauthorized copyright material had to be removed, a note will indicate the deletion.**

**Oversize materials (e.g., maps, drawings, charts) are reproduced by sectioning the original, beginning at the upper left-hand corner and continuing from left to right in equal sections with small overlaps. Each original is also photographed in one exposure and is included in reduced form at the back of the book.**

**Photographs included in the original manuscript have been reproduced xerographically in this copy. Higher quality 6" x 9" black and white photographic prints are available for any photographs or illustrations appearing in this copy for an additional charge. Contact UMI directly to order.**

# **UMI**

**A Bell & Howell Information Company  
300 North Zeeb Road, Ann Arbor MI 48106-1346 USA  
313/761-4700 800/521-0600**



**INTERNATIONAL PROTECTION OF INTELLECTUAL PROPERTY  
RIGHTS**

**Stefania Emma Scandizzo**

A Dissertation in Economics

Presented to the Faculties of the University of Pennsylvania in Partial Fulfillment of the Requirements for  
the Degree of Doctor of Philosophy

1997



Supervisor of Dissertation

  
Graduate Group Chairperson

**UMI Number: 9814911**

---

**UMI Microform 9814911**  
**Copyright 1998, by UMI Company. All rights reserved.**

**This microform edition is protected against unauthorized  
copying under Title 17, United States Code.**

---

**UMI**  
**300 North Zeeb Road**  
**Ann Arbor, MI 48103**

**To my parents**

## ACKNOWLEDGMENTS

I am greatly indebted to my advisor Wilfred Ethier for providing me with continued guidance and encouragement, without which this work would not have been possible. I also wish to thank Andrew Atkeson, Antonella Ianni, Stephen Morris and Patrick Kehoe for constructive comments and advice at various stages of my research.

Among the many friends and colleagues with whom I have shared the unique experience of graduate school, I thank particularly Sadiq Currimbhoy, Roberta Gatti, Ricardo Lagos, Miguel Molico and Valeria Tortorelli for useful discussions and suggestions, and most importantly for their invaluable moral support.

To my parents, who have always given me their unconditional support, I am forever indebted.

## ABSTRACT

# INTERNATIONAL PROTECTION OF INTELLECTUAL PROPERTY RIGHTS

Stefania Emma Scandizzo

Wilfred Ethier

Objective of this dissertation is to examine countries' incentives for Intellectual Property Rights (IPR) protection, in particular in the case of developing countries. In the first essay, a model of repeated patent races is used to show how a country with innovative potential may nonetheless maintain inadequate IPR protection. I find that this is due to 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 in the case of unsuccessful local innovation. In more technologically advanced economies reputational considerations may be sufficient to maintain strong protection. Otherwise a commitment mechanism, such as participation in WTO, or, more controversially, some form of bilateral punishment, may serve to increase welfare by increasing the level of innovation in the economy. In the second essay I examine the more general case of two countries which must interdependently choose their level of IPR protection. With respect to the one country case, a higher level of technological development will be necessary in both countries for the high IPR protection outcome to be supported. In the more general case of  $n$  countries, the world tends to divide into a high protection group and a low protection group. In the third essay I consider the effect of imperfect intellectual property rights on technology transfer and on the pattern of trade between two countries with different levels of technological development. Imperfect patent protection and imitation are introduced in a two country endogenous growth model with two activities, production and innovation. Assuming that imitation affects both activities, the backward country faces the following trade off: with weaker protection less technology enters the country, but what does enter can be more effectively exploited. If protection isn't too strong, it will shift the comparative advantage of research in favor of the laggard country.

# Contents

<b>1</b>	<b>Introduction</b>	<b>1</b>
<b>2</b>	<b>Intellectual Property Rights and International R&amp;D Competition</b>	<b>5</b>
2.1	Introduction	5
2.2	The Model	8
2.2.1	Innovation	8
2.2.2	Preferences	10
2.2.3	Production	11
2.2.4	Spillovers	11
2.2.5	Imitation	12
2.2.5.1	Integrated versus segmented markets	13
2.2.6	Welfare	14
2.3	Government Intervention	15
2.3.1	Optimal IPR policy in a one shot patent race	16
2.3.1.1	Optimal policy in the Home country	16
2.3.1.2	Repercussions in the Foreign country	18
2.3.2	Optimal IPR policy in the infinite horizon	19
2.3.3	Retaliation	21
2.4	Concluding Remarks	24
<b>3</b>	<b>A Model of Endogenous Intellectual Property Rights Protection in the Global Economy</b>	<b>26</b>
3.1	Introduction	26
3.2	The Model	28
3.2.1	Innovation	28
3.2.2	Preferences	30
3.2.3	Production	31
3.2.3.1	The high tech industry	31
3.2.3.2	The traditional sector	32
3.2.4	Imitation	32
3.2.5	Government Intervention	34
3.2.6	Optimal policy in the one shot patent race	35
3.2.6.1	Optimal IPR policy in the infinite horizon	40



3.2.7	Comparison to equilibrium in one country model .....	42
3.3	Extension: N countries .....	44
3.4	Concluding Remarks .....	47
<b>4</b>	<b>Comparative Advantage, Innovation and Intellectual Property Rights Protection</b>	<b>49</b>
4.1	Introduction .....	49
4.2	The Model .....	52
4.2.1	Production .....	53
4.2.2	Innovation .....	54
4.3	International Trade .....	55
4.3.1	The role of patent protection .....	58
4.3.2	The imitation technology .....	60
4.4	Comparative steady state analysis .....	61
4.5	Numerical Simulations .....	65
4.6	Concluding Remarks .....	68
	<b>Bibliography</b>	<b>70</b>

# **Chapter 1**

## **Introduction**

In recent years, the protection of Intellectual Property Rights (IPRs) has become an issue of growing concern and one of the most contentious areas on 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 is notoriously weak or altogether absent.

The debate regarding the international protection of IPRs, in particular within the framework of GATT and now the WTO, has often taken the following form. On the one hand, industrialized countries contend that weak IPR protection creates a disincentive for 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 contend that IPR protection creates monopoly power, and keeps them from becoming competitive in more technological sectors, that are usually the most profitable. In this light, it would appear that the only way of extending IPR protection internationally would entail granting developing countries concessions in other areas of trade policy.

In reality this way of looking at the problem of IPR protection is tied to a vision of the world that entails a division into industrialized, innovating countries and developing, imitating countries. It is assumed that countries that imitate do so because they do not have the technology to innovate. In reality most 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, Mexico, Chile, Argentina, and Brazil, just 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 industrialized countries, there exist a nonnegligible number of competitive firms in developing countries now undertaking innovative activity. It is therefore not clear why these countries continue to maintain such weak IPR protection.

The issue of the optimal level of IPR protection in a closed economy has been amply examined in the context of the literature on patent races: Loury (1979), Lee and Wilde (1980), Reinganum (1981), etc.; and of the literature on optimal patent length and breadth, for example Nordhaus (1969). The objective of a system of IPR protection is to reach a balance between the need to provide incentives for the investment in innovation and the social desirability of allowing the dissemination of knowledge once discovery takes place. A loss in consumer surplus due to monopoly power bestowed by IPRs is deemed necessary to compensate innovators for their efforts, in as innovation is a risky and uncertain enterprise: a certain amount of static misallocation is accepted as the cost of preserving dynamic incentives.

The issue of IPR protection in the open economy is more complex, in that all countries are affected by other governments policies and the globally efficient level of protection may not correspond to the best action by part of the single governments. IPR protection in an open economy has been examined mainly in the context of North - South models, that consider innovation entirely concentrated in the North and imitation concentrated in the South, in that the South is technologically incapable of doing innovation. The seminal work in this area is that of Grossman and Helpman (1991). In this framework, it follows that the North wishes to have strong IPR protection to promote innovation and protect local discoveries, and the South wishes to have weak protection so as to maximize the benefits of imitation.

The issue of international competition in R&D in an environment of imperfect IPR protection, however, has been largely overlooked. This is tied to the fact that most international R&D competition is considered to take place between industrialized countries, most of which have established systems of IPR protection, while most imitation is thought to take place in less developed countries, where historically innovative activities have been negligible. The increased rate of development of many historically backwards countries has been accompanied

by a shift in the comparative advantage in R&D, and this calls for an examination of what are the incentives for IPR protection in a world where innovative activities take place in a range of countries characterized by different levels of technological development. The fact that some innovating countries continue to maintain weak IPR protection while others have embraced systems of stronger IPR protection leads us to believe that the trade-off between innovation and imitation is not the same for all countries.

I consider the problem of IPR protection in the context of two issues: international R&D competition and foreign direct investment (FDI). With respect to R&D competition in the global environment, one reason why a government may choose to allow weak IPR enforcement is tied to the uncertain nature of research: when firms race to discover a new technology all must pay the cost of research but only one firm will win the patent. Weak protection creates a disincentive to local innovation, but permits the country, through imitation, to increase the benefits from foreign innovation. FDI is considered one of the most important channels through which technology is shifted from developed to less developed economies. Through imitation, the recipient country will reduce the amount of technology transferred from abroad, but will be able to more effectively exploit what does enter.

In Chapter Two I consider the incentives for IPR protection in a country whose trading partner is more technologically advanced and already committed to a high level of IPR protection. A dynamic model of patent races conducted along a continuum of product lines is used to explain why a country with innovative potential may nonetheless maintain inadequate IPR protection. A possible explanation is that there is a time consistency 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 in the case of unsuccessful local innovation. The suboptimal but time consistent policy therefore involves an insufficient level of protection, and therefore an insufficient level of innovation. In more technologically advanced economies, reputational considerations may be sufficient to maintain strong protection. Otherwise a commitment mechanism, such as participation in WTO, or, more controversially, some form of bilateral punishment, may serve to increase welfare by increasing the level of innovation in the economy.

While in Chapter Two I concentrate on the interaction between a middle income country (a country with non negligible innovative potential) and more developed economy already committed to strong IPR protection, in Chapter Three I extend the analysis to the more general case of two countries, both without a commitment mechanism, and examine the incentives for IPR protection. In this case it will be necessary for both countries to be sufficiently technologically advanced for high protection to result, even in the more advanced country. This because not only does the interaction between government and domestic firms tend to bring about low protection, but so does the interaction between governments of different countries. I then extend the analysis to the case of  $n$  countries, where the result is a division of the world into two groups: a high protection club and a low IPR protection group. A commitment mechanism, such as participation in WTO, can serve to extend high protection also to non member countries by increasing the long run benefits of high protection.

In Chapter Four, I consider the effect of imperfect intellectual property rights on technology transfer and the pattern of trade between two countries with different levels of technological development. Imperfect patent protection and imitation are introduced in a two country endogenous growth model with two activities, production and innovation. Assuming that imitation affects both activities, the backward country faces the following trade off: with weaker protection less technology enters the country, but what does enter can be more effectively exploited. If protection isn't too strong, it will shift the comparative advantage of research in favor of the laggard country.

## **Chapter 2**

# **Intellectual Property Rights and International R&D**

## **Competition**

### **1 Introduction**

The protection of intellectual property rights (IPRs) has become one of the most contentious areas of dispute in the international trade arena. In industrialized countries innovators are rewarded for their efforts through a system of patents, copyrights and trademarks. With the increased globalization of trade, there has been a push for this type of protection to be extended throughout the rest of the world, in particular to the growing import markets of developing countries, where IPR protection is notoriously weak or altogether absent. This has led to a fierce debate: on the one side industrialized countries contend that weak IPRs create a disincentive to innovation, with negative effects on growth and welfare; on the other hand developing countries claim that IPRs effectively grant monopoly power and keep them from becoming competitive in high tech, high profit industries. Given these opposing views it is commonly believed that the only way of extending IPR protection is to grant developing countries concessions in other areas.

This paper seeks to shed light on this debate by considering the incentives for IPR protection in developing countries. International R&D competition often results in outcomes where the industrialized countries innovate and the developing countries imitate. The classic framework for analyzing this issue is the North-South model: the North innovates and the South, having no innovative capabilities, imitates. It is understandable that the North will wish to have strong IPR protection to promote innovation and protect local discoveries, as it is evident that the South will wish to have weak protection to maximize the benefits of imitation. However

in reality many imitating countries have the potential to be successful innovators, and often have a non negligible number of competitive firms participating in R&D. Given the presence of innovative potential one may well ask why these countries continue to have weak IPR regimes: apparently the trade-off between innovation and imitation is not the same for all countries.

This question is important because many of the countries that have been most heavily targeted for their weak IPR regimes are not the least developed economies but in fact middle income countries where innovation is increasingly present: Korea, India, China, Singapore, Taiwan, Brazil, Mexico.

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/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 increase the benefits from foreign innovation. In this scenario, imitation can serve as a form of insurance: allowing at least some firms to be imitators permits a country to avoid reaping no profits at all 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 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. This explains weak IPR protection not as a result of lobbying pressures or other political concerns, but as a consequence of a government's inability to commit to policies that *ex post* it would not find optimal to pursue. This result undermines the view that the international harmonization of IPR protection necessitates concessions to developing countries in other areas.

In some cases reputational considerations may be sufficient to induce the government to maintain high protection, but this will only be the case of countries that are highly successful at innovation. In other innovating countries two other solutions exist. International agreements that imply commitment to a strong IPR regime, for example participation in WTO, may be sufficient to solve the time inconsistency problem. Secondly, unilateral retaliation from the country's trade partners may help keep the offender in check and serve to maintain strong protection. This second result is more controversial in that unilateral retaliation is in general frowned upon in the international community.

This paper builds on the extensive literature on patent races: Loury (1979), Lee and Wilde (1980), Reinganum (1982), and Dixit (1988). 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 differs in that it assumes innovative activity in the Southern country. 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 creating a disincentive for research in its domestic firms. This paper is also tied to the small 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 product standards). Lastly, it is related to the literature on the time inconsistency of trade policies, as in Eaton and Grossman (1985) and Staiger and Tabellini (1987).

The rest of this paper is structured as follows. In section 2 a dynamic model of patent races conducted along a continuum of product lines is presented. In section 3 I examine how the government intervenes in the



matter of IPR protection both in the short and in the long run. I then consider commitment, reputation and unilateral punishment as a solution to the time inconsistency problem. Lastly, some concluding remarks are presented.

## 2 The Model

Assume two countries, Home and Foreign and two types of goods,  $d(z)$ , a high tech good, and  $C$ , 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.

### 2.1 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  $\lambda$  times as many services as the previous one:

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

Assume  $\lambda$  to be exogenous, constant, greater than 1, and common to all product lines.

Suppose there are  $X$  domestic firms conducting research and  $Y$  foreign ones. We can treat  $X$  and  $Y$  as continuous variables.<sup>1</sup> In each period, individual firms in each country race to discover a new innovation along a continuum of identical product lines,  $j \in [0, 1]$ .<sup>2</sup> Let us consider the situation at Home (the situation in Foreign will be 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

<sup>1</sup> This is not an unreasonable approximation. In the semiconductor or biotechnology industry, for example, there are often more than a dozen competitors at the beginning of a race.

<sup>2</sup> 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 are conducting research in each one.

$K'(x) > 0$  and  $K(x)$  is continuous and differentiable. Assume furthermore that  $K'(x) < M$ , where  $M$  is a finite number: in this way we avoid that the cost of innovation "explodes" for some firms.

At the beginning of each period a race takes place in each product line and 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, 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 we take as exogenous both the length of a race and the effort expended by each participant, furthermore we assume that 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  $\Pi_W$  (for winner). The payoff for an individual domestic firm  $x$  from conducting research is

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

For a foreign  $y$  it will be<sup>3</sup>

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

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

For each individual firm innovation along each single product line is stochastic; however, since we are considering R&D that 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

<sup>3</sup> Throughout this paper, asterisks will be used to denote foreign variables.

the number of Foreign innovations will be  $Y/(X + Y)$  . It is apparent that 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  $X$ .

## 2.2 Preferences

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

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

Instantaneous utility from consumption of the high tech good is given by

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

where  $d_{mt}(j)$  denotes consumption of quality  $m$  in product line  $j$  at time  $t$ . The summation extends over a set of qualities that coincides with 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. We can choose units so that the lowest quality of each product (the one available at time  $t = 0$ ) offers one unit of service, that is  $q_0(j) = 1$ . This implies that  $q_m(j) = \lambda^m$ .

