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**Heterogeneity of Southern Countries and Southern Intellectual Property Rights Policy**

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# HETEROGENEITY OF SOUTHERN COUNTRIES AND SOUTHERN

# INTELLECTUAL PROPERTY RIGHTS POLICY

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# 1. Introduction

The Uruguay round established a global agreement on intellectual property, which is called TRIPS (Traded-related aspects of intellectual property rights). Under this agreement, most developing countries should introduce the international minimum standards of protection by this year (2006).  A recent debate in the WTO (World Trade Organization) meeting has been whether it is desirable to extend IPR protection to the least developed countries.  The declaration in the Doha round extends the deadline for the least developed countries to introduce patent protection on pharmaceuticals until 2016. This proposal seems reasonable since the least developed countries do not have the capacity to absorb new knowledge from the innovations while they desperately need the products developed by northern firms.

A number of papers deal with the issue of IPR protection in terms of North-South trade. Chin and Grossman (1988) use a duopoly model to compare the welfare effects of IPR protection between two regimes: 'full IPR protection' and 'no IPR protection'. They show that the economic interests of the North and the South are generally in conflict in the sense that 'no IPR protection' benefits the South while it hurts the North. Diwan and Rodrik (1991) argue northern and southern countries generally have different preferences for technology. They model the 'appropriate technology' for southern countries, and suggest that southern countries benefit from IPR protection. Deardorff (1992) argues that, when IPR protection increases, the North is always benefited while the South is hurt, and emphasizes that the effect on world welfare will be negative if IPR protection is extended to all southern countries. Helpman (1993) suggests that tightening IPR protection hurts both North and South in the presence of slow imitation while it benefits only the North when the imitation rate is high. He also points out that higher protection of IPR by the South could lead to slow innovation of northern firms, partly because of the lack of

competition. Grossman and Lai (2004) develop a dynamic model in which ongoing innovation occurs in both the North and the South. Among their many findings are that, under given conditions, patent protection in an open economy Nash equilibrium will be less than in the closed economy equilibrium and that the larger, more productive North will choose larger protection of IPR then will the South. They also find that overall world welfare depends on a world index of patent protection, where the index weights the patent protection in each country by country size.

Žigić (1998) extends Chin and Grossman's model by introducing technological spillovers to examine the role of IPR protection when only the northern firm conducts innovative activity. The degree of spillovers is interpreted as an indicator of the inverse strength of IPR protection. He shows that the South may benefit from tightening IPR protection through the spillover effect of the increased northern firm's R&D investment; however, by considering only one Southern firm he effectively assumes all southern countries will have the same spillover rate. In a subsequent paper, Zigic (2000), using a similar two country model, analyzes a four stage game in which the Southern country chooses its level of IPR protection, and the Northern country (where all output is sold) uses an import tariff not only for strategic reasons, but also because of its impact on R&D. Yang (1998) shows, using a partial equilibrium model, that both the North and the South would be better off if some southern countries impose more IPR protection while the others impose less. However, he does not identify which southern countries should provide more IPR protection for the northern technology.[1] McCalman (2001), explicitly noting the large heterogeneity in countries' enforcement of IPRs, estimates the welfare and transfer effects of harmonizing these standards.

By considering only one southern country and a common spillover parameter, Zigic ignores the fact that the southern countries may face different spillovers. In Levin et al. (1987)

and Cohen and Levinthal (1989), firms may be different in their abilities to absorb or assimilate

intra-industry spillovers.[2] We extend Žigić (1998) by introducing different spillovers among

southern countries to examine welfare effects of IPR protection. Only the northern country

innovates, and *n*-1 southern countries have different capacities to absorb knowledge spillovers

from the northern innovations.[3] We assume, as in Žigić, the abilities to absorb spillovers in any

southern country decrease (increase) when IPR protection is tightened (relaxed). A two-stage

game is considered. In the first stage, the northern firm invests in R&D to create the new process.