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  $\tilde{m}_t(j)$  that carries the lowest price per unit of quality. This yields the following demand functions

$$d_{mt}(j) = \frac{E(t)}{p_{mt}(j)} \quad \text{for } m = \tilde{m}_t(j), \quad 0 \text{ otherwise} \quad (6)$$

where  $E(t)$  denotes per period expenditure and  $p_{mt}(j)$  is the price of quality  $m$  of product  $j$  at time .

The same is true in the Foreign country, with  $d_{mt}^*(j) = E^*(t)/p_{mt}(j)$ .

## 2.3 Production

For simplicity, assume identical production technologies across all product lines  $j$  and all qualities  $q$ . Assuming labor as the only factor of production, we 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  $w$ .

Regarding market structure, assume that all firms engage in Bertrand price competition. We have seen above that a winning firm, as long as it is not imitated, will have 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 (whom I will call the "follower" firm). The follower firm charges price  $w$ , the lowest price consistent with nonnegative profits. The highest price the state of the art firm can charge is  $\lambda w$ , in fact at this price consumers are indifferent between the older good and the state of the art good which is more expensive but gives greater services. By charging a price a shade below  $\lambda w$  the state of the art firm can capture all the market: therefore in every period only the state of the art good is produced and consumed. This price yields sales of  $E/\lambda w$  in Home and  $E^*/\lambda w$  in Foreign, therefore monopoly profits to the state of the art firm in each period will be (in the absence of imitation)

$$\Pi_M = \left(1 - \frac{1}{\lambda}\right) (E + E^*) \quad (7)$$

## 2.4 Spillovers

Technological advance in one industry often has positive effects on other industrial sectors of the economy. (For example, progress in the semiconductor industry has positive effects on the automobile industry.) Assume that besides the industry considered above there is a second industry in the economy that produces a homogeneous good  $C(t)$  under perfect competition, constant returns to scale and no distortions.  $C(t)$  is produced according to the production function

$$C(t) = F[A(t)L(t)] \quad (8)$$

where

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

Therefore productivity in the homogenous good industry 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 I can ignore them and obtain the same qualitative results.)

## 2.5 Imitation

Assume for simplicity that the Foreign country has perfect patent protection: imitation by Foreign firms is impossible. (This way we are implicitly modelling the case of trade between an industrialized country, that historically is 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 the 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. We will ignore the problem of imitation technology and assume that imitation depends entirely on how well intellectual property rights are enforced: imitation will be a decreasing function of IPR protection.

Denote  $\alpha$  the index of IPR protection. I shall interpret  $\alpha$  as the probability of a winning firm receiving monopoly profits  $\Pi_M$ . Therefore  $(1-\alpha)$  is the probability of the imitation occurring and of the winning firm receiving lower profits  $\Pi_{Cm}$ . The expected payoff from winning the race is

$$\Pi_W = \alpha\Pi_M + (1 - \alpha)\Pi_{Cm} \quad (10)$$

If imitation occurs, imitation profits  $\Pi_C$  are divided among all imitators. Therefore expected profits to a race's "losers",  $\Pi_L$ , is

$$\Pi_L = (1 - \alpha)\frac{\Pi_C}{X} \quad (11)$$

Let us consider now the relationship between  $\Pi_M$ ,  $\Pi_{Cm}$  and  $\Pi_C$ . Assume for simplicity that with imitation monopoly profits are divided fully between firms, with no effect on consumers.<sup>4</sup> Then

$$\Pi_M = \Pi_{Cm} + \Pi_C \quad (12)$$

Denote  $\gamma \in (0, 1)$  the share of monopoly profits that remains with the state of the art firm. Then

$$\Pi_{Cm} = \gamma \Pi_M = \gamma \left(1 - \frac{1}{\lambda}\right) (E + E^*) \quad (13)$$

$$\Pi_C = (1 - \gamma) \left(1 - \frac{1}{\lambda}\right) (E + E^*) \quad (14)$$

### 2.5.1 Integrated versus segmented markets

I have implicitly assumed that the market for imitated goods is integrated, i.e. goods that are imitated at Home can be sold also in the Foreign market. In this way imitation affects profits in both markets. We should however distinguish between integrated and segmented markets. In the latter case, imitation in each market depends on the existing IPR regime in the market, since imitated goods cannot be shipped from one market to the other. Assuming perfect IPR protection in the Foreign country, imitated goods will only be sold in the Home market, so the state of the art firm will continue to reap monopoly profits in the Foreign market regardless of imitation. Denoting imitation profits that accrue from the Home market as  $\Pi_{CH}$  and those that accrue from the Foreign market as  $\Pi_{CF}$  we have

$$\Pi_C = \Pi_{CH} + \Pi_{CF} \quad (15)$$

where

$$\Pi_{CH} = (1 - \gamma) \left(1 - \frac{1}{\lambda}\right) E \quad (16)$$

<sup>4</sup> We could easily consider the case in which

$\Pi_M < \Pi_{Cm} + \Pi_C$  and consumer surplus increases with imitation (due to lower consumer prices). None of the qualitative results change, the version used in the text has the advantage of expository simplicity.

$$\Pi_{CF} = (1 - \gamma) \left(1 - \frac{1}{\lambda}\right) E^* \quad (17)$$

In the case of segmented markets  $\Pi_{CF} = 0$ , so that  $\Pi_C = \Pi_{CH}$ . With imitation the state of the art firm will continue to reap monopoly profits  $\Pi_{MF} = (1 - \frac{1}{\lambda}) E^*$  in the Foreign market and the lower profits  $\Pi_{CmH} = \gamma (1 - \frac{1}{\lambda}) E$  in the Home market.

It is apparent that with segmented markets the effect of imitation on profits and, as we shall see in the following sections, on welfare will depend on the relative sizes of  $E$  and  $E^*$ . Imitation in a large market will have a much stronger effect on profits and welfare than imitation in a small market.

We shall assume hereon that markets are integrated, and make considerations regarding segmented markets where warranted.

## 2.6 Welfare

We will consider the social welfare that accrues from each individual innovation in each period. Let  $S_H$  denote the sum of "social benefits" from *domestic* innovation, i.e. all innovation effects except profits. It has two components: (1) Home consumer surplus ( $E \log \lambda$  - the increase in consumer surplus due to innovation) and (2) Home "spillovers"  $f(X)$  (increased productivity in the homogeneous good sector).  $S_F$  denotes the social benefit from foreign innovation: since I have assumed no spillovers from foreign innovation it will consist solely of consumer surplus.<sup>5</sup> This captures the idea that innovation is always a good thing, but that it is better to have innovation occur domestically than abroad.

Social welfare that accrues from a *domestic* discovery,  $W_{HD}$ , is

$$W_{HD} = S_H + \alpha \Pi_M + (1 - \alpha) [\Pi_{Cm} + \Pi_C] \quad (18)$$

with  $dW_{HD}/d\alpha = 0$ . Social welfare from a *foreign* discovery,  $W_{FD}$ , is

$$W_{FD} = S_F + (1 - \alpha) \Pi_C \quad (19)$$

<sup>5</sup>  $S_H^*$  will be the social benefit to the Foreign country from Home innovation (consumer surplus  $E^* \log \lambda$ ), and  $S_F^*$  the social benefit to the Foreign country from Foreign innovation (consumer surplus  $+ f^*(Y)$ ).

with  $dW_{FD}/d\alpha < 0$ . It is apparent that  $W_{HD} > W_{FD}$ . Total welfare each period will be given by

$$W_{Tot} = \frac{X}{X+Y} * W_{HD} + \frac{Y}{X+Y} * W_{FD} - \int_0^X K(x)dx \quad (20)$$

### 3 Government Intervention

Before examining the role of government intervention, we must consider more specifically the timing of events. 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 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 timing 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  $\alpha$ . Firms make their investment decision based on this  $\alpha$ . In particular, since the payoff from successful innovation increases with protection so will the number of firms conducting R&D:  $dX/d\alpha > 0$ .<sup>6</sup> Note however that  $Y$  is also affected by a change in  $\alpha$ , since  $dY/dX < 0$ .<sup>7</sup> Enforcement doesn't take place until after discovery:

<sup>6</sup> To derive  $dX/d\alpha$  use the implicit function theorem

$$\begin{aligned} \frac{dX}{d\alpha} &= -\frac{P\alpha}{P_X} \\ \frac{dP(X)}{dX} &= -\frac{\Pi_w}{(X+Y)^2} - \frac{dK(X)}{dX} < 0 \\ \frac{dP(X)}{d\alpha} &= \frac{\Pi_M - \Pi_{C_m}}{X+Y} > 0 \end{aligned}$$

Therefore  $dX/d\alpha > 0$ .

<sup>7</sup> Once again, using the implicit function theorem:

$$\begin{aligned} \frac{dY}{dX} &= -\frac{P_X}{P_Y} \\ P_X &= -\frac{\Pi_w}{(X+Y)^2} < 0 \\ P_Y &= -\frac{\Pi_w}{(X+Y)^2} - \frac{dK(Y)}{dY} < 0 \end{aligned}$$

Therefore  $dY/dX < 0$ .



at this point the welfare function of the government is different in as investment decisions have already been made, i.e.  $X$  and  $Y$  are fixed.

We shall make the following assumptions regarding  $\alpha$ :

$$\alpha \in [\alpha_{\min}, \alpha_{\max}] \quad \text{where} \quad \alpha_{\min} > 0, \quad \alpha_{\max} < 1 \quad (21)$$

We can interpret  $\alpha_{\min}$  as the "natural" rate of imitation, i.e. the risk of imitation in the absence of any IPR protection (which need not necessarily be one). Instead  $\alpha_{\max}$  is the maximum protection that can be accorded through legislation: even with the strictest legislation and enforcement there may exist a nonnegative risk of imitation.

### 3.1 Optimal IPR policy in a one shot patent race

#### 3.1.1 Optimal policy in the Home country

Let us consider the case in which the R&D race occurs only once in time, and compare the case in which the government can precommit to its IPR regime versus the case in which it is free to renege. We shall see that 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. Furthermore, we shall see that there will be more innovators operating in the Home country if the government is forced to commit to its IPR regime than in the no commitment case.

Let us consider the government's incentives in deciding the country's IPR regime. 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. Therefore in deciding between strong or weak protection the government must weigh these two opposing forces.

We need to distinguish the government's problem *before* and *after* discovery, i.e. in stage one and in stage two.

At the beginning of the race, i.e. in stage one, the government's problem is to maximize  $W_{Tot,s1}$

$$\max_{\alpha} W_{Tot,s1} = \frac{X(\alpha)}{X(\alpha) + Y(X(\alpha))} * W_{HD} + \frac{Y(X(\alpha))}{X(\alpha) + Y(X(\alpha))} * W_{FD} - \int_0^{X(\alpha)} K(x)dx \quad (22)$$

Note that  $W_{Tot,s1}$  is increasing in the level of protection, as long as the following is true:

$$f(X) > \frac{\Pi_C}{dX/d\alpha} - \Pi_{Cm} - \alpha\Pi_C$$

This will always hold for  $f(X)$  sufficiently large, which we shall assume hereon.<sup>8</sup>

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

$$\max_{\alpha} W_{Tot,s3} = \frac{X}{X + Y} * W_{HD} + \frac{Y}{X + Y} * W_{FD} \quad (23)$$

where  $X$  and  $Y$  are fixed.

**Proposition 1:** (*The precommitment optimal IPR policy*) With full commitment, the optimal IPR policy is maximum protection.

This follows directly from  $dW_{Tot,s1}/d\alpha > 0$ . With full commitment, the government does not have the option of renegeing in stage three, and its problem is only that of maximizing  $W_{Tot,s1}$  in stage one, the solution of which is  $\alpha = \alpha_{max}$ . 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  $\alpha = \alpha_{min}$ , given that  $dW_{Tot,s3}/d\alpha < 0$  since  $dW_{HD}/d\alpha = 0$  and  $dW_{FD}/d\alpha < 0$ .

<sup>8</sup>

$$\frac{dW_{Tot,s1}}{d\alpha} = \frac{Y}{X + Y} \left\{ \frac{dX}{d\alpha} [f(X) + \Pi_{Cm} + \alpha\Pi_C] - \Pi_C \right\}$$

Therefore

$$\frac{dW_{Tot,s1}}{d\alpha} > 0 \quad \text{if} \quad f(X) > \frac{\Pi_C}{dX/d\alpha} - \Pi_{Cm} - \alpha\Pi_C$$

This will be true for  $f(X)$  large enough.

In stage two firms make their investment decisions, and being rational they know that if the government cannot precommit to its announced policy in stage three it will impose  $\alpha = \alpha_{\min}$ . Therefore they decide whether to participate in the innovation race taking into account  $\alpha = \alpha_{\min}$ , regardless of the announced policy. The equilibrium number of firms participating in the innovation will be the  $X$  that solves:

$$P(R, X) = \frac{\Pi_W(\alpha_{\min})}{X + Y} - K(X) = 0$$

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

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:

$$\max \alpha \frac{X_{\min}}{X_{\min} + Y} * W_{HD}(\alpha_{\min}) + \frac{Y}{X_{\min} + Y} * W_{FD}(\alpha_{\min})$$

The solution is  $\alpha = \alpha_{\min}$ , 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  $dW_{Tot}/dX > 0^9$  in general, welfare is lower than in the commitment case.

### 3.1.2 Repercussions in the Foreign country

Let us now consider the effect of these policies on the Foreign country. Since we have assumed that imitation only takes place in the Home country, imitation profits accrue only to Home firms. Welfare in the Foreign country from a discovery that takes place in Foreign is

$$W_{FD}^* = S_F^* + \alpha \Pi_M + (1 - \alpha) \Pi_{Cm} \quad (24)$$

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

9

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

$$\frac{dW_{Tot}}{dX} > 0 \text{ when } [f(X) + \alpha \Pi_M + (1 - \alpha) \Pi_{Cm}] > K(X)$$

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

$$W_{HD}^* = S_H^* \quad (25)$$

Total welfare each period is:

$$W_{Tot}^* = \frac{X}{X+Y} * W_{HD}^* + \frac{Y}{X+Y} * W_{FD}^* - \int_0^Y K(y)dy \quad (26)$$

It is apparent that, since  $dW_{FD}^*/d\alpha > 0$ <sup>10</sup>, 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  $\alpha = \alpha_{max}$ .

### 3.2 Optimal IPR policy in the infinite horizon

Consider now the case where patent races are repeated infinitely through time. For simplicity, assume that the government can impose only two levels of protection: high ( $\alpha_H$ ) and low ( $\alpha_L$ ). 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.

Notice that  $W_{HD}(\alpha_H) = W_{HD}(\alpha_L)$ , since with imitation monopoly profits are simply redistributed between firms. Note instead that

$$W_{FD}(\alpha_L) - W_{FD}(\alpha_H) = (\alpha_H - \alpha_L)\Pi_C > 0 \quad (27)$$

It therefore follows 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

<sup>10</sup>

---


$$\frac{dW_{FD}^*}{d\alpha} = \Pi_M - \Pi_{Cm} > 0.$$

best response therefore will be to impose low protection. In the one shot race we saw that 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.

Assume the "game" is played as follows. The government announces a policy regime. If once innovation occurs the government deviates from its announced regime, it loses reputation and in the future firms will always expect it to follow the low protection regime, i.e. the system reverts to the one-shot no commitment solution. We shall assume that reversion to the one-shot equilibrium lasts forever. We assume firms are rational and informed but not strategic: they do not act as if protection were low to "punish" the government. An equilibrium will be credible if the incentive to deviate from it, the "temptation", is not greater than the cost of a deviation, the "punishment" (or "enforcement").