The outcome of innovations reduces the unit production cost of the northern firm. The

technology developed by the northern firm provides benefits to the southern firms through

spillovers. The degree of spillovers is different across southern firms, depending on their ability

to realize knowledge spillovers. In the second stage, all firms engage in Cournot competition.

In this paper, we investigate the welfare effects of spillovers (or IPR protection), and

discuss the conflicts between the North and the South. The global welfare effects of spillovers

are also examined. We consider optimal IPR policy from a southern perspective, when countries

act non-cooperatively and when they can collectively agree on policy. We find that more

efficient southern countries prefer a tighter collective IPR policy then do less efficient Southern

countries. However, from a world welfare perspective it is better for the more efficient countries

to expand their spillover. This implies that private and social incentives may not be coordinated.

This paper is organized as follows. Section 2 presents the model and identifies the

equilibrium while section 3 provides comparative static analysis. Section 4 investigates the

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[1] This is because he assumes that all southern countries are identical.
[2] Cohen and Levinthal (1989) calls this ability 'absorptive capacity'.
[3] In terms of the North, the issue of IPR protection may be 'imitation' of southern countries rather than spillovers. Usually, 'imitation' and 'spillovers' are interpreted differently in the sense that 'imitation' is costly while 'spillovers' are costless. By different capacity to absorb spillovers, however, we are implicitly considering costly spillovers. Thus, the terms 'imitation' and 'spillovers' are interchangeable in this paper even though we prefer 'spillovers', following Žigić.

welfare effects of spillovers and of optimal southern policy. The last section provides

conclusions.

## 2. The Model and Solution

There are $n$ countries in the world market: one northern country (labeled by 1) and $n$-1

southern countries (labeled 2,3,..,$n$). Each country has only one firm. All innovations take place in

the northern country, which conducts R&D. Through a spillover effect, $n$-1 southern countries

can partly appropriate the knowledge generated by the northern country, depending on their

knowledge absorptive abilities and their IPR policy and enforcement. Both North and South have

access to an old technology to produce a good demanded in the world market.

The northern firm has the following unit production cost function, which is the one used

by <u>Chin and Grossman (1988)</u>: $c_1 = \alpha_1 - (\gamma\chi)^{1/2}$, where $\alpha_1$ describes pre-innovation cost in the

north, and $\gamma$ is a parameter denoting R&D efficiency. The term $(\gamma\chi)^{1/2}$ is the R&D production

function, which exhibits diminishing returns with respect to R&D investment, $\chi$.[4] The

$i^{th}$ southern firm's unit cost function is: $c_i = \alpha_i - \beta_i (\gamma x)^{1/2}$, $i = 2,3,....,n$ where $\alpha_i$ reflects the

intrinsic cost heterogeneity across countries and $\beta_i \in (0,1)$ denotes the spillover, or the strength

of inverse IPR protection, as in Žigić (1998). The spillover parameter is determined by two

factors: the IPR protection policy and a country-specific learning characteristic. The country-

specific characteristic may reflect the country's imitation ability to absorb R&D knowledge,[5] or

the extent to which the innovation is appropriate for the technological conditions of the particular

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[4] For more detail, see D'Aspremont and Jacquemin (1988) and Kamien et al. (1992).
[5] Cohen and Levinthal (1989) call this ability 'absorptive capacity'.

southern country[6]. Even if southern countries adopt a common IPR protection level, the actual spillover may differ across countries, depending on their ability to use the R&D knowledge[7]. Without loss of generality, we order the countries such that: $\alpha_1 < \alpha_2 < \alpha_3 < ... < \alpha_n$. Note that $\beta_1 \equiv 1$ in our set-up and $\beta_i \le 1$ for all $i$, with strict inequality if spillovers are not complete. Consumers are assumed identical, and country $i$'s consumers consume $\theta_i \in [0,1]$ proportion of total demand, which is given as a linear inverse demand function: $P = A - Q$, $Q = \Sigma q_i$.