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

$$\begin{aligned} & \frac{1}{1-\beta} [X(\alpha_H)W_{HD}(\alpha_H) + Y(X(\alpha_H))W_{FD}(\alpha_H)] \\ & > X(\alpha_H)W_{HD}(\alpha_L) + Y(X(\alpha_H))W_{FD}(\alpha_L) + \\ & \quad + \frac{\beta}{1-\beta} \left[ X(\alpha_L)W_{HD}(\alpha_L) + Y(X(\alpha_L))W_{FD}(\alpha_L) + \int_{X(\alpha_L)}^{X(\alpha_H)} K(x)dx \right] \end{aligned} \quad (28)$$

Remembering that  $W_{HD}(\alpha_H) = W_{HD}(\alpha_L) = W_{HD}$ , this is equivalent to

$$\begin{aligned} & \frac{\beta}{1-\beta} [X(\alpha_H) - X(\alpha_L)] W_{HD} \\ & > Y(X(\alpha_H))[W_{FD}(\alpha_L) - W_{FD}(\alpha_H)] + \\ & \quad + \frac{\beta}{1-\beta} [Y(X(\alpha_L))W_{FD}(\alpha_L) - Y(X(\alpha_H))W_{FD}(\alpha_H) + \int_{X(\alpha_L)}^{X(\alpha_H)} K(x)dx] \end{aligned} \quad (29)$$

Equation 28 says that high protection is a time consistent policy only if the benefit of maintaining high protection (left hand side) is higher than the "temptation" of deviating and imposing low protection (first term on the right hand side) plus the "punishment" for deviating.

This is true, i.e. the government does not have an incentive to renege on a policy of high protection, if the

country's trading partner is not too big or particularly efficient at research ( $Y$  is not too large relative to  $X$ ), if the social and private benefits of domestic innovation are large ( $W_{HD}$  is large), and if  $X$  is very reactive to IPR protection ( $dX/d\alpha$  large, i.e.  $\Pi_M$  much larger than  $\Pi_{Cm}$ ).

If this is the case, an international equilibrium will ensue where both countries impose maximum IPR protection.

Consider the case instead where equation 28 does **not** hold, i.e. the case where reputational considerations are not sufficient for the government to maintain strong protection. This might be the case when the country in question is small compared to its trading partner or when the social benefits from innovation are not particularly large. In this case the following will hold:

**Proposition 4:** If

$$\begin{aligned} & \frac{\beta}{1-\beta} [X(\alpha_H) - X(\alpha_L)] W_{HD} \\ < & Y(X(\alpha_H)) [W_{FD}(\alpha_L) - W_{FD}(\alpha_H)] + \\ & + \frac{\beta}{1-\beta} [Y(X(\alpha_L)) W_{FD}(\alpha_L) - Y(X(\alpha_H)) W_{FD}(\alpha_H) + \int_{X(\alpha_L)}^{X(\alpha_H)} K(x) dx] \end{aligned} \quad (30)$$

the only time consistent policy is low IPR protection.

In this case, welfare in the Foreign country will be lower than in the case of Proposition 3, in as we've seen that welfare from domestic innovations decreases as Home imitation increases. Furthermore, even welfare at Home will be lower, since less innovation is taking place.

### 3.3 Retaliation

One way that this negative situation can be solved is through a commitment mechanism: for example if both countries are members of the World Trade Organization (WTO) and must make a binding commitment to high protection, the high protection outcome is sustainable. However, often the countries that are most criticized for their IPR regimes either do not belong to the WTO or have been granted a "grace period" before enforcing stronger IPR legislation. Even in these cases the Foreign country still has an option: it can 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 4, i.e. make a high protection outcome sustainable. This will not only increase welfare in the Foreign country but also in the Home country. The result is that not only enforcement by a supernational organization but also punishment from a trade partner can serve to maintain strong protection.

**Proposition 5:** The country with weak IPR protection, i.e. for which equation 28 does not hold, can be induced to maintain strong protection through retaliation by its trading partner

$$temptation < punishment + \Delta$$

in other words

$$\begin{aligned} & \frac{1}{1-\beta} [X(\alpha_H)W_{HD}(\alpha_H) + Y(X(\alpha_H))W_{FD}(\alpha_H)] \\ < & X(\alpha_H)W_{HD}(\alpha_L) + Y(X(\alpha_H))W_{FD}(\alpha_L) + \\ & + \frac{\beta}{1-\beta} \left[ X(\alpha_L)W_{HD}(\alpha_L) + Y(X(\alpha_L))W_{FD}(\alpha_L) + \int_{X(\alpha_L)}^{X(\alpha_H)} K(x)dx \right] \\ & - \Delta \end{aligned} \tag{31}$$

where  $\Delta$  is the retaliation imposed by the trading partner for maintaining weak protection (beyond the punishment already inherent in deviating).

Let us consider different forms of bilateral retaliation and see which one would be most effective. It is commonly believed that an effective form of punishment in the case of weak IPRs is to reduce the payoff to the low protection country for goods for which innovation is successful. This entails lowering  $W_{HD}$  when IPRs are weak, for example by limiting access of Home innovations to the Foreign market and therefore lowering  $\Pi_M$ . But as one sees from equation 30 (left hand side) this will only serve to **increase** the incentive to renege, and therefore is not effective. We see that to effectively induce the Home country to change its IPR policy the Foreign country must intervene on  $W_{FD}$ .

A second form of retaliation is to lower profits in the case of imitation: i.e. lower  $W_{FD}(\alpha_L)$  by lowering

$\Pi_C$ . To examine this form of retaliation we must distinguish between the case of integrated and segmented markets.

In the case of segmented markets this form of retaliation is ineffective, since the Foreign country can at most affect profits that accrue within its own borders. (However, in this case the effect of imitation may also be less, depending on the size of the two markets.) If the market for imitated goods is instead integrated, the effectiveness of this policy will depend fundamentally on the size of imitation profits that derive from the Foreign market, i.e. on the size of  $E^*$ . (For example, in the case of the U.S. - China dispute, sales of imitated compact discs in the U.S. was inconsequential compared to sales in China and the rest of Asia.)

Remembering that

$$\begin{aligned} W_{FD} &= S_F + (1 - \alpha)(\Pi_{CH} + \Pi_{CF}) \\ &= S_F + (1 - \gamma) \left(1 - \frac{1}{\lambda}\right) E + (1 - \gamma) \left(1 - \frac{1}{\lambda}\right) E^* \end{aligned} \quad (32)$$

we see that the Foreign country cannot affect  $\Pi_{CH}$  but only  $\Pi_{CF}$ , for instance through the imposition of a tariff.

Finally, the Foreign country can punish the Home country by imposing retaliation in other sectors of the economy, for example a tariff on Home's exports of goods in other sectors. The most obvious example is the U.S. threat to impose punitive tariffs on China for its continued violation of American IPRs, particularly in the fields of compact discs, videos and software. These sectors themselves weren't punished, instead important Chinese export industries, such as textiles, footwear, apparel and electronics, were targeted. This type of "lump sum" punishment is in fact the most effective in that 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 retaliation is large enough it will induce the Home country to maintain high protection, furthermore if large enough this 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.

This form of retaliation however will be most effective if it is "credible", i.e. if the Foreign country actually



has an incentive to punish once imitation takes place. Trade sanctions most often do not exclusively affect the country towards which they are directed. A retaliation so severe that it will also have negative effects on the welfare of the Foreign country will in fact not be optimal once imitation actually takes place, furthermore if Home policymakers are aware of this retaliation will not be effective. Retaliation will be more effective the higher are the negative effects on the Home country and the smaller the repercussions for the Foreign country.

#### **4 Concluding Remarks**

In this paper I use a model of intertemporal patent races to study the incentives for intellectual property rights protection, and the effects of such protection both locally and on the 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 situation I wish to capture is that of a middle income country competing in an innovation race with an industrialized country where strong IPRs are already in place.

I find that, contrary to popular opinion, weak IPRs are maintained in some countries not because imitation is a more desirable activity than innovation, 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 who will be losing a part of its monopoly profits through imitation.

One way this problem may be solved is through participation in an supernational international organization, such as WTO, that forces governments to commit to 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.

Unfortunately supernational organization often do not have sufficient enforcement power, or developing countries are granted "grace periods" for enforcement of protection. In this situation, unilateral punishment may serve as an efficient enforcement mechanism for the country's trading partner. This result may appear controversial given that unilateral retaliation is in general frowned upon by the international community, in that it can degenerate into mutually detrimental trade wars. However in the absence of an efficient international enforcement system a "punishment" mechanism may prove preferable to inaction.

In this paper, I have 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.

## Chapter 3

# A Model of Endogenous Intellectual Property Rights

## Protection in the Global Economy

### 1 Introduction

Intellectual property rights (IPR) protection has been an argument of ongoing debate in the international arena. While in most industrialized countries a system of patents, copyrights and trademarks already exists that rewards innovators for their effort, the increased globalization of trade has created a push for this sort of protection to be extended in the rest of the world.

What incentives does a government face in choosing its level of IPR protection? On the one hand higher protection creates an incentive for domestic innovation, which besides producing monopoly profits also creates local spillovers that enhance domestic welfare. On the other hand lower protection permits easier imitation, which is less costly and permits appropriation of a part of monopoly profits in the case of unsuccessful innovation. Lastly, the government must also take into consideration how other countries will react to its actions: weak protection in one market lowers the incentives for innovation also in others, so it may weaken the argument for strong protection in other countries.

Previously <sup>11</sup> I examined the case of a country choosing its IPR regime when its trading partner was already committed to a high level of IPR protection. In other words I considered the case in which one country, notably the more technologically advanced one, has a fixed level of IPR protection while the less developed country must choose its own level of protection. The underlying assumption has been that the Foreign country is

---

<sup>11</sup> See Chapter 2.

committed to a certain level of protection (in our case perfect protection) and will never change it. I now assume that *both* countries choose their level of IPR protection, taking into account the actions of the trading partner. I would expect to see that the level of protection of the trading partner affect a country's decision regarding its own level of protection. In particular, it is interesting to see whether a country's level of IPR protection serve as a strategic trade tool in interacting with the country's partners.

The following results ensue. In the one country model, low protection may result due to the time inconsistency problem inherent in how intellectual property rights regimes work. In a two country model, in the absence of a precommitment mechanism, there is also a second mechanism working against the outcome of high protection. Not only does the interaction between government and domestic firms tend to bring about a result of low protection, so does the interaction between governments of different countries. In other words, not only do domestic firms react to low protection in a way that tends to perpetuate low protection, but low protection in a foreign market has the same effect. For reputational considerations to be sufficient in the long run to ensure the maintenance of high protection domestic conditions will have to be much stronger than in the case in which the country's trading partner is already committed to strong protection.

It will be necessary for *both* countries to be sufficiently advanced technologically for a high protection to result, even in the more advanced country. The latter might be able to maintain high protection if its trading partner were committed to strong IPR protection, but not if its partner were not. This argument can be extended to the case of  $n$  countries, where the likely equilibrium to ensue will be a division of the world into two groups: a high IPR protection group and a low IPR protection group.

This appears to be an argument in favor of the commitment mechanism of GATT. Bilateral negotiations in this area of trade relationships tend to result in failure, in particular because the punishment mechanism actually tends to perpetuate the undesirable outcome. Tit for tat will not work because not only is the interaction between governments in question affected, but so are the expectations of innovating firms. Uncertainty in the IPR regime, both domestically and abroad, will tend to reduce the amount of innovative activity undertaken, with negative results on welfare in both countries. Commitment through an international organization

such as the WTO can serve to extend high protection also to non member countries by increasing the long run benefits of high protection.

## 2 The Model

The model used is very similar to that presented in Chapter Two. Assume two countries, Home and Foreign and two types of goods:  $d(z)$ , a high tech good, and  $c$ , 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.

### 2.1 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  $\lambda$  times as many services as the previous one:

$$q_m(j) = \lambda q_{m-1}(j) \quad \forall j, m \quad (33)$$

Assume  $\lambda$  to be exogenous, constant, greater than 1, and common to all product lines.

There are  $X$  domestic firms conducting research and  $Y$  foreign ones. We can treat  $X$  and  $Y$  as continuous variables. In each period, firms in each country race to discover a new innovation along a continuum of identical product lines,  $j \in [0, 1]$ .<sup>12</sup> Let us consider the situation at Home (the situation in Foreign is symmetric). To participate in the innovation race firms must pay a fixed cost  $wa_I(x)$  at the beginning of each period, which differs between firms. Firms are ranked in order of increasing cost such that  $da_I(x)/dx > 0$  and  $a_I(x)$  is continuous and differentiable. Assume furthermore that  $a_I(x) < M$ , where  $M$  is a finite number; in this way we avoid that the cost of innovation "explodes" for some firms.

<sup>12</sup> 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 firm conducting research in each one.

At the beginning of each period a race takes place in each product line and 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, 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 we take as exogenous both the length of a race and the effort expended by each participant, furthermore we assume that 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  $\Pi_W$  (for winner). The payoff for an individual domestic firm  $x$  from conducting research is

$$P(x) = \frac{\Pi_W}{X + Y} - wa_I(x) \quad (34)$$

For a foreign  $y$  it is<sup>13</sup>

$$P^*(y) = \frac{\Pi_W}{X + Y} - w^*a_I^*(y) \quad (35)$$

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 both the number of domestic firms and of foreign firms as given. For  $a_I(x)$  or  $a_I^*(y)$  very large we may have solutions where  $X$  or  $Y$  equal zero, but we shall concentrate on equilibria where both countries innovate.

For each individual firm innovation along each single product line is stochastic; however, since we are considering R&D that 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  $Y/(X + Y)$ . It is apparent that while the individual probability of winning the innovation race decreases with  $X$  (this is the "common pool" negative externality), the probability

<sup>13</sup> Throughout this paper, asterisks will be used to denote foreign variables.

of innovation occurring domestically, and therefore aggregate domestic innovation, increases with  $X$ .

## 2.2 Preferences

Consumers have the following intertemporal preferences

$$U_t = \sum_{t=0}^{\infty} \beta^t [\log D_t + \log C_t dt] \quad (36)$$

where

$$\log D_t = \int_0^1 \log \left[ \sum_m q_m(j) d_{mt}(j) \right] dj. \quad (37)$$

and

$$\log C_t = \log(X_t) \gamma c_t \quad (38)$$

where  $d_{mt}(j)$  denotes consumption of the high tech good of quality  $m$  in product line  $j$  at time  $t$ . The summation extends over a set of qualities that coincides with 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. We can choose units so that the lowest quality of each product (the one available at time  $t = 0$ ) offers one unit of service, that is  $q_0(j) = 1$ . This implies that  $q_m(j) = \lambda^m$ . Furthermore, since innovation occurs for sure in each period we can rewrite 37 as

$$\log D_t = \int_0^1 \log \left[ \sum_t \lambda^t d_t(j) \right] dj \quad (39)$$

Utility deriving from consumption of the traditional good depends on the amount of innovation in the economy. Local imitation permits consumers to derive more utility not only from higher quality technological goods, but also from traditional goods. In this way domestic innovation causes a positive spillover that doesn't occur when innovation occurs domestically: domestic innovation not only increases the utility associated to the goods that are improved, but permits increased utility from other sectors of the economy.<sup>14</sup>

<sup>14</sup> Alternatively we can model spillovers to consider cumulative effect of innovation:

$$\log C_t = \log \left( \prod_t X_t \right) \gamma c_t$$

Nothing should change given the form of the utility function.

Since the utility function is separable, we can focus on the market for high tech goods only. 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  $\tilde{m}_t(j)$  that carries the lowest price per unit of quality. Defining  $E$  the expenditure on d-goods, the solution of the subutility problem yields the following demand functions

$$d_{mt}(j) = \frac{E(t)}{p_{mt}(j)} \quad \text{for } m = \tilde{m}_t(j). \quad 0 \quad \text{otherwise} \quad (40)$$

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  $d_{mt}^*(j) = E^*(t)/p_{mt}(j)$ .

## 2.3 Production

### 2.3.1 The high tech industry

For simplicity, assume identical production technologies across all product lines  $j$  and all qualities  $q$ . Assuming labor as the only factor of production, we 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  $w$ .

Regarding market structure, assume that all firms engage in Bertrand price competition. We have seen above that a winning firm, as long as it is not imitated, will have 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 (which I will call the "follower" firm). The follower firm charges price  $w$ , the lowest price consistent with nonnegative profits. The highest price the state of the art firm can charge is  $\lambda w$ , in fact at this price consumers are indifferent between the older good at the state of the art good which is more expensive but gives greater services. By charging a price a shade below  $\lambda w$  the state of the art firm can capture all the market: therefore in every period only the state of the art good



is produced and consumed.

$$\Pi_M = \left(1 - \frac{1}{\lambda}\right) (E + E^*) \quad (41)$$

### 2.3.2 The traditional sector

Good  $c_t$  is produced under perfect competition, constant returns to scale and no distortions. The labor requirement in this sector is  $a_c$ . Perfect competition and zero profits will imply

$$w = \frac{1}{a_c} \quad (42)$$

Assuming  $a_c = a_c^*$ , wages will be equalized in the two economies.

## 2.4 Imitation

I define  $\alpha$  the index of IPR protection in the Home market, with  $\alpha$  representing the probability that a firm winning the innovation race actually reap monopolistic profits. I will instead call  $\alpha^*$  the index of IPR protection in the Foreign market.

For simplicity, I will assume only two levels of protection: high protection ( $\alpha_H, \alpha_H^*$ ) and low protection ( $\alpha_L, \alpha_L^*$ ). I will also assume symmetry, i.e.  $\alpha_H = \alpha_H^*$  and  $\alpha_L = \alpha_L^*$ .

The market for imitated goods is assumed to be segmented, i.e. imitated goods cannot be shipped from one market to the other. In this way imitation in each market depends on the existing regime in that market. I will assume furthermore that there is a preference for domestic goods (either a preference on the part of consumers or an institutional bias) such that when imitation of foreign goods occurs the imitator captures the entire domestic market. Instead in the case of imitation of domestic goods it is assumed that monopoly profits are divided equally between domestic innovator and domestic imitator.<sup>15</sup>

Remembering that expenditure at Home is  $E$  and expenditure in Foreign is  $E^*$ , then monopoly profits in

<sup>15</sup> This way of modelling imitation is consistent with what actually happens in the real world: innovators are more protected in their domestic markets from foreign imitation than from domestic imitation. However in foreign markets their level of protection is independent of domestic policy. Alternatively we can assume that also when imitation of foreign goods occurs profits are split between imitator and innovator: this will give more symmetric results but entails accepting the assumption of tacit collusion between innovators and imitators in different countries.

the absence of imitation will be

$$\Pi_M = (1 - \frac{1}{\lambda})(E + E^*) \quad (43)$$

In the case of imitation of a Home discovery, a Home imitator will receive  $(1 - \frac{1}{\lambda})\frac{1}{2}E$  while a Foreign imitator will receive  $(1 - \frac{1}{\lambda})E^*$ . The Home innovator will receive  $(1 - \frac{1}{\lambda})E$  if the imitator is Foreign and  $(1 - \frac{1}{\lambda})(\frac{1}{2}E + E^*)$  if the imitator is domestic. In this way total domestic profits do not change when imitation occurs only domestically, there is simply a redistribution of profits between innovators and imitators. Total domestic profits however are reduced by foreign imitation.

The expected payoff from successful innovation in the Home country is:

$$\begin{aligned} \Pi_W &= (1 - \frac{1}{\lambda}) \left[ \alpha^* E^* + \alpha E + (1 - \alpha) \frac{1}{2} E \right] \\ &= (1 - \frac{1}{\lambda}) \left[ \alpha^* E^* + \frac{1}{2} (1 + \alpha) E \right] \end{aligned} \quad (44)$$

How firms in both countries interact to changes in IPR policy in either market can be derived by applying the implicit function theorem to the zero marginal profit condition  $P(X) = 0$  and  $P(Y) = 0$ . This gives us the following:

- 1)  $dX/d\alpha > 0$ .  $dX/d\alpha^* > 0$ ;
- 2)  $dY/d\alpha^* > 0$ .  $dY/d\alpha > 0$ ;
- 3)  $dX/d\alpha < dY/d\alpha^*$ ;
- 4)  $dY/d\alpha^* < dY/d\alpha$ .<sup>16</sup>

Furthermore, if we assume  $da_I(x)/dx = da_I^*(y)/dy$  we can also assert the following

- 5)  $dX/d\alpha < dY/d\alpha$

<sup>16</sup> Applying the implicit function theorem

$$\frac{dX}{d\alpha} = -\frac{P_\alpha}{P_X}, \quad \frac{dY}{d\alpha^*} = -\frac{P_{\alpha^*}}{P_Y}$$

Therefore

$$\frac{dX}{d\alpha} = \frac{\frac{1}{2} \frac{E}{X+Y}}{\frac{\Pi_W}{(X+Y)^2} + \frac{dK(X)}{dX}}, \quad \frac{dY}{d\alpha^*} = \frac{\frac{1}{2} \frac{E^*}{X+Y}}{\frac{\Pi_W}{(X+Y)^2} + \frac{dK(Y)}{dY}}$$

As for the effect of protection in the other country:

$$\frac{dX}{d\alpha^*} = \frac{\frac{E^*}{X+Y}}{\frac{\Pi_W}{(X+Y)^2} + \frac{dK(X)}{dX}}, \quad \frac{dY}{d\alpha} = \frac{\frac{E}{X+Y}}{\frac{\Pi_W}{(X+Y)^2} + \frac{dK(Y)}{dY}}$$

$$6) dX/d\alpha^* > dY/d\alpha^*$$

## 2.5 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 in three separate stages. In stage one, the governments in both countries simultaneously announce a level of intellectual protection, i.e. a level of  $\alpha$  and  $\alpha^*$ . In stage two, firms in both countries make their investment decisions, i.e. decide whether or not to participate in the innovation race. In stage three, innovation takes place and IPR protection is enforced in both countries.

$S_H$  denotes the sum of "social benefits" from domestic innovation, which is composed of two factors: (1) consumer surplus that derives from the consumption of higher quality goods,  $E \log \lambda$ ; and (2) consumer surplus deriving from increased satisfaction in consumption of traditional goods,  $\gamma \log X$ .  $S_H$  is therefore increasing in  $X$ :  $dS_H/dX > 0$ .  $S_F$  denotes the social benefit from foreign innovation: since I have assumed no spillovers from foreign innovation it will consist solely of consumer surplus tied to the consumption of d-goods:  $E \log \lambda$ .<sup>17</sup>

Social welfare that accrues to the Home country from a domestic discovery,  $W_{HD}$ , is

$$\begin{aligned} W_{HD} &= S_H + \alpha^*(1 - \frac{1}{\lambda})(E + E^*) + (1 - \alpha^*)(1 - \frac{1}{\lambda})E \\ &= S_H + (1 - \frac{1}{\lambda})(E + \alpha^*E^*) \end{aligned} \quad (45)$$

With domestic imitation profits remain within the country, while there is a loss of profits, and therefore of social welfare, when imitators are foreign:  $dW_{HD}/d\alpha = 0$ ,  $dW_{HD}/d\alpha^* > 0$ .

Social welfare that accrues to the Home country from a foreign discovery,  $W_{FD}$ , is

$$W_{FD} = S_F + (1 - \alpha)(1 - \frac{1}{\lambda})E \quad (46)$$

Note that  $dW_{FD}/d\alpha < 0$ , while  $dW_{FD}/d\alpha^* = 0$ .

<sup>17</sup>  $S_H^*$  will be the social benefit to the Foreign country from a Home innovation ( $E^* \log \lambda$ ), and  $S_F^*$  the social benefit to the Foreign country from a domestic (i.e. Foreign) innovation ( $E^* \log \lambda + \gamma \log Y$ ).

Respectively, social welfare in the Foreign country from a Home innovation and from a Foreign one are:

$$W_{HD}^* = S_H^* + (1 - \alpha^*)(1 - \frac{1}{\lambda})E \quad (47)$$

$$\begin{aligned} W_{FD}^* &= S_F^* + \alpha(1 - \frac{1}{\lambda})(E + E^*) + (1 - \alpha)(1 - \frac{1}{\lambda})E^* \\ &= S_F^* + (1 - \frac{1}{\lambda})(E^* + \alpha E) \end{aligned} \quad (48)$$

Total welfare will be given by

$$W_{Tot} = \frac{X}{X+Y}W_{HD} + \frac{Y}{X+Y}W_{FD} - \int_0^X wa_f(x)dx \quad (49)$$

$$W_{Tot}^* = \frac{X}{X+Y}W_{HD}^* + \frac{Y}{X+Y}W_{FD}^* - \int_0^Y w^* a_f^*(x)dy \quad (50)$$

## 2.6 Optimal policy in the one shot patent race

Let us first consider the case in which the R&D race occurs only once in time, and compare the case in which governments can precommit to their IPR regimes versus the case in which they are free to renege (i.e. the commitment equilibrium versus the no commitment equilibrium). In the case in which the Foreign country is committed to a high protection regime and only Home is choosing its level of IPR protection, a policy that maximizes welfare at the beginning of the race is time inconsistent in that the government has an incentive to lower welfare whenever domestic innovation is unsuccessful. This proves to be true also in the case in which both countries choose the level of their IPR protection, however we shall see that the possibility of the other country lowering protection is an ulterior incentive to have lower protection oneself.

Low protection gives higher instantaneous profits, but will also lower the number of domestic firms engaging in research. This lowers the amount of domestic innovation and therefore the associated social benefits. In this case however in choosing the level of IPR protection the government must consider not only how firms will react but also how the other government will react. Once innovation takes place, for each country the best scenario would be one in which the other country protects IPRs strongly, while domestic protection is weak.

We must distinguish between the government's problem *before* and after *discovery*, i.e. in stage one and in stage three. (I will concentrate on the payoffs for the Home country in that those of the Foreign country are symmetric).

Let us assume now that the two trading partners are different in particular in two respects: 1) market sizes  $E \neq E^*$ ; 2) technological ability in innovative activities  $a_I(z) \neq a_I^*(z)$ . What we expect to see is that for a more technologically advanced country high IPR protection may prove to be a dominant strategy regardless of the IPR regime of its trading partner, so outcomes may obtain where one country imposes high protection while the other weak protection.

Different levels of technological development will entail differing amounts of innovation, i.e. the number of innovating firms in the two countries will be different. Let us assume from here on that the Foreign country is the more technologically advanced of the two, i.e.  $a_I(z) > a_I^*(z)$ . This will imply  $X < Y$ . In general it will be true that, in the case of no imitation,

$$W_{Tot} < W_{Tot}^* \quad (51)$$

At the beginning of the race the governments problem is to maximize  $W_{Tot,s1}$ :

$$W_{Tot,s1} = \frac{X(\alpha, \alpha^*)}{X(\alpha, \alpha^*) + Y(\alpha, \alpha^*)} W_{HD}(X(\alpha, \alpha^*)) + \frac{Y(\alpha, \alpha^*)}{X(\alpha, \alpha^*) + Y(\alpha, \alpha^*)} W_{FD}(\alpha, \alpha^*) - \int_0^X wa_I(x) dx \quad (52)$$

where  $dW_{Tot,s1}/d\alpha > 0$  for certain easily satisfied parameter conditions (i.e. that  $K(x)$  not explode).

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

$$W_{Tot,s3} = \frac{X}{X+Y} W_{HD} + \frac{Y}{X+Y} W_{FD} \quad (53)$$

where  $X$  and  $Y$  are fixed.

**Proposition 1:** (*The precommitment optimal IPR policy*) With full commitment, the optimal IPR policy is maximum protection, irrespective of the level of protection in the other country.

This follows directly from  $dW_{Tot,s1}/d\alpha > 0$ . With full commitment, not only does the government not have the option of renegeing and therefore maximizes  $W_{Tot,s1}$ , the solution of which is  $\alpha = \alpha_H$ , but the

solution is completely independent of the level of protection in the other country. In other words, irrespective of the level of IPR protection abroad, with commitment the optimal strategy is always to maximize the level of domestic protection by maximizing IPR protection.

It is interesting to note that with commitment government interaction ex ante is irrelevant. Each country's government will try to maximize domestic innovation irrespective of the other governments action. So there is no strategic interaction of any type.

**Proposition 2:** (*The non commitment IPR policy*) In the absence of a commitment mechanism, maximum protection is not time consistent in either country. The time consistent policy will consist of minimum protection and a socially insufficient number of innovating firms in both countries.

**Proof.** This can be proved by backwards induction. We must first consider how governments interact in stage three, i.e. at the moment of enforcement, and then consider how this affects firms' behavior.

Consider the game that is played between governments once discovery is made. Let  $\alpha_H$  ( $\alpha_H^*$ ) denote the strategy of high IPR protection and let  $\alpha_L$  ( $\alpha_L^*$ ) denote the strategy of low protection. The following are the payoffs, i.e. the levels of social welfare, to the Home country for different combinations of strategies (the payoffs to the Foreign country are defined analogously):

Payoff to Home if both countries enforce low protection:

$$\begin{aligned} W_{Tot.s3}(\alpha_L, \alpha_L^*) &= \frac{X}{X+Y}[S_H + (1 - \frac{1}{\lambda})(E + \alpha_L^* E^*)] + \frac{Y}{X+Y}[S_F + (1 - \frac{1}{\lambda})(1 - \alpha_L)E] \\ &= \frac{X}{X+Y}S_H + \frac{Y}{X+Y}S_F + (1 - \frac{1}{\lambda}) \left[ E + (\frac{X}{X+Y}\alpha_L^* E^* - \frac{Y}{X+Y}\alpha_L E) \right] \end{aligned}$$

Payoff to Home if both countries enforce high protection:

$$\begin{aligned} W_{Tot.s3}(\alpha_H, \alpha_H^*) &= \frac{X}{X+Y}[S_H + (1 - \frac{1}{\lambda})(\alpha^* + 1)E] + \frac{Y}{X+Y}[S_F + (1 - \frac{1}{\lambda})(1 - \alpha)E] \\ &= \frac{X}{X+Y}S_H + \frac{Y}{X+Y}S_F + (1 - \frac{1}{\lambda}) \left[ E + (\frac{X}{X+Y}\alpha_H^* E^* - \frac{Y}{X+Y}\alpha_H E) \right] \end{aligned}$$

Lastly, the payoff to Home if Home imposes low protection while Foreign imposes high protection:

$$W_{Tot.s3}(\alpha_L, \alpha_H^*) = \frac{X}{X+Y}[S_H + (1 - \frac{1}{\lambda})(E + \alpha_H^* E^*)] + \frac{Y}{X+Y}[S_F + (1 - \frac{1}{\lambda})(1 - \alpha_L)E]$$

$$= \frac{X}{X+Y}S_H + \frac{Y}{X+Y}S_F + (1 - \frac{1}{\lambda}) \left[ E + (\frac{X}{X+Y}\alpha_H^*E^* - \frac{Y}{X+Y}\alpha_L E) \right]$$

To get some intuition of what happens when the government is unable to commit to its policy announcement, let us consider the special case of two identical countries:  $E = E^*$ ,  $a_I(z) = a_I^*(z)$ , and  $\alpha_p = \alpha_p^*$ . Let us consider the scenario once innovation has occurred and the government in each country must decide whether to enforce high or low protection. In this case the payoff to Home if both countries enforce low protection is:

$$\begin{aligned} W_{Tot,s3}(\alpha_L, \alpha_L^*) &= \frac{1}{2}[S_H + (1 - \frac{1}{\lambda})(\alpha_L^* + 1)E] + \frac{1}{2}[S_F + (1 - \frac{1}{\lambda})(1 - \alpha_L)E] \\ &= \frac{1}{2}(S_H + S_F) + (1 - \frac{1}{\lambda})E \end{aligned} \quad (54)$$

since  $\alpha_L = \alpha_L^*$ .

Payoff to Home if both countries enforce high protection:

$$\begin{aligned} W_{Tot,s3}(\alpha_H, \alpha_H^*) &= \frac{1}{2}[S_H + (1 - \frac{1}{\lambda})(\alpha_H^* + 1)E] + \frac{1}{2}[S_F + (1 - \frac{1}{\lambda})(1 - \alpha)E] \\ &= \frac{1}{2}(S_H + S_F) + (1 - \frac{1}{\lambda})E \end{aligned} \quad (55)$$

since  $\alpha_H = \alpha_H^*$ .

Lastly, the payoff to Home if Home imposes low protection while Foreign imposes high protection:

$$\begin{aligned} W_{Tot,s3}(\alpha_L, \alpha_H^*) &= \frac{1}{2}[S_H + (1 - \frac{1}{\lambda})(\alpha_H^* + 1)E] + \frac{1}{2}[S_F + (1 - \frac{1}{\lambda})(1 - \alpha_L)E] \\ &= \frac{1}{2} \left[ (S_H + S_F) + (1 - \frac{1}{\lambda})[2 + (\alpha_H^* - \alpha_L)E] \right] \end{aligned} \quad (56)$$

Note that  $W_{Tot,s3}(\alpha_L, \alpha_H^*) > W_{Tot,s3}(\alpha_L, \alpha_L^*) = W_{Tot,s3}(\alpha_H, \alpha_H^*)$ .