The game among $n$ firms consists of two stages, and we use the subgame perfect Nash equilibrium. In the first stage, the northern firm chooses R&D investment, $\chi$. In the second stage, *given* the R&D investment, the $n$ firms engage in Cournot-Nash competition. We first solve for the Nash equilibrium in the second stage and then work backwards to solve for the first stage R&D level. In the second stage, each firm maximizes its profit, which is given as:

$$\pi_i = P(Q)q_i - c_iq_i = \left((A-Q)-c_i\right)q_i \quad \forall i=1,...,n \quad Q \equiv \sum_{i=1}^{n} q_i \tag{1}$$

The first order condition for each firm (country) is:

$$(d\pi_i/dq_i) = (P - c_i - q_i) = 0, \quad i = 1,...,n \tag{2}$$

Summing (2) across all firms, and assuming an interior solution for each firm yields:

$$NP - \sum_{i=1}^{N} c_i - Q = 0 \rightarrow P = \frac{(A+N\overline{c})}{(N+1)}; \quad \overline{c} \equiv \frac{\sum_{i=1}^{N} c_i}{N} = \overline{\alpha} - \overline{\beta}(\gamma\chi)^{1/2}; \overline{\alpha} \equiv \frac{\sum_{i=1}^{N} \alpha_i}{N}; \overline{\beta} \equiv \frac{\sum_{i=1}^{N} \beta_i}{N} \tag{3}$$

This solution has the well-known property that, under constant marginal costs, aggregate

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[6] For example, the innovation may be labor-saving, and hence would reduce costs proportionately more in imitating countries with cost conditions most similar to those in the north (i.e., relatively high wage-rental ratios).

[7] The spillover parameter depends on the country's innate ability to use the knowledge $(\omega_i)$, and its (inverse) IPR protection policy, $\rho_i$ which includes IPR law **and** enforcement policy. Letting $\rho_i = 0$ be "perfect" IPR protection,

equilibrium price and quantity depend on the number of firms and average cost per firm, but not on the distribution of the cost vectors $\{(\alpha_1,...,\alpha_N),(\beta_1,...,\beta_N)\}$. For future reference, define:

$$\varepsilon_i \equiv (\alpha_i - \bar{\alpha}); \quad \varsigma_i = (\bar{\beta} - \beta_i) \tag{4}$$

so that $(\varepsilon_i, \varsigma_i)$ represent the deviation of a firm's cost function from the industry average. The deviations are defined so that positive values for each correspond to higher than average costs. Using (2) and (3) yields:

$$q_i^* = \frac{(A - \bar{\alpha} - (n+1)\varepsilon_i) + ((n+1)\beta_i - \beta^T)(\gamma\chi)^{1/2}}{n+1}; \quad \pi_i^* = (q_i^*)^2; \quad \beta^T \equiv \sum_{i=1}^{n} \beta_i = n\bar{\beta}$$

$$Q^* = \frac{n(A - \bar{\alpha}) + \beta^T(\gamma\chi)^{1/2}}{n+1}; \quad P^* = \frac{A + n\bar{\alpha} - \beta^T(\gamma\chi)^{1/2}}{n+1} \tag{5}$$

where the "*" indicates the equilibrium value.

In the first stage, given the second stage outcome, the northern firm chooses $\chi$ to maximize its profit (including R&D cost):

$$V_1 = (P - c_1)q_1^* - \chi; \quad \frac{dV_1}{d\chi} = (P + q_1 P' - c_1)\left(\frac{dq_1^*}{d\chi}\right) + q_1^* P'\left(\sum_{i \neq 1}\left(\frac{dq_i^*}{d\chi}\right)\right) - \left(q_1^* \frac{dc_1}{d\chi} + 1\right) = 0 \tag{6}$$

The first term on the RHS vanishes by the envelope theorem, whereas the last term reflects the impact of R&D expenditures on firm 1's total costs. The middle term represents the strategic aspect of the firm's decision, which arises only because R&D decisions are made *before* output decisions. From (5) it is readily seen that:

$$\sum_{i \neq 1}\left(\frac{dq_i^*}{d\chi}\right) = \frac{\left((n+1)\sum_{i \neq 1}\beta_i - (n-1)\beta^T\right)(\gamma/\chi)^{1/2}}{2(n+1)} = \frac{(2\beta^T - (n+1))(\gamma/\chi)^{1/2}}{2(n+1)} \tag{7}$$

and $\rho_i = 1$ no protection, define: $\beta_i = g(\omega_i, \rho_i)$, with $g_\omega \geq 0$, $g_\rho \geq 0$. Two countries with the same level of (incomplete) IPR protection would have different effective spillovers if they had different $\omega_i$.