It is easy to see that once innovation occurs an equilibrium of high protection in both countries is not possible, notwithstanding that, given that the two countries are identical, low protection merely entails a redistribution of profits between firms leaving total welfare unchanged. High protection is never a best reply because a situation of low protection domestically with high protection abroad is always the best possible outcome for an individual country. ( $W_{Tot,s3}(\alpha_L, \alpha_H^*) > W_{Tot,s3}(\alpha_L, \alpha_L^*) = W_{Tot,s3}(\alpha_H, \alpha_H^*)$ ). So even if maintaining high protection - and therefore respecting the policies announced in the first stage - does not entail lower profits than reneging, it is not an equilibrium. The Nash equilibrium in this stage of the game

will always be that of both countries' governments enforcing low protection.

Let us now return to the more general case. When countries are different the Nash equilibrium in stage three will continue to be low IPR protection in both countries, for it is still true that  $W_{Tot,s3}(\alpha_L, \alpha_H^*) > W_{Tot,s3}(\alpha_L, \alpha_L^*), W_{Tot,s3}(\alpha_L, \alpha_H^*) > W_{Tot,s3}(\alpha_H, \alpha_H^*)$ . The only difference is that low protection is Pareto inferior for the Foreign country, as long as

$$\frac{Y}{X} > \frac{E^*}{E} \quad (57)$$

In stage two firms make their investment decisions, and being rational they know that if the governments cannot precommit to their announced policies in stage three they will impose  $(\alpha_L, \alpha_L^*)$ . Therefore they will take this into account when deciding whether or not to participate in the innovation race, regardless of the announced policy. The equilibrium number of firms participating in the innovation race will be  $X, Y$  with  $X = Y$  that solve

$$P_R(X) = 0. \quad P_R^*(Y) = 0 \quad (58)$$

Given that  $dX/d\alpha > 0$  and  $dY/d\alpha > 0$  this will be the minimum number of innovating firms (we excluded *ex ante* the case of no innovating firms).

In stage one the governments announce their IPR policies. If firms could be "fooled" into believing the governments will maintain their announced IPR regimes, high protection would be announced. But since firms are rational the governments solve the problem:

$$\max \alpha \frac{X_{\min}}{X_{\min} + Y_{\min}} W_{HD}(\alpha, \alpha^*) + \frac{Y_{\min}}{X_{\min} + Y_{\min}} W_{FD}(\alpha, \alpha^*) - \int_0^X wa_I(x) dx$$

The solution is  $\alpha = \alpha_L$ , i.e. the optimal policy is for both governments to announce the policies expected

18

$$W_{Tot,s3}^*(\alpha_H, \alpha_H^*) > W_{Tot,s3}^*(\alpha_L, \alpha_L^*) \quad \text{if} \\ \left( \frac{Y}{X+Y} \alpha_H E - \frac{X}{X+Y} \alpha_H^* E^* \right) > \left( \frac{Y}{X+Y} \alpha_L E - \frac{X}{X+Y} \alpha_L^* E^* \right)$$

Since  $\alpha_H = \alpha_H^*$  and  $\alpha_L = \alpha_L^*$  this will be true if

$$\frac{Y}{X} > \frac{E^*}{E}$$



by the firms. ■

### 2.6.1 Optimal IPR policy in the infinite horizon

Consider now the case where patent races are repeated infinitely through time. We wish to see whether weak protection tends to persist in the long run.

Assume the "game" is played as follows. In stage one both governments decide their policy regimes. If once innovation occurs one or both governments deviate from the announced regime, it (they) suffer a loss of reputation and in the future firms will always expect it (them) to follow the low protection regime. Furthermore, the other government will also react by imposing low protection forever. I assume that reversion to the one-shot game lasts forever. Firms are rational but not strategic, they do not act to punish the government. Governments however are strategic, when deciding whether to honor their announced policy or not they also consider the likely actions of their trading partner's government.

To make notation less cumbersome, from here on I will use the notation  $X_{HH}$  to represent  $X(\alpha_H, \alpha_H^*)$ , i.e. the equilibrium number of innovating firms at Home with protection level  $\alpha_H$  in the Home country and protection level  $\alpha_H^*$  in the Foreign country.

**Proposition 3a:** An outcome of high protection in both countries will be a time consistent equilibrium in the infinite horizon if and only if the following condition holds for both countries:

$$\begin{aligned}
& \frac{1}{1-\beta} \left( \frac{X_{HH}}{X_{HH}+Y_{HH}} W_{HD}(\alpha_H, \alpha_H^*) + \frac{Y_{HH}}{X_{HH}+Y_{HH}} W_{FD}(\alpha_H, \alpha_H^*) \right) \\
> & \frac{X_{HH}}{X_{HH}+Y_{HH}} W_{HD}(\alpha_L, \alpha_H^*) + \frac{Y_{HH}}{X_{HH}+Y_{HH}} W_{FD}(\alpha_L, \alpha_H^*) + \\
& \frac{\beta}{1-\beta} \left\{ \left( \frac{X_{LL}}{X_{LL}+Y_{LL}} W_{HD}(\alpha_L, \alpha_L^*) + \frac{Y_{LL}}{X_{LL}+Y_{LL}} W_{FD}(\alpha_L, \alpha_L^*) \right) + \right. \\
& \left. + \int_{X(\alpha_L)}^{X(\alpha_H)} wa_I(x) dx \right\}
\end{aligned} \tag{59}$$

This is equivalent to

$$\begin{aligned}
& \frac{\beta}{1-\beta} \left( \frac{X_{HH}}{X_{HH} + Y_{HH}} S_H(X_H) - \frac{X_{LL}}{X_{LL} + Y_{LL}} S_H(X_L) \right) + \\
& \left( \frac{X_{HH}}{X_{HH} + Y_{HH}} \alpha_H^* - \frac{X_{LL}}{X_{LL} + Y_{LL}} \alpha_L^* \right) E^* \\
> & \frac{Y_{HH}}{X_{HH} + Y_{HH}} (\alpha_H - \alpha_L) E + \\
& \frac{\beta}{1-\beta} \left\{ \left( \frac{Y_{HH}}{X_{HH} + Y_{HH}} \alpha_H - \frac{Y_{LL}}{X_{LL} + Y_{LL}} \alpha_L \right) E \right. \\
& \left. + \frac{\lambda}{\lambda-1} \int_{X(\alpha_L)}^{X(\alpha_H)} w a_I(x) dx \right\}
\end{aligned} \tag{60}$$

and the same hold true symmetrically for the Foreign country. Equation 60 says that high protection is a time consistent policy only if the benefit of maintaining high protection (right hand side) is greater than the "temptation" of deviating and imposing low protection (first term on the left hand side) plus the punishment for deviating, given that if the country reverts to low protection so will its trading partner.<sup>19</sup>

This appears more complicated than it is, in that it takes into account the change in the worldwide distribution of innovations that comes about when protection changes. We must take into account that when protection *decreases* not only does aggregate innovation decrease, but innovation shifts towards the country doing *more* innovation, i.e. when  $X < Y$ <sup>20</sup>

$$\begin{aligned}
\frac{d \frac{X}{X+Y}}{d\alpha} &> 0, & \frac{d \frac{X}{X+Y}}{d\alpha^*} &> 0 \\
\frac{d \frac{Y}{X+Y}}{d\alpha} &< 0, & \frac{d \frac{Y}{X+Y}}{d\alpha^*} &< 0
\end{aligned}$$

So it appears that this scenario will be most probable when: 1) local market is small (E small); 2) technological gap with trading partner not too large (X and Y not too different); 3) spillover effect large; 4) X very sensitive to changes in  $\alpha$ .

<sup>19</sup> Notice that it is not necessary to compare the equilibrium of high protection in both countries to the case in which one country maintains high protection while the other switches to low: if high protection is preferable to a scenario where both countries maintain low protection it certainly is preferable to the case in which the other country alone reneges and adopts low protection.

<sup>20</sup>

$$\frac{d \frac{X}{X+Y}}{d\alpha} = \frac{\frac{dX}{d\alpha} Y - \frac{dY}{d\alpha} X}{(X+Y)^2}$$

This will be greater than zero as long as  $\frac{dX}{d\alpha} - \frac{dY}{d\alpha} < Y - X$ , which is not an extreme assumption, in particular in that  $\frac{dX}{d\alpha} < \frac{dY}{d\alpha}$  depends in part on the assumptions regarding imitation, more general assumption (i.e. the monopolist not suffering an entire loss of its foreign market in the face of foreign imitation) would easily give the above assertion.

We have assumed up to now that if a country reneges and lowers protection its trading partner punishes it by doing the same. This outcome may actually not be renegotiation-proof, it may be in the best interest of the second country to maintain high protection regardless. This increases the temptation for the first country, in that "punishment" will be lower: it will only derive from the changed behavior of the domestic firms. Maintaining high protection becomes however more difficult for the second country, in that the benefits of higher domestic innovation are weakened by the reduced profits due to foreign imitation.

**Proposition 3b:** For a single country to maintain high protection over time, regardless of the behavior of its trading partner, the following must hold:

$$\begin{aligned}
& \frac{\beta}{1-\beta} \left\{ \left( \frac{X_{HL}}{X_{HL} + Y_{HL}} S_H(X_H) - \frac{X_{LL}}{X_{LL} + Y_{LL}} S_H(X_L) \right) + \right. \\
& \left. \left( \frac{X_{HL}}{X_{HL} + Y_{HL}} - \frac{X_{LL}}{X_{LL} + Y_{LL}} \right) \alpha_L^* E^* \right\} + \\
> & \frac{Y_{HL}}{X_{HL} + Y_{HL}} (\alpha_H - \alpha_L) E + \\
& \frac{\beta}{1-\beta} \left\{ \left( \frac{Y_{HL}}{X_{HL} + Y_{HL}} \alpha_H - \frac{Y_{LL}}{X_{LL} + Y_{LL}} \alpha_L \right) E + \right. \\
& \left. + \frac{\lambda}{\lambda-1} \int_{X(\alpha_L)}^{X(\alpha_H)} w_{a_I}(x) dx \right\}
\end{aligned} \tag{61}$$

In other words high protection must be a weakly dominant strategy.

## 2.7 Comparison to equilibrium in one country model

How do these conditions compare to the case in which country choosing its level of IPR protection interacts with a trading partner already committed to a strong IPR regime? To answer this question, let us rewrite the necessary conditions in this second case in such a way that in comparable to propositions 3a and 3b.

In the one country case, high protection is a time consistent policy if and only if

$$\frac{\beta}{1-\beta} \left[ \frac{X_H}{X_H + Y_H} W_{HD}(X_H) - \frac{X_L}{X_L + Y_L} W_{HD}(X_L) \right] \tag{62}$$

$$\begin{aligned}
&> \frac{Y_H}{X_H + Y_H} (W_{FD}(\alpha_L) - W_{FD}(\alpha_H)) + \\
&\quad + \frac{\beta}{1 - \beta} \left\{ \left[ \frac{Y_L}{X_L + Y_L} W_{FD}(\alpha_L) - \frac{Y_H}{X_H + Y_H} W_{FD}(\alpha_H) \right] \right. \\
&\quad \left. + \int_{X(\alpha_L)}^{X(\alpha_H)} wa_I(x) dx \right\}
\end{aligned}$$

We can rewrite this as

$$\begin{aligned}
&\frac{\beta}{1 - \beta} \left\{ \left[ \frac{X_H}{X_H + Y_H} S_H(X_H) - \frac{X_L}{X_L + Y_L} S_H(X_L) \right] + \right. \tag{63} \\
&\quad \left. \left( \frac{X_H}{X_H + Y_H} - \frac{X_L}{X_L + Y_L} \right) \left( 1 - \frac{1}{\lambda} \right) (E + E^*) \right\} \\
&> \frac{Y_H}{X_H + Y_H} (\alpha_H - \alpha_L) \left( 1 - \frac{1}{\lambda} \right) E + \\
&\quad + \frac{\beta}{1 - \beta} \left\{ \left( \frac{Y_L}{X_L + Y_L} \alpha_H - \frac{Y_H}{X_H + Y_H} \alpha_L \right) \left( 1 - \frac{1}{\lambda} \right) E \right. \\
&\quad \left. + \int_{X(\alpha_L)}^{X(\alpha_H)} wa_I(x) dx \right\}
\end{aligned}$$

We see that Proposition 3a represents a more stringent condition for a high IPR protection equilibrium in as it must hold for *both* countries *simultaneously*. It appears that in the two country case "punishment" is weaker, this is because the payoff in the case of domestic innovation, which is what induces a country to innovate and therefore the government to maintain protection, depends in part on protection in the other country, which is outside of the control of the domestic government. However even though the incentives to maintain protection are stronger, they work only if *both* countries can be induced to maintain protection. If one of the two countries is sufficiently technologically backwards to prefer low protection, the more technological country will have a more difficult time maintaining strong protection.

Consider instead Proposition 3b. This is clearly a stronger condition, in that the left hand side of 61 is smaller than the left hand side of 63. It will be necessary that the payoff from domestic innovation, in particular the spillover effect (first term on the right hand side) be particularly large for the condition to hold.

### 3 Extension: N countries

The two country analysis is easily extended to the case of n countries that must all choose their level of IPR protection. Assume that the n countries are ordered in terms of increasing cost of participating in the innovation race. Denote  $K_i(z) = w_i a_{Fi}(z)$  the cost of participating in the innovation race for country  $i \in [0, n]$ , then  $K_1(z) > K_2(z) > \dots > K_n(z)$ . This will imply  $X_1 < X_2 < \dots < X_N$ . We can interpret this ordering as an ordering in terms of increasing level of technological sophistication.

We need to introduce some more notation. Let  $\alpha_i$  be the level of IPR protection in country  $i$ , which can be either  $\alpha_{iH}$  or  $\alpha_{iL}$ . Let  $X_i(\alpha_{iH}, \alpha_{-iL})$  be the number of Home innovating firms in country  $i$  when IPR protection is high domestically but is low in all other countries, i.e.  $\forall X_j \quad j \neq i$ . Let  $\alpha$  be the vector of IPR protection in all countries, such that  $\alpha_H$  represents high protection in all countries.

Let us consider again possible equilibria in the repeated game.

**Proposition 4:** An outcome of high protection in all countries is a time consistent equilibrium if and only if the following conditions hold for all countries.

$$\begin{aligned}
 & \frac{1}{1-\beta} \left( \frac{X_j(\alpha_H)}{\sum_i X_i(\alpha_H)} W_{HD}(\alpha_H) + \frac{\sum_{i \neq j} X_i(\alpha_H)}{\sum_i X_i(\alpha_H)} W_{FD}(\alpha_H) \right) \\
 & > \frac{X_j(\alpha_H)}{\sum_i X_i(\alpha_H)} W_{HD}(\alpha_L, \alpha_{-jH}) + \frac{\sum_{i \neq j} X_i(\alpha_H)}{\sum_i X_i(\alpha_H)} W_{FD}(\alpha_L, \alpha_{-jH}) + \\
 & \frac{\beta}{1-\beta} \left\{ \left( \frac{X_j(\alpha_L)}{\sum_i X_i(\alpha_L)} W_{HD}(\alpha_L) + \frac{\sum_{i \neq j} X_i(\alpha_L)}{\sum_i X_i(\alpha_L)} W_{FD}(\alpha_L) \right) + \right. \\
 & \left. + \int_{X(\alpha_L)}^{X(\alpha_H)} K(x) dx \right\}
 \end{aligned} \tag{64}$$

which we can rewrite as

$$\begin{aligned}
 & \frac{\beta}{1-\beta} \left\{ \left[ \frac{X_j(\alpha_H)}{\sum_i X_i(\alpha_H)} S_H(X_H) - \frac{X_j(\alpha_L)}{\sum_i X_i(\alpha_L)} S_H(X_L) \right] + \right. \\
 & \left. \left( \frac{X_j(\alpha_H)}{\sum_i X_i(\alpha_H)} \alpha_H - \frac{X_j(\alpha_L)}{\sum_i X_i(\alpha_L)} \alpha_L \right) \left( 1 - \frac{1}{\lambda} \right) \sum_{i \neq j} E_i \right\}
 \end{aligned} \tag{65}$$

$$\begin{aligned}
&> \frac{\sum_{i \neq j} X_i(\alpha_H)}{\sum_i X_i(\alpha_H)} (\alpha_H - \alpha_L) \left(1 - \frac{1}{\lambda}\right) E_j + \\
&\quad + \frac{\beta}{1 - \beta} \left\{ \left( \frac{\sum_{i \neq j} X_i(\alpha_H)}{\sum_i X_i(\alpha_H)} \alpha_H - \frac{\sum_{i \neq j} X_i(\alpha_L)}{\sum_i X_i(\alpha_L)} \alpha_L \right) \left(1 - \frac{1}{\lambda}\right) E \right. \\
&\quad \left. + \int_{X(\alpha_L)}^{X(\alpha_H)} K(x) dx \right\}
\end{aligned}$$

For such a condition to hold it will be necessary that for *all* countries the following conditions hold: 1) spillovers large and very reactive to X; 2) market size not too different between countries; 3) technological level of countries not too different (i.e. X not too different between countries).