The sign of (7) depends on $\beta^T$, and hence the strategic interaction can increase or decrease firm 1's investment in R&D. If $\beta^T > ((n+1)/2)$, this interaction reduces the firm's investment in R&D, meaning that further R&D investment by firm 1 would lower its total costs but also lower profits due to the output effect on other firms.[8]  Using (5) and (7) in (6) and simplifying yields:

$$(dV_1/d\chi) = \frac{q_1^* ((n+1)-\beta^T)(\gamma/\chi)^{1/2}}{(n+1)} - 1 = 0 \tag{8}$$

It is readily seen that the second order condition holds.  Solving (8), using (5), yields:

$$\chi^* = \frac{\gamma(A-\bar{\alpha}-(n+1)\varepsilon_1)^2 \Delta^2}{D^2} \text{ where } \Delta \equiv n+1-\beta^T \geq 1; \ D \equiv [(n+1)^2 - \gamma\Delta^2] \tag{9}$$

A meaningful solution requires $D > 0$[9].  For future reference, rewrite this condition as:

$$D = (n+1)^2 (1-\gamma(1-\tilde{\beta})^2) > 0 \text{ where: } \tilde{\beta} \equiv (\beta^T/(n+1)), \ \Delta = (n+1)(1-\tilde{\beta}) \tag{10}$$

Now, since $\tilde{\beta} \in [(1/(n+1)),1]$, for this condition on $D$ to hold for all $\beta_j$ requires:

**Assumption 1:** $\gamma < ((n+1)/n)^2$

Using equilibrium R&D in (5) yields equilibrium output levels and price:

$$q_i^* = (-\phi_i) + \left(\frac{A-\bar{\alpha}-(n+1)\varepsilon_1}{D}\right)(n+1-\gamma\Delta(1-\beta_i)); \ \phi_i \equiv (\alpha_i - \alpha_1) = (\varepsilon_i - \varepsilon_1)$$

$$Q^* = \frac{(A-\bar{\alpha})(n(n+1)-\gamma\Delta(n-\beta^T))-\varepsilon_1\gamma\Delta\beta^T}{D} \tag{11}$$

Note that, given the *intrinsic* overall cost structure of the industry (*i.e.,* $\bar{\alpha}$), the more efficient the innovating firm (country) is, the larger will be innovation and overall industry output.

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[8]Naturally, firm 1's R&D investment is reduced by the presence of other firms.  The strategic term merely shows how R&D investment is affected by the fact it is chosen before outputs, rather than simultaneously with outputs.
[9] If $(n+1)^2 < \gamma\Delta^2$ then the optimal R&D is unbounded $(\chi \to \infty)$.

The equilibrium R&D level and aggregate output depend on the aggregate spillover $\left(\beta^T\right)$, but not on the distribution of spillovers among firms[10]. We assume all firms produce positive amounts in equilibrium, which implies research productivity, $\gamma$, is not too large.[11]

It is desirable to compare the condition for the *n*-firm oligopoly equilibrium to exist in our model with the corresponding condition for the duopoly equilibrium to exist both in Chin and Grossman (1988) and in Žigić (1998). These conditions were $\gamma < 3/2$ for Chin and Grossman and $\gamma < 3/\{(1-\beta)(2-\beta)\}$ for Žigić. Both papers assumed two countries (n=2, $\beta_{Min} = \beta$), with identical intrinsic costs $\left(\phi_i = 0\right)$. Thus, our condition that output be positive (footnote 10) reduces to $\gamma < 3/\{(1-\beta)(2-\beta)\}$, the same condition as in Žigić. Furthermore, upon setting $\beta = 0$ (as in Chin and Grossman) yields their condition for existence.

Both Chin and Grossman and Žigić consider two more types of equilibria: monopoly and strategic predation. They show that the northern firm will enjoy a pure monopoly position for a sufficiently high value of the R&D efficiency parameter ($\gamma$) while it will act strategically to induce the southern firm's exit (strategic predation) for an intermediate value of R&D efficiency. These two types of equilibria also can exist when there is more than one southern country in the world. The monopoly condition, assuming identical intrinsic costs $\left(\alpha_i = \alpha_1 \ \forall i\right)$, in our set-up is

$$\gamma > \frac{1}{1-\beta_{Max}}$$, which is the same as the corresponding condition for Žigić and Chin and

Grossman (with $\beta = 0$). Strategic predation, when the innovating firm faces more than one

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[10]Any changes in $\left(\beta_2,...,\beta_n\right)$ that preserves the sum will not affect firm 1's R&D effort.

[11] Note that (11) can be rewritten as: $q_i^* = \left(q_1^* - \phi_i\right) - \gamma\Delta(1-\beta_i)\left(q_1^*/(n+1)\right)$. For $\phi_i \equiv 0$ $q_i^* > 0$ implies: $\gamma < \left[(n+1)/\Delta(1-\beta_{Min})\right]$. If this condition is to hold for all $\beta$, then it is more restrictive then is Assumption 1. Also, if intrinsic costs differ across firms, then we must require that these differences not be too large.

rival (n>2), is more complicated then in the two country set-up since the threshold levels of innovation required for predation depend upon whether the innovating firm is trying to force one firm, two firms, or all rival firms from the market. Even though the outcome comparison among these equilibria is an interesting issue, we do not consider these equilibria since we are interested in investigating the own and cross welfare effects of spillovers in the southern countries.

### 3. Comparative statics

A change in the "spillover" rate in any southern country has direct and indirect effects. The direct impact lowers costs in that country only, improving its competitiveness versus all other countries (thereby hurting firms in those other countries). Since the increased spillover lowers the private return to R&D, it causes the Northern firm to reduce R&D expenditures; this, in turn, raises costs for all firms but raises costs **most** for those firms with large spillover rates. Thus, the increased spillover in one country will likely harm not only the Northern firm but also other firms with high spillover rates but may (will) benefit firms with very low spillover rates.

**Proposition 1.** *An increased spillover rate in Southern country i reduces the Northern firm's R&D, raises costs for all other firms, but results in lower costs for firm i if its spillover rate is sufficiently low.*

**Proof.** Differentiating (9) yields:

$$\left(\frac{d\chi^*}{d\beta_i}\right) \equiv \left(\frac{-2\chi^*}{\Delta}\right) - \left(\frac{2\chi^*(2\gamma\Delta)}{D}\right) = -2\left(\frac{\chi^*}{\psi}\right) < 0; \quad \psi \equiv \left(\frac{\Delta\left[(n+1)^2 - \gamma\Delta^2\right]}{\left[(n+1)^2 + \gamma\Delta^2\right]}\right) > 0 \qquad (12)$$

$$\left(\frac{dc_j}{d\beta_i}\right) = -\left(\gamma\chi^*\right)^{1/2}\delta_{ij} - \left(\beta_j/2\right)\left(\gamma\chi^*\right)^{1/2}\left(\frac{d\chi^*}{d\beta_i}\right)\left(\frac{1}{\chi^*}\right) = \left(\gamma\chi^*\right)^{1/2}\left\{-\delta_{ij} + \left(\frac{\beta_j}{\psi}\right)\right\} \qquad (13)$$

where $\delta_{ij} = 1$ if $i=j$ and zero otherwise.  Since R&D falls, the costs of all firms - except firm $i$ - must increase.  For $j=i$, if $\beta_i$ is small enough costs fall.  Formally:

$$\left(dc_i/d\beta_i\right) \underset{>}{\leq} 0 \text{ as } \beta_i \underset{>}{\leq} \psi \qquad\qquad\qquad \text{QED} \qquad (14)$$

By construction, $\Delta > 1$; thus, for $\gamma$ sufficiently small, the inequality $(\beta_i < \psi)$ in (14) will be satisfied for all southern countries.  Since $\psi$ is a decreasing function of $\gamma$, the larger R&D efficacy, the less likely it is that a southern firm will reduce its costs by increasing its spillover.