A more likely equilibrium will be one in which some countries choose to maintain high IPR protection while others not. In other words, for some countries, notably the more technologically advanced ones, reputational considerations will be sufficient to maintain high protection, even without commitment and even when some trading partners opt for low protection. For others, reputational considerations without some sort of commitment or punishment mechanism will not be sufficient, and a regime of low protection will ensue.

Since countries are ordered in terms of increasing level of technological sophistication, we define the marginal country  $m$  such that all countries  $j \in [1, m)$  opt for low protection while all countries  $j \in [m, n)$  choose to maintain high protection. If  $\alpha$  is the vector of protection in the world,  $(\alpha_{1L}, \dots, \alpha_{(m-1)L}, \alpha_{mH}, \dots, \alpha_{nH})$  represents low protection in countries  $j \in [1, m)$  and high protection in countries  $j \in [m, n)$ . To reduce notation, I denote this as  $\alpha_m$ . I will denote  $\alpha_{-m}$  the vector of protection in all countries except the  $m$ -th and  $E_{-j}$  the vector of expenditure in all countries except  $j$ .

**Proposition 5:** An outcome of low protection in countries  $j \in [1, m)$  and of high protection in countries  $j \in [m, n)$  will be time consistent if for countries  $j \in [m, n)$  the following holds:

$$\begin{aligned}
&\frac{\beta}{1 - \beta} \left\{ \left[ \frac{X_j(\alpha_m)}{\sum_i X_i(\alpha_m)} S_H(X_H) - \frac{X_j(\alpha_{jL}, \alpha_{-m})}{\sum_i X_i(\alpha_{jL}, \alpha_{-m})} S_H(X_L) \right] + \right. \\
&\quad \left. \left( \frac{X_j(\alpha_m)}{\sum_i X_i(\alpha_m)} - \frac{X_j(\alpha_{jL}, \alpha_{-m})}{\sum_i X_i(\alpha_{jL}, \alpha_{-m})} \right) \left(1 - \frac{1}{\lambda}\right) \alpha_{-m} E_{-j} \right\} \\
&> \frac{\sum_{i \neq j} X_i(\alpha_m)}{\sum_i X_i(\alpha_m)} (\alpha_{jH} - \alpha_{jL}) \left(1 - \frac{1}{\lambda}\right) E_j +
\end{aligned} \tag{66}$$

$$\begin{aligned}
& + \frac{\beta}{1-\beta} \left\{ \left( \frac{\sum_{i \neq j} X_i(\alpha_m)}{\sum_i X_i(\alpha_m)} \alpha_{jH} - \frac{\sum_{i \neq j} X_i(\alpha_{jL}, \alpha_{-m})}{\sum_i X_i(\alpha_{jL}, \alpha_{-m})} \alpha_{jL} \right) \left(1 - \frac{1}{\lambda}\right) E_j \right. \\
& \left. + \int_{X(\alpha_L)}^{X(\alpha_H)} K(x) dx \right\}
\end{aligned}$$

while the inverse inequality hold for all countries  $j \in \{1, m\}$ .

We assume that all countries choose their level of protection simultaneously and that there is perfect information: all countries know the incentive compatibility constraints of their trade partners. If we were to assume that the number of countries were a continuous variable  $m$  would be determined by an equality in expression 66. If we instead consider a discrete number of countries  $m$  will be determined as the smallest  $j$  for which the inequality holds.

The result we obtain is equivalent to saying that there is a certain technological threshold below which a country is not able to sustain high IPR protection without some sort of commitment mechanism. notwithstanding it would be in its best interest to do so. Countries therefore divide into two groups: a high protection "club", and a low protection "club".

Given this division between high protection countries and low protection countries, what role can an international organization such as the WTO play? Assume that joining WTO entails a commitment to high protection, any defection being cause for sanction from other members.

Let us consider first the case in which countries  $j \in \{m, n\}$  adhere to WTO and commit to high protection. This will not change the international equilibrium, in that it will not change the behavior of the  $j \in \{1, m\}$  countries that have opted for low protection. These in fact already are reacting to the fact that they expect countries  $j \in \{m, n\}$  to maintain high protection in that this is their best response to the actions of the other countries. Commitment therefore will not make a difference.

For a change in the international equilibrium to occur, in particular for high IPR protection to be extended to a larger number of countries, at least some of the countries in the range  $\{1, m\}$  must be induced to join WTO. Here two observations can be made. Firstly, the countries that appear most easily induced to join WTO are the "marginal" ones, i.e. the ones closest to but less than  $m$ .

Secondly, an interesting implication of this model is that if some of the least technological countries can be induced to join the IPR club and commit to high protection, this will cause a increase in protection *even among those countries still not committed to a high protection regime*. In fact for the marginal countries the costs and benefits of high versus low protection are not very different (i.e. the right and left hand side of 66 are not very different), and therefore a change in the number of countries opting for high protection can invert the direction of the inequality in 66, inducing high protection. Therefore while it may be most difficult to induce the least technological countries to join the IPR club, it may be most beneficial to do so from the point of view of global extension of intellectual property rights protection in that it implies higher protection also in countries that have not committed. Commitment by marginal countries will instead only involve the committed countries.

## **4 Concluding Remarks**

In this paper I use a model of intertemporal patent races to examine how internal incentives and international commercial relationships interact in determining the level of intellectual property rights protection in the economy. I consider the case of two countries both sufficiently technologically advanced to engage in innovative activities, although at different levels of development.

I find that it is much more difficult to maintain high protection when one's trading partner is not committed to a high level of protection. A country for which reputational considerations might be sufficient to maintain high IPR protection when trading with a partner committed to high protection, might instead opt for low protection when trading with a partner who instead has no commitment mechanism. A high protection equilibrium will be the more difficult to obtain the more different the two countries are. This appears to be an argument in favor of international agreements such as those developed under the framework of GATT.

In extending the model to take into account a world made up of many countries, I find that it is increasingly difficult to obtain a high IPR protection equilibrium. A more likely result is that the world divide into two



clubs: a high protection club and a low protection club. An international agreement of commitment to high protection will have no effect if adhered to only by countries already in the high protection club. The best way to extend protection at an international level is to induce the least technological countries to adhere to the commitment mechanism.

## **Chapter 4**

# **Comparative Advantage, Innovation and Intellectual Property Rights Protection**

### **1 Introduction**

Intellectual property rights (IPRs) play an important role in international trade. Many governments, especially those of developed countries, contend that weak or nonexistent IPRs distort trading patterns and reduce technology transfer, thereby lowering welfare and growth. Moreover, incentives for Research and Development decrease, further diminishing growth. Others contend that IPRs create monopoly power and keep less developed economies from becoming competitive in more advanced industries, therefore hindering their growth and development.

One way IPRs distort trade is through their affect on foreign direct investment. Multinationals can be an important means of transferring technology to developing countries, however weak IPRs reduce the incentives for foreign firms to invest locally due to reduced expected profitability.

Nonetheless, different industries react differently to IPR protection, in part because R&D does not have the same weight in all industries. For example, given a certain level of IPR protection in a foreign market, some industries might choose not to enter, while others will. Furthermore, even if IPR legislation is the same for all industries it is possible for it to be enforced differently across industries. Therefore, for some industries a certain country might be labeled "bad" from an IPR point of view, while for others it would not.

Consider for example the case of two multinationals operating in a foreign market, one a chemical firm and the other a machinery producer. For the first R&D costs are very high and imitation is relatively easy,

making IPR protection an important issue. For the latter, on the other hand, patent protection is less of an issue because R&D expenses are lower and imitation more difficult, in fact for competitors to make effective use of the firm's technology they also need access to many expensive and complex complementary inputs. Furthermore, since rents in the chemicals industry tend to be high, there is a higher incentive for local firms to be aggressive in exploiting weak laws and enforcement. It therefore follows that the chemical firm's reaction to a country's level of patent protection be very different from that of the machinery producer's.

Most of the literature on FDI and imitation, and on innovation and imitation in general in an international environment, tend to be conducted in a North-South framework, i.e. a world where all innovative activities are concentrated in industrialized countries and less developed countries are capable only of imitation. In reality weak IPR protection is an issue in many countries where innovation is taking place at an increasing pace. In a country without innovative capabilities imitation can serve only to create a short term comparative advantage in production. It has been argued that imitation may also be a means of speeding up the creation of a comparative advantage in R&D.

Consider two countries, both engaging in the activities of production and R&D. For the country with a comparative disadvantage in research, there exists the following trade-off. Imperfect intellectual property protection reduces the amount of technology transferred from more advanced countries, which has a negative effect on utility and growth. On the other hand, the possibility of imitation permits the country to better exploit what technology does enter the country, increasing the efficiency of research. What we want to see is whether for some countries some extent of imperfect intellectual property protection can be beneficial. This is most interesting not in a North - South framework, but when we consider two countries that are not too different from each other. In this case a certain comparative advantage might be the effect of a fortuitous event: some initial conditions and successive learning by doing. Imitation can therefore be considered a form of strategic trade policy.

The literature on innovation and imitation in an international setting tends to focus on the case of perfect patent protection versus the case of nonexistent patent protection. Furthermore, most studies are carried out

in the context of a North-South setting, where only one country innovates. In this case imitation only affects production, with no long term effects on comparative advantage. To study the effect of imperfect patent protection in a technologically more backward country that however has the capability of innovating, I start by presenting the continuum of goods, Grossman and Helpman style model of Taylor (1993). The continuum of goods serves to capture the idea that different industries react differently to changes in IPR protection. I then introduce an imperfect level of intellectual property protection, and an imitation process which permits the laggard country to "catch up" in research through imitation.

"Imitation" and "patent protection" are defined very restrictively. Firstly, intellectual property rights protection is asymmetric: domestic firms are always completely protected, foreign firms aren't. Secondly, imitation cannot take place in industries where goods are imported, but only in industries where the production actually takes place in the country in question (for example in the case of multinationals). Furthermore we are more interested in imitation increasing efficiency of research than efficiency in production, since it is the first that will have effects on the country's long run comparative advantage.

We see the following results. With imperfect protection, technology transfer will be less than in the case of perfect protection. Furthermore there will be a reduction in production efficiency, as firms that would have operated as multinationals under perfect protection prefer to produce in less efficient, but more protected, locations. The effect on research will depend on the imitation process (i.e. on how much imitation actually lowers the cost of innovation), and on the extent of patent protection. If protection is imperfect, but not too weak, it may increase the range of industries for which research takes place in the laggard country. However if protection is too weak no multinationals will operate, and no imitation will be possible: the only effect will be a decrease in utility due to less innovation taking place in the industries targeted for imitation because expected profits will be lower.

## 2 The Model

The basic model is that of Taylor (1994), I will therefore closely follow his presentation. There is one factor of production, labor, in fixed and inelastic supply. Consumers are endowed with labor and share an identical, time separable and homothetic utility function defined over a continuum of final goods  $z$ .

$$U = E_0 \left[ \int_0^{\infty} e^{-\rho t} \ln u(t) dt \right] \quad (67)$$

where

$$\ln u(t) = \int_0^1 b(z) \ln[x(z, t)] dz \quad (68)$$

$\rho$  is the rate of time preference, and  $b(z)$  is the budget share of each good. Assume  $b(z)$  satisfies

$$dB(z) = b(z)dz, \quad 1 = \int_0^1 b(z)dz, \quad B(1) = 1, \quad B(0) = 0. \quad (69)$$

Consumers must choose both their pattern of spending in every period  $E(t)$  and their level of consumption of each good  $x(z, t)$ . Consumers maximize per-period utility subject to the given level of expenditures  $E(t)$ . The solution to this problem gives us that the quantity consumed of each good in time  $t$  is

$$x(z, t) = b(z)E(t)/p(z, t) \quad z \in [0, 1] \quad (70)$$

Spending per period  $E(t)$  is chosen by optimizing subject to an intertemporal budget constraint. We implicitly assume the existence of a market for consumption loans. Furthermore, consumers can smooth consumption by investing in securities offered by firms that do research. These securities are risky but the risk is idiosyncratic, so consumers can construct a risk-free portfolio by investing in all of the firms. The intertemporal budget constraint takes the form

$$dA(t)/dt = r(t)A(t) + w(t)L - E(t) \quad (71)$$

where  $r(t)$  is the risk-free return. Substituting the demand functions into the consumers' utility function and

solving the control problem for  $E(t)$  gives

$$[dE(t)/dt]/E(t) \equiv \hat{E} = r(t) - \rho \quad (72)$$

## 2.1 Production

Firms have two activities, production and research (R&D). Each good is produced only by labor  $L$ , and the unit labor requirement  $a(j, z)$  reflects technology in the industry.

$$a(j, z) = a(z)\varphi(j, z) \quad (73)$$

$\varphi(z, j)$  captures the impact of future innovation, through the innovative step  $n(z)$ , which we assume continuous in  $z$  and constant over time. (Later we can assume for simplicity that  $n(z) = \nu$ . i.e. that the innovative step is the same for all industries.) So technological progress occurs through reductions in labor requirements.

$$\varphi(j + 1, z) = [1 - n(z)]\varphi(j, z) \quad (74)$$

When an innovator successfully discovers the next generation technology for some industry  $z$  he obtains exclusive control over it (unless imitation takes place) and contributes to the level of common "know how" in the industry. Knowledge spillovers are industry specific: new technologies introduced in industry  $z$  are useful only in that industry.

Firms select from the set  $z$  of industries a portfolio of research projects to undertake. Competition will be Bertrand: at any time  $t$  a new innovator with state of the art technology  $j$  can at most charge the price charged by firms using the earlier generation of technology (or  $\varepsilon$  more). So the expected profit margins for firms that employ older technology and for state of the art firms is

$$\begin{aligned} \pi^e(j - 1, z) &= 0 \\ \pi^e(j, z) &= wa(z)\varphi(0, z)n(z)[1 - n(z)]^{j-1}, \quad j \geq 1. \end{aligned} \quad (75)$$

Aggregate profits for the state of the art firm will be

$$\Pi(j, z, t) = \pi^e(j, z)x(z, t) = n(z)b(z)E(t) \quad (76)$$

## 2.2 Innovation

The innovation technology is Poisson with an arrival rate that varies proportionally with R&D expenditures. One unit of research at intensity  $i$  at time  $t$  requires  $a_I(z, t)$  units of labor. The level of R&D effort chosen in industry  $z$  is denoted by  $i(z)$ . If industry innovators undertake level  $i$  of research in industry  $z$  at time  $t$ , then the instantaneous probability of success will be  $i(z)dt$ . Free entry into research requires that expected benefits equal costs, i.e.  $V(z) = wa_I(z)$  when  $i(z) > 0$ .