Since the value of $\psi$ recurs below, it is worthwhile simplifying the expression.  Define:

$$\tilde{m} \equiv \left(1-\tilde{\beta}\right) \in \left[\frac{1}{n+1}, \frac{n}{n+1}\right]; \quad \psi(\gamma) \equiv \left(\frac{(n+1)\tilde{m}\left(1-\gamma\tilde{m}^2\right)}{1+\gamma\tilde{m}^2}\right) \qquad (15)$$

Turning to the impact of increased spillovers on that firm's output, it is clear its output will increase if its unit production costs fall.  However, since the costs of all *other* firms must increase, it is possible for a firm's output to increase even if its production costs rise; clearly, what matters is how much its costs increase compared to the average cost increase for all firms.  It is also possible that the output of a "low-spillover" firm will increase, even though it has not increased its own spillover rate.  By the same logic, aggregate output could increase if both the productivity of R&D investment and the aggregate spillover rate are low.  Formally, from (5):

$$\left(\frac{dq_j^*}{d\beta_i}\right) = \frac{(\gamma\chi)^{1/2}}{(n+1)} \cdot \left[\left((n+1)\delta_{ij}-1\right) + \left(\frac{\left(\beta^T-(n+1)\beta_j\right)}{\psi}\right)\right] \qquad (16)$$

$$\left(\frac{dQ^*}{d\beta_i}\right) = \left(-\frac{dP}{d\beta_i}\right) = \frac{(\gamma\chi)^{1/2}}{n+1} \cdot \left[1 + \left(\frac{-\beta^T}{\psi}\right)\right] = \frac{(\gamma\chi)^{1/2}}{n+1} \cdot \frac{\left(1-2\tilde{\beta}-\gamma\left(1-\tilde{\beta}\right)^2\right)}{\left(1-\tilde{\beta}\right)\left(1-\gamma\left(1-\tilde{\beta}\right)^2\right)} \qquad (17)$$

**Proposition 2.**

    i.    The equilibrium output of the firm which increases its spillover rate increases if and

        only if: $\beta_i < \left( \left( n\psi + \beta^T \right) / (n+1) \right)$

    ii.    If the aggregate spillover rate is sufficiently high, the equilibrium output of a low

        spillover firm may increase as a result of some ***other*** firm increasing its spillover rate:

$$\text{i.e.,} \quad \left( dq_j^* / d\beta_i \right) \underset{<}{\geq} 0 \text{ as } \beta_j \underset{>}{\leq} \left[ \left( 2\tilde{\beta} - 1 + \gamma \left( 1 - \tilde{\beta} \right)^2 \right) / \left( 1 + \gamma \left( 1 - \tilde{\beta} \right)^2 \right) \right], \qquad j \neq i$$

    iii.    If R&D investment is not too productive, then for low aggregate spillover rates an

        increase in the spillover rate leads to *higher aggregate equilibrium output; i.e.*,

$$\left( dQ^* / d\beta_i \right) \underset{<}{\geq} 0 \quad as \quad \gamma \underset{>}{\leq} \left[ \left( 1 - 2\tilde{\beta} \right) / \left( 1 - \tilde{\beta} \right)^2 \right]$$

    Note that existence requires $\gamma < \left( 1 - \tilde{\beta} \right)^{-2}$; hence, condition (iii) must hold for small

spillover rates. This implies that over some interval increased spillover rates benefit consumers

as well as some firms. Note that for aggregate spillover rates such that $\tilde{\beta} > (1/2)$, then further

increases in spillover rates must lower aggregate output.