To fund investments in R&D, firms sell shares to consumers. No arbitrage relates equity capital to the interest rate on a risk free bond. Shares from successful ventures pay dividends at rate  $\Pi(z)dt$ . earn capital gains at rate  $[[dV(z)/dt]/V(z)]dt$  and suffer a capital loss of  $wa_I(z)$  with probability  $i(z)$ . Therefore the expected rate of return on shares of firms in industry  $z$  is

$$r(z, t) = [\Pi(z) + dV(z)/dt - wa_I(z)i(z)]/V(z) \quad (77)$$

To relate this to the consumer's problem, note that

$$A(t) = \int_0^1 V(z, t)dz.$$

Since each project's risk is idiosyncratic, the expected rate of return  $r(z,t)$  must equal the risk free rate  $r(t)$ . If  $a_I(z)$  remains constant over time,  $dV(z)/dt = 0$ .

$$r(t) = r(z, t) = n(z)b(z)E(t)/wa_I(z, t) - i(z) \quad (78)$$

Combining this with the consumer's equilibrium condition we get:

$$\hat{E} = \frac{n(z)b(z)E(t)}{wa_I(z,t)} - i(z,t) - \rho \quad (79)$$

This ensures that the consumer and the capital market equilibrium conditions are met. To close the model the labor market must also clear.

$$L = \int_0^1 b(z)[1 - n(z)]E(t)dz + \int_0^1 a_I(z,t)i(z,t)dz \quad (80)$$

### 3 International Trade

Consider now a two country world where financial capital is internationally mobile and R&D can be undertaken in either country. The  $z$  industries are labelled in order of declining home country comparative advantage in goods production. We can therefore construct the schedules of relative labor productivities in goods and R&D production at time  $t$ :

$$A(z,t) = a^*(z)\varphi(t,z)/a(z)\varphi(t,z), \quad z \in [0,1] \quad (81)$$

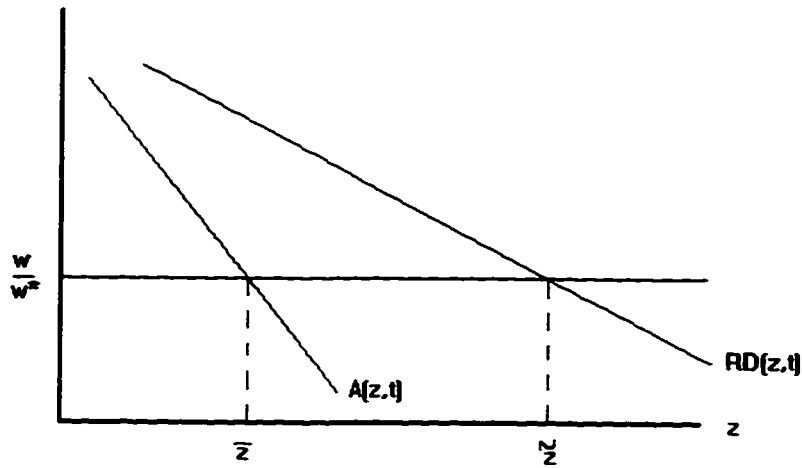
$$RD(z,t) = a_I^*(z,t)/a_I(z,t), \quad z \in [0,1] \quad (82)$$

where  $A(z)$  and  $RD(z)$  are continuous in  $z$  by assumption.  $A(z)$  is declining in  $z$  by construction.

I furthermore make the necessary assumptions on  $RD(z)$  such that it never crosses  $A(z)$ : (1)  $RD(z)$  is monotonic in  $z$ ; (2)  $RD(z)$  is falling in  $z$ ; and (3)  $A(z') < RD(z')$  for all  $z' \in [0,1]$ , i.e. the  $RD(z)$  schedule lies to the right of the  $A(z)$  schedule. This implies that the Home country has a comparative advantage in research, while the Foreign country has a comparative advantage in goods production.

Define  $\omega = w/w^*$ . For any given  $\omega$ , the  $A(z)$  schedule defines the competitive margin in goods production while the  $RD(z)$  schedule defines the competitive margin in R&D production. The competitive margin in production and in research,  $\bar{z}$  and  $\bar{z}$  respectively, are given by





1.

$$\omega = A(\bar{z}) \quad (83)$$

$$\omega = RD(\tilde{z}) \quad (84)$$

So  $\bar{z}$  is defined by  $\omega = A(\bar{z})$  and  $\tilde{z}$  is defined by  $\omega = RD(\tilde{z})$ . Therefore any  $\omega$  divides the world's available technologies into two sets: the set of *front line technologies* and the set of *backwards technologies*.

Given the above assumptions, Home produces all goods such that  $z \in [0, \bar{z}]$  but conducts research on all goods  $z \in [0, \tilde{z}]$ . Foreign instead conducts research on goods  $z \in [\tilde{z}, 1]$  but produce goods  $z \in [\bar{z}, 1]$ . In the presence of perfect patent protection, goods  $z \in [\tilde{z}, \bar{z}]$  will be researched at Home but produced in Foreign, in other words the Home firms will go multinational. (There will be technology transfer from Home to Foreign.) Profits from industries in  $z \in [\tilde{z}, \bar{z}]$  will go to the Home country as royalty payments. (See figure 3.1.)

To close the model, we need to ensure that the balance of payments is maintained. The countries' net foreign asset position isn't changing, so we can limit ourselves to looking at the current account balance.

$$\left[ \int_0^{\bar{z}} b(z)E^*(t)dz - \int_{\bar{z}}^1 b(z)E(t)dz \right] + \left[ \lambda r(t)w^* A_I^* - (1 - \lambda)r(t)A_I + \int_{\bar{z}}^{\bar{z}} n(z)b(z)[E + E^*]dz \right] = 0 \quad (85)$$

where

$$A_I = \int_0^{\bar{z}} a_I(z, t), \quad A_I^* = \int_{\bar{z}}^1 a_I^*(z, t) \quad (86)$$

and  $\lambda$  is the home consumers' share of world assets. As stated above, capital is internationally mobile, so consumers can invest in either country, however research will only take place where it is more efficient. In fact the potential flow of profits is the same for innovators in both countries but the costs of research are lower in the country with the corresponding front line research technology. So only the innovators in the lower cost country will be able to raise the necessary funds for innovation. Taking into account that  $r(t)=r^*(t)$  because capital is internationally mobile and that consumers' equilibrium condition implies  $\hat{E}=\hat{r}-\rho$  and  $\hat{E}^*=\hat{r}-\rho$ , so from

79

$$i(z) = n(z)b(z)[E + E^*]/a_I(z) - r, \quad z \in [0, \bar{z}] \quad (87)$$

$$i^*(z) = n(z)b(z)[E + E^*]/w^*a_I^*(z) - r, \quad z \in [\bar{z}, 1] \quad (88)$$

The first expression in brackets is the Home trade balance in goods, the first term being Foreign import payments to Home and the second being Home import payments to Foreign. The second expression represents Home's balance in services: the first term is payments from investments in the Foreign country, the second payments to Foreign investments at Home, and the third term represents royalty payments. Rearranging and substituting we obtain:

$$\omega = \frac{[[L^* + \rho A_T^*][B(\bar{z}) + \int_{\bar{z}}^{\bar{z}} n(z)b(z)dz]]}{[[L + \rho A_T][1 - B(\bar{z}) - \int_{\bar{z}}^{\bar{z}} n(z)b(z)dz]]} \equiv SS(z) \quad (89)$$

At time zero the solution to the system of equations 83, 84, 89 gives  $\omega$ ,  $\bar{z}$  and  $\bar{z}$ .

When innovation takes place incentives lead them to be implemented on the frontline technologies, so innovation lowers all  $a(z_j)$  for  $z < \bar{z}$  and lowers  $a^*(z_j)$  for all  $z > \bar{z}$ . This eventually deforms the  $A(z)$  schedule, but  $\omega$ ,  $\bar{z}$  and  $\bar{z}$  will remain constant over time: comparative advantage will not change but only sharpen. The time path for technological progress in a given industry is lumpy and stochastic, but the process of technological advance at the aggregate level is smooth and non random.

### 3.1 The role of patent protection

Suppose that at some time  $t > 0$  a new technology is discovered by a Home firm, making it the state of the art firm of the industry.

With *perfect* patent protection the only risk that state of the art Home firms face from entering the Foreign market is that a new innovation displace them, but this same risk exists at Home. If there is *no* patent protection for non national firms *no* technology transfer will take place, i.e. there will be no multinationals at all. In fact in this case state of the art Home firms will always prefer to remain at Home and apply their innovation to a less efficient technology than go multinational and lose their monopoly profits for sure. Finally if patent protection exists in the Foreign country but is *imperfect*, then some Home industries will choose to enter the Foreign markets as multinationals, while others will prefer to produce at Home at higher costs and export.<sup>21</sup>

Imperfect IPR protection means that there exists a certain instantaneous probability  $p dt$  of imitation taking place, i.e. of a local firm increasing its efficiency in research through contact with state of the art Home firm operating in Foreign territory. I assume imitation can only take place when foreign goods are actually produced

<sup>21</sup> We are ignoring the possibility of Home firms entering the Foreign market by licensing their new technology to Foreign firms, but we can include this case in the exporting case, because the choice for the Home firm is basically between that of assuming risk or not and licensing can be considered a risk free investment.

in the domestic market, and not for goods that are imported. So imitation will be possible only for industries  $z \in [\bar{z}, \bar{z}]$ . Imitation is completely costless. Furthermore, since competition is Bertrand, we must assume that Foreign has some "local advantage" so that when imitation occurs its costs are lower than those of Home firms - otherwise there is non incentive to imitate. For simplicity, we assume that patent protection is asymmetric: Foreign firms are completely protected, Home firms are not.

Consider now the options available for a state of the art firm in Home for industries  $z \in [\bar{z}, \bar{z}]$ . If they choose to produce at Home their profit margin will be:

$$\pi(j, z) = \{w^* a^*(z) - wa(z)[1 - n(z)]\} \varphi(j, z) \quad (90)$$

(We have assumed Bertrand competition, so state of the art firms set prices equal to that of the "second best" firm. but have lower costs by the factor  $(1-n(z))$ . However the price is set by the Foreign firms, more efficient in production, while the innovation is applied to Home technology.) If instead they choose to go multinational and produce in Foreign the profit margin will be:

$$\psi(j, z) = (1 - p)n(z)w^* a^*(z) \varphi(j, z) \quad (91)$$

where  $(1-p)$  takes into account the possibility of imitation. Home firms will always choose to go multinational when  $\psi(j, z) > \pi(j, z)$ , i.e. when

$$\frac{wa(z)}{w^* a^*(z)} > \frac{1 - (1 - p)n(z)}{1 - n(z)} \quad (92)$$

or

$$\omega > \frac{1 - (1 - p)n(z)}{1 - n(z)} A(z)$$

Note that when  $p=0$ , i.e. when patent protection is perfect, this condition will always hold, and Home will go multinational for all  $z \in [\bar{z}, \bar{z}]$ .

Independently of the imitation process itself, the *risk* of patent infringement has effects on technology transfer and international trade. The range of industries for which Home decides to go multinational shrinks.

in particular the new interval will be  $[z'', \bar{z}]$  where  $z'' > \bar{z}$ , while the range of goods produced at Home increases (the  $A(z)$  schedule shifts to the right). So Home will go multinational only in those industries in which the gains are greater than the risks, which are also the industries in which Foreign has the most to gain from entering. In fact these are the industries in which Foreign's comparative disadvantage in research is small, but its comparative advantage in production is large.

### 3.2 The imitation technology

We must now consider what happens when imitation actually occurs. To be able to solve the model, we must specify a research technology and how imitation affects it. We can derive some general results however by simply taking into account that imitation causes the  $RD(z)$  schedule to shift down and to the left, as imitation permits the Foreign country's research sector to become relatively more efficient with respect to Home's in the industries where imitation occurs. The process of imitation is stochastic, but the number of industries in which imitation occurs is deterministic.

One can consider different ways in which imitation affects the research technology. If we assume that spillovers from technology are industry specific, i.e. imitation in one industry lowers the unit labor requirement for research *only* in that industry, the shift of the  $RD(z)$  curve will be discontinuous. If we assume spillovers exist also *across* industries we can model imitation as a parallel shift of the  $RD(z)$  schedule: this maintains the continuity of the  $RD(z)$  curve but is less credible (why should copying computer software technology make a country equally more efficient in semiconductor research as in agricultural research?). However we can assume that spillovers across industries exist but are differentiated, being highest for those closest to the one where imitation occurs and lowest for those farthest away. We can justify this by the fact that the ordering by comparative advantage is closely tied to an ordering by similar industries. (If an industry has a comparative advantage in industry  $z'$ , it will most likely also have a comparative advantage in industry  $z''$  that is either very similar to  $z'$  or tied to it through complementarities.)

In truth, the actual importance of this is minimal: the important thing is that with imitation the  $RD(z)$  schedule shifts down and to the left. Whether it shifts in a continuous or discontinuous fashion, or whether the shift is proportionate or not, is an issue of secondary importance.

#### 4 Comparative steady state analysis

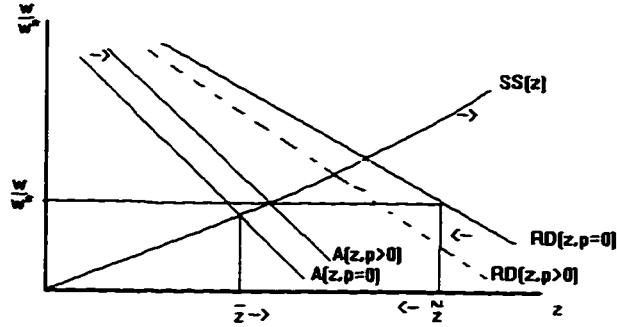
Once an imperfect level of patent protection is enforced, how will the new steady state be characterized? With the risk of imitation, the  $A(z)$  schedule shifts to the right. With imitation, the  $RD(z)$  schedule will shift down and to the left. As royalty payments from the Foreign to the Home country decrease, home's relative wage must decrease to maintain the balance of payments in equilibrium, this will have an opposite effect on Foreign's comparative advantage in research. This process will continue until the interval of "imitable" industries reduces to zero, as the  $A'(z)$  curve and the  $RD(z)$  curve move towards each other. The new steady state equilibrium will be given by the solution to the following three equations:

$$\omega = \frac{1 - (1 - p)n(z)}{1 - n(z)} A(z) = A'(z) \quad (93)$$

$$\omega = RD'(z) \quad (94)$$

$$\omega(p) = \frac{[L^* + r(t)A_I^*]B(\bar{z})}{[L + r(t)A_I][1 - B(\bar{z})]} \equiv SS(z) \quad (95)$$

93 is simply the original  $A(z)$  schedule corrected for the fact that imperfect protection will cause more goods to be produced at Home, and therefore lies to the right of it. 94 takes into account the changes in the Foreign country's unit labor requirement in research due to imitation, and therefore lies to the left of the original  $RD(z)$  schedule. 95 is the balance of payments equilibrium without royalty payments, because a steady state will be reached only when no more imitation can occur because no more technology will enter the Foreign country. So it will also be true that in the new steady state  $z^* = \bar{z}$ . Therefore there will be no



2.

more multinationals, in part because some Home firms, given the level of existing patent protection, prefer to produce at Home even though it is less efficient, in part because through imitation Foreign firms have "stolen" the "primacy" of the market from Home multinationals.

The study of the effects of introducing an incomplete level of intellectual property rights protection is complicated by the fact that there exists a trade off for the Foreign country to weakening its patent protection: an increase in  $p$  will allow more imitation to take place, but the range of industries available for imitation (i.e. the number of industries for which Home firms enter Foreign as multinationals) will decrease.

Following Taylor (1994), we can write the equilibrium relationships more generally as

$$\omega \equiv A(\bar{z}, p), \quad \text{where} \quad A_1 < 0, \quad A_2 > 0 \quad (96)$$

$$\omega \equiv RD(\hat{z}, p), \quad \text{where} \quad R_1 < 0, \quad R_2 < 0 \quad (97)$$

$$\omega \equiv SS(\bar{z}, \hat{z}, L/L^*, p), \quad \text{where} \quad S_1 > 0, \quad S_2 > 0, \quad S_3 < 0, \quad S_4 > < 0? \quad (98)$$

The response to a positive increase in  $p$  will depend on the existing pattern of trade. Taking total differen-

tials we find that

$$\frac{d\omega}{dp} = \frac{S_4 A_1 R_1 - S_1 R_1 A_2 - A_1 S_2 R_2}{\Delta} \quad (99)$$

where

$$\Delta = A_1 R_1 - S_1 R_1 - S_2 A_1 > 0$$

$$\frac{d\bar{z}}{dp} = \frac{1}{A_1} \frac{d\omega}{dp} - \frac{A_2}{A_1} \quad (100)$$

$$\frac{d\bar{z}}{dp} = \frac{1}{R_1} \frac{d\omega}{dp} - \frac{R_2}{R_1} \quad (101)$$

Therefore the desired effect,  $d\bar{z}/dp < 0$  will occur if  $d\omega/dp > R_2$ , i.e. either if  $d\omega/dp$  is positive or if the negative effect on the Foreign country's terms of trade doesn't outweigh the positive effect of imitation of its research technology (positive in the sense that it reduces the cost of research for the Foreign country). This depends on how imitation is modeled, in fact if the effect of imitation is small, i.e. if  $R_2$  is small, then it is possible for the effect on Foreign's comparative advantage to be the opposite of the objective, i.e.  $d\bar{z}/dp > 0$ .