**Lemma 1:** If assumption 1 holds, then $\left( dq_j^* / d\beta_j \right) > 0$; that is, an increase in the spillover rate

by firm $j$ must increase its equilibrium output.


**Proof:** See appendix.

## 4. Welfare effects

In this section we investigate the effect of a change in spillovers (or IPR protection) on global welfare and welfare for each country. Since, from a global perspective, the original equilibrium is inefficient, an increase in some spillover rate can have an ambiguous impact on welfare. The inefficiency of the original equilibrium arises from several sources including: (i) given the level of R&D, too little information is shared among countries; (ii) there is underinvestment in R&D; (iii) given costs, too little output is produced; and finally (iv) the given level of output is produced inefficiently since - under constant costs - all output should be produced in the low cost country. An increase in the spillover rate to some country reduces the inefficiency due to (i), exacerbates the inefficiency due to (ii); and - as seen in the previous section - has an ambiguous impact on total output (and hence on the inefficiency due to (iii)).

The welfare of each (Southern) country consists of its firm's (oligopoly) profits and consumer surplus. Thus, for all countries but the Northern country, welfare is given by:

$$W^j = \pi^j + \theta^j CS = \left(q_j^*\right)^2 + \theta^j \left\{ \int_0^{Q^*} P(y)\,dy - P\left(Q^*\right)Q^* \right\} \tag{18}$$

where $CS$ is aggregate consumer surplus, $\theta^j$ is country $j$'s consumer share, and hence $\theta^j CS$ is consumer surplus in country $j$. Profits of the Northern firm, and hence welfare of the Northern country, also must reflect the expenditures on R&D:

$$W^1 = \pi^1 + \theta^1 CS = \left\{\left(q_1^*\right)^2 - \chi^*\right\} + \theta^1 \left\{ \int_0^{Q^*} P(y)\,dy - P\left(Q^*\right)Q^* \right\} \tag{19}$$

Using (18) and (19), we first consider how changes in the spillover rate in country $i$ affects each country. Subsequently, we discuss the likely equilibrium of a game in which countries non-cooperatively set their IPR policy, then we consider IPR policy when the South

can coordinate its policy choices. Finally, we consider how differences among southern

countries will impact optimal IPR policy. Differentiating (18) with respect to $\beta_i$ yields:

$$\frac{dW^j}{d\beta_i} = 2\left(q_j^*\right)\left(\frac{dq_j^*}{d\beta_i}\right) - \theta^j Q^*\left(\frac{dP}{d\beta_i}\right); \quad \left(\frac{dq_j^*}{d\beta_i}\right) = \left(\frac{dP}{d\beta_i} - \frac{dc_j}{d\beta_i}\right); \quad (20)$$

In (20), $\left(\theta^j Q^*\right)$ represents country $j$'s consumption $\left(D^j\right)$ of the good. Rewrite (20) as:

$$\frac{dW^j}{d\beta_i} = \left[\left(X_j\frac{dP}{d\beta_i}\right) - \left(q_j^*\frac{dc_j}{d\beta_i}\right) + \left(P - c_j\right)\frac{dq_j^*}{d\beta_i}\right]; \quad X_j \equiv \left(q_j^* - D^j\right); \quad j \neq 1 \quad (21)$$

The first term in (21) represents the standard terms of trade effect: an increase in world price

benefits (hurts) a country if it is net exporter (net importer). The second term is the benefit (cost)

to the country, given output, due to the exogenous change in unit production costs, while the

third term reflects the change in monopoly profits - at given price -due to the change in the firm's

output level. For the case in which all output is consumed in the North, the impact of increased

spillover in country $i$ on the welfare of any Southern country $j$ is uniquely determined by the

change in output in that country. Hence, it follows from Proposition 2 and Lemma 1:

**Proposition 3:** Consider an increase in the spillover rate in southern country $i$. Assuming all

output is consumed in the North and Assumption 1 holds, then:

    i.    Welfare will increase in country $i$.