The range of goods produced at Home will increase ( $d\bar{z}/dp > 0$ , i.e. if  $d\omega/dp < A_2$ ). This will always be true if  $d\omega/dp < 0$ , and will also be true if  $d\omega/dp > 0$  but is outweighed by the effect of Home firms shifting production from Foreign locations to domestic locations. For a given level of  $p$ , the shift of  $A(z)$  will be greater the larger the technological step  $n(z)$ .

The effect of imperfect patent protection on the terms of trade, i.e. whether  $d\omega/dp$  is positive or negative, depends on the following:

$$\frac{d\omega}{dp} > < 0 \quad \text{if} \quad S_4 > < S_1 \frac{A_2}{A_1} - S_2 \frac{R_2}{R_1} \quad (102)$$

Note that the first term on the right hand side is negative, while the second is positive. The terms of trade effect will be positive if the effect of patent protection on the balance of trade is smaller than the effect of  $p$  on the  $A(z)$  schedule and on the  $RD(z)$  schedule, weighted by the effects of  $\bar{z}$  and  $\bar{z}$  on the balance of payments.



Looking at the balance of payments, we see that two opposite forces affect relative wages.

$$\omega(p) = \frac{[[L^* + r(t)A_I^*][B(\bar{z}) + \int_{\bar{z}}^{\bar{z}} n(z)b(z)dz]}{[[L + r(t)A_I][1 - B(\bar{z}) - \int_{\bar{z}}^{\bar{z}} n(z)b(z)dz]} \equiv SS(z) \quad (103)$$

First, when the Home country perceives that patent protection is imperfect, exports from the Home country increase while royalty payments decrease. These two factors have opposite effects on relative wages: the first tends to increase  $\omega$  ( $B(\bar{z})$  increases), the second to decrease it ( $\int_{\bar{z}}^{\bar{z}} n(z)b(z)dz$  decreases). Which factor actually dominates depends on the size of the Home export sector relative to the range of industries over which it goes multinational and the values of  $n(z)$  and  $b(z)$  over the relevant interval. With certain regularity conditions on  $n(z)$  and  $b(z)$  we can expect  $\omega$  to increase, i.e.  $w^*$  decreases. (In fact, if  $b(z)=1$  and if  $n(z)=n$  for all  $z$  then this will be always true.) This will cause  $\bar{z}$  to shift to the right and  $\bar{z}$  to shift to the left, i.e. in this model the mere *risk* of patent infringement causes a shift in comparative advantage towards the Foreign country. But this effect is short term, once the Home country no longer perceives the risk the distortion will disappear and comparative advantage will return to its original values.

If imitation takes places, royalty payments from Foreign to Home will decrease even more, causing  $\omega$  to decrease for sure, i.e.  $w^*$  to increase. Furthermore investments in Foreign  $A_I^*$  will increase as Foreign firms gain comparative advantage in research, while  $A_I$  decreases. In summary, imitation causes the SS curve to shift down unequivocally but how much is uncertain, depending on fundamentals of the model.

What is the effect of imperfect patent protection and imitation on welfare? Consumer utility grows at the rate

$$\hat{u}(t) = - \int_0^{\bar{z}} \{b(z) \ln[1 - n(z)]i(z)\} dz + \int_{\bar{z}}^1 \{b(z) \ln[1 - n(z)]i^*(z)\} dz > 0$$

where innovation in Home and Foreign are given by

$$i(z) = \Pi(z)/a_I(z) - \rho, \quad z \in [0, \bar{z}]$$

$$i^*(z) = \Pi(z)/w^*a_I^*(z) - \rho, \quad z \in [\bar{z}, 1]$$

The effect on welfare is also not clear-cut, since various different forces are in effect. Firstly, in the industries susceptible to imitation expected profits are lower when patent protection is imperfect, this will reduce the incentive to innovate in these industries, with a negative effect on utility for consumers in both Home and Foreign. Secondly, with regards to the incentive to innovate in Foreign, two opposite forces interact: an increase in the productivity of research in Foreign will tend to increase innovation, and therefore utility, while the increase in foreign wages has the opposite effect. The net effect will be positive if

$$\int_{\underline{z}}^1 \frac{di^*(z)}{dp} dz > 0 \quad \text{if} \quad \frac{dw^*}{dp} \int_{\underline{z}}^1 a_I^*(z) dz < w^* \int_{\underline{z}}^1 \frac{da_I^*(z)}{dp} dz$$

This will be true whenever  $d\omega/dp > 0$ , or if  $d\omega/dp < 0$  but is small.

Thirdly, as royalty payments paid to the Home country decrease and these profits pass to Foreign firms, the Home country unequivocally loses while the Foreign country unequivocally gains. The net effect on world welfare depends ultimately on the fundamentals of the model, on the imitation technology and on the degree of patent protection. If the latter is so weak that the inefficiency from having Home firms produce in less efficient locations and conduct less research on the targeted industries is larger than the positive catching up effect of imitation, then the net effect will be negative.

## 5 Numerical Simulations

The dynamic system is complex and cannot be solved explicitly, so resolving the system for a set of parameter values can shed some light on the effects discussed above. The new equilibrium achieved with imperfect patent protection should have the following characteristics. Firstly, we expect the imitation technology to drive the model: the stronger the effect of imitation on the  $RD(z)$  schedule the stronger the effect of imperfect patent protection on the research position of the Foreign country. Secondly, we expect to see a Laffer curve effect: initially decreasing protection improves the comparative advantage of the Foreign country in research, but after a certain point weaker protection actually worsens the Foreign country's position.

For simplicity, I assume discrete instead of continuous time. I linearize both the  $A(z)$  and the  $RD(z)$  curve and impose the necessary conditions for the  $A(z)$  and the  $RD(z)$  curves not to cross and to have Home be the country with the comparative advantage in research. The functional form for  $SS(z)$  follows from these assumptions. I then specify a simple imitation technology: in each period imitation occurs in  $p[\bar{z} - \underline{z}]$  industries. This causes a downward shift of  $RD(z)$  of  $\eta * p[\bar{z} - \underline{z}]$  in each period, where the choice of  $\eta$  determines the effectiveness of imitation.

For different sets of feasible parameter values, I consider different values of  $\eta$  and  $p$ . The results are as expected. Small values of  $p$  have the desired effect of shifting comparative advantage in research towards the Foreign country. However large values of  $p$  eventually lead to a worsening of the Foreign country's position. The fundamental parameter in this analysis is  $\eta$ , the effectiveness of imitation, in fact the smaller this is the more likely that imperfect protection will not have the desired result.

Regarding notation,  $\rho$ ,  $n$ ,  $L$  and  $L^*$  are as defined in the text. I define  $p.int$  as the intercept on the  $y$  axis of the  $A(z)$  curve, while  $m1$  is its slope. Furthermore  $rd.int$  is the  $y$  intercept of the  $RD(z)$  curve, with  $m2$  its slope. The table shows the direction of  $z$  for different combinations of  $\eta$  and  $p$ . A decrease in  $z$  is the desired result, i.e. a shift in the comparative advantage in research towards the laggard country, if  $p$  is not too large and  $\eta$  not too small. For larger values of  $p$  and smaller values of  $\eta$  there is actually a tendency for comparative advantage to *worsen* for the laggard country.

rdint.0 = 1.4  
 pint = 1.25  
 m1 = 0.5  
 m2 = 0.6  
 LH = 100  
 LF = 130  
 n = 0.05  
 $\rho$  = 0.04

$\eta, p$	0.1	0.2	0.3	0.4
0.005	-	-	+	+
0.0005	+	+	+	+
0.00005	+	+	+	+

rdint.0 = 1.4  
 pint = 1.25  
 m1 = 0.4  
 m2 = 0.6  
 LH = 100  
 LF = 150  
 n = 0.05  
 $\rho = 0.04$

$\eta, p$	0.1	0.15	0.2	0.3
0.005	-	-	+	+
0.0005	+	+	+	+
0.00005	+	+	+	+

rdint.0 = 1.35  
 pint = 1.25  
 m1 = 0.5  
 m2 = 0.6  
 LH = 100  
 LF = 150  
 n = 0.1  
 $\rho = 0.04$

$\eta, p$	0.1	0.15	0.2	0.3
0.005	-	-	+	+
0.0005	-	-	+	+
0.00005	+	+	+	+

rdint.0 = 1.4  
 pint = 1.25  
 m1 = 0.5  
 m2 = 0.7  
 LH = 100  
 LF = 150  
 n = 0.05  
 $\rho = 0.04$

$\eta, p$	0.1	0.2	0.3	0.4
0.005	-	-	+	+
0.0005	+	+	+	+
0.00005	+	+	+	+

rdint.0 = 1.4  
 pint = 1.25  
 m1 = 0.7  
 m2 = 0.6  
 LH = 100  
 LF = 130  
 n = 0.1  
 $\rho = 0.04$

$\eta, p$	0.1	0.2	0.3	0.4
0.05	-	-	-	+
0.005	-	-	+	+
0.0005	-	-	+	+
0.00005	-	-	+	+

rdint.0 = 1.4  
 pint = 1.25  
 m1 = 0.7  
 m2 = 0.6  
 LH = 100  
 LF = 100  
 n = 0.1  
 $\rho = 0.04$

$\eta, p$	0.1	0.2	0.3	0.4
0.005	-	-	-	+
0.0005	-	-	+	+
0.00005	-	-	+	+

rdint.0 = 1.45  
 pint = 1.25  
 m1 = 0.7  
 m2 = 0.6  
 LH = 100  
 LF = 200  
 n = 0.08  
 $\rho = 0.04$

$\eta, p$	0.1	0.2	0.3	0.4
0.005	+	+	+	+
0.0005	+	+	+	+
0.00005	+	+	+	+

rdint.0 = 1.5  
 pint = 1.35  
 m1 = 0.7  
 m2 = 0.6  
 LH = 100  
 LF = 130  
 n = 0.05  
 $\rho = 0.04$

$\eta, p$	0.3	0.4	0.5	0.6
0.005	-	-	-	+
0.0005	-	-	-	+
0.00005	-	-	+	+

## 6 Concluding Remarks

This paper investigates the effect of imperfect intellectual property rights protection in a world where multinationals are the only source of technology transfer. Imitation is considered a form of strategic trade policy with the objective of shifting the long run comparative advantage in research in favor of the technologically backward country. This is consistent with the observation that growth in the "miracle" countries of South-east Asia has consistently been accompanied by an increase in the exports of goods not previously exported. A model of endogenous growth and trade is used to evaluate whether it is in the interest of the technologically backward country to have perfect patent protection or if weaker protection might not be better. I assume imitation cannot take place in the case of imports, but only in industries where production takes place locally (as in fact in the case of multinationals). Patent protection is assumed to be asymmetric: domestic firms are always completely protected, foreign firms aren't. In this way I can focus on the association between multinationals and foreign imitation. Lastly, imitation affects not only production but has also a positive affect on local research, in this way long run comparative advantage is affected.

The government of the technologically backwards country is faced with the following trade off when de-

cluding the level of patent protection to enforce. On the one hand, imperfect intellectual property protection permits local firms to exploit foreign technology, and the weaker the enforcement the higher the level of exploitation. On the other hand, however, imperfect patent protection reduces technology transfer from abroad, and the weaker the enforcement the less technology will be transferred. The optimal level of protection depends on the fundamentals of the model, in particular on the imitation technology, i.e. how imitation affects research. It will also depend on the relative sizes of the two economies and on the relative weight of productive and innovative activities in the two regions. The next step should be to specifying a functional form for the imitation technology and for the  $A(z)$  and  $RD(z)$  schedules so that one can solve explicitly for the optimal level of protection, I leave this for future research.

With respect to the perfect patent protection equilibrium as described in Taylor (1994), the imperfect patent protection scenario has the following features. Technology transfer is initially reduced, as some firms prefer to produce in less efficient but more protected locations, and eventually disappears, as imitation shifts comparative advantage in research towards the imitating country in industries where multinationals operated. If patent protection is not too weak, research will shift to the laggard country in some industries, with ambiguous effects on welfare. However if patent protection is too weak, the laggard country's comparative disadvantage could worsen, with negative welfare effects.

## **BIBLIOGRAPHY**

- Alesina, Alberto, (1988). "Credibility and Policy Convergence in a Two-Party System with Rational Voters". *American Economic Review*, vol.78, n.4, pg.796-804.
- Aoki, Reiko and T. Prusa (1993). "International Standards for Intellectual Property Protection and R&D Incentives", *Journal of International Economics*, 35, pp.251-273.
- Chari, V.V., P. Kehoe and E. Prescott (1989). "Time Consistency and Policy" in R. Barro ed., *Modern Business Cycle Theory*, Harvard University Press, pp. 265-305.
- Chin, Judith and G. Grossman (1988). "Intellectual Property Rights and North-South Trade", NBER Working Paper no.2769.
- Dixit, Avinash (1988). "International R&D Competition and Policy" in A.M. Spence and H.A. Hazard, eds., *International Competitiveness*, Ballinger, pp.149-171.
- Dixit, Avinash (1988). "A general model of R&D competition and policy", *RAND Journal of Economics*, vol.19, no.3, pp.317-326.
- Dornbusch, R., S. Fischer and P.Samuelson, (1977). "A Continuum Ricardian Model of Comparative Advantage, Trade and Payments", *American Economic Review*, vol.67, pg.823-839.
- Eaton, Jonathan and G. Grossman (1985). "Tariffs as Insurance: Optimal Commercial Policy when Markets are Incomplete", *Canadian Journal of Economics*, vol.18, no.2, pp.258-272.
- Ethier, Wilfred and J. Markusen (1994). "Multinational Firms, Technology Diffusion and Trade" , *Journal of International Economics*, forthcoming.
- Grossman, Gene and E. Helpman (1991). *Innovation and Growth in the Global Economy*, MIT Press.
- Jensen, Richard and M. Thursby (1996). "Patent Races, Product Standards, and International Competition", *International Economic Review*, vol.37, no.1, pp.21-49.

- Krasner, Stephen and Judith Goldstein (1984). "Unfair Trade Practices: The Case for a Differential Response". *American Economic Review*, vol.74, pg.282-287.
- Kydland, Finn and E. Prescott (1977). "Rules Rather than Discretion: The Inconsistency of Optimal Plans", *Journal of Political Economy*, 85, pp.473-491.
- Lee, Tom and L. Wilde (1980). "Market Structure and Innovation: A Reformulation", *Quarterly Journal of Economics*, 94, pp.429-436.
- Loury, Glenn (1979). "Market Structure and Innovation", *Quarterly Journal of Economics*, 93, pp.395-410.
- Mansfield, Edwin (1994). "Intellectual Property Protection, Foreign Direct Investment and Technology Transfer", International Finance Corporation Discussion Paper n.19, The World Bank.
- Reinganum, Jennifer (1982). "A Dynamic Game of R&D Patent Protection and Competitive Behavior". *Econometrica*. vol.50, no.3, pp.671-688.
- Staiger, Robert and G. Tabellini (1987). "Discretionary Trade Policy and Excessive Protection", *American Economic Review*, vol.77, no.5, pp.823-837.
- Taylor, M.S., (1993). "Quality ladders and Ricardian trade", *Journal of International Economics*. vol.34, pg.225-243.
- Taylor, M.S., (1994). "Trips, Trade, and Growth", *International Economic Review*, vol.35, pg.361-381.