    ii.    If the overall spillover rate is not too large $\left(\tilde{\beta} < (1/2)\right)$, and R&D efficiency is

        sufficiently low $\left(\gamma < \left((1 - 2\tilde{\beta})/(1 - \tilde{\beta})^2\right)\right)$, then the increased spillover rate in country

        $i$ causes world price to fall and harms all other southern countries.

iii. If R&D efficiency is sufficiently high $\left(\gamma > \left(\left(1-2\tilde{\beta}\right)\big/\left(1-\tilde{\beta}\right)^2\right)\right)$, so the increased

spillover rate in $i$ causes world price to rise, southern countries with low spillover

rates may benefit from the increased spillover rate in a different southern country.

iv. Aggregate consumer surplus increases if and only if: $\left(dQ^*/d\beta_i\right) > 0$, i.e., if and only

if $\gamma < \left(\left(1-2\tilde{\beta}\right)\big/\left(1-\tilde{\beta}\right)^2\right)$.

v. The profits of the Northern firm decrease.

vi. At least one country must be hurt by the change in $\beta_i$.

**Proof:** Claims i-iv of the proposition follow directly from Proposition 2 and Lemma 1. Note

that aggregate consumer surplus is given by:

$$CS\left(Q^*\right) = \int_0^{Q^*} P(y)dy - P\left(Q^*\right)Q^* = \left(\left(Q^*\right)\big/2\right), \quad \frac{dCS}{d\beta_i} = Q^*\left(\frac{\gamma\Delta H\left(1-2\tilde{\beta}-\gamma\left(1-\tilde{\beta}\right)^2\right)}{\left(n+1\right)\left(1-\tilde{\beta}\right)\left(1-\gamma\left(1-\tilde{\beta}\right)^2\right)}\right) \quad (22)$$

In (22) we define: $H \equiv \left(A - \bar{\alpha} - \left(n+1\right)\varepsilon_1\right)$. For part v, the profits of the northern firm are:

$$\pi_1 = q_1^2 - \chi^*; \quad \text{hence:} \quad \frac{d\pi_1}{d\beta_i} = 2q_1\frac{dq_1}{d\beta_i} - \frac{d\chi}{d\beta_i} = -2\frac{\gamma\Delta H^2}{D^2} < 0 \quad (23)$$

In the above equations, we have used (12) and (16) to simplify the expressions. For part vi, note

that if price increases, then the north has to be hurt (consumer surplus falls, profits fall), while if

price decreases then southern countries with unchanged spillover rates are hurt.             QED

Note that while intrinsic cost differences across firms affect the *magnitude* of how increased

spillovers affect any firm (country), they will not alter the sign of this affect. Thus, absent

domestic consumption, the (qualitative) incentives for increasing spillovers will be the same for all southern countries. An immediate corollary to Proposition 3, due to part i, is:

**Corollary 3.1:** Suppose all output is exported to the north. Then in a non-cooperative Nash equilibrium in which Southern countries commit to their IPR policy (spillover rate) prior to the northern firm's R&D choice, all southern countries will choose no *IPR* protection (i.e., will choose their maximum possible spillover rate).

Thus, in this equilibrium, the only thing that constrains southern firms from having complete spillovers $(\beta_i = 1)$ is their own ability to adopt the *northern innovation* as well as the extent to which the innovation is appropriate for their local cost conditions[12]. If southern countries consume, as well as produce, the good then their incentives to protect *IPR* change. If other southern countries have high spillover rates, then country $i$ knows that increases in its own spillover rate must raise world price which, while helping its firms, hurts its consumers. Hence, local demand – as well as intrinsic cost differences – will affect the spillover choices (IPR decisions) of each southern country.

The fact that any southern country gains, *ceteris paribus*, from relaxing its own IPR laws does not imply that they collectively gain. Specifically, one could ask what the optimal policy – from the perspective of southern countries - would be if they could commit to a common IPR policy. Following the suggestion in footnote 7, suppose the spillover in country $i$ is:

$$\beta_i = \omega_i \rho_i; \quad \omega^T = \sum_{i=2}^{n} \omega_i \le (n-1); \quad \beta^T = 1 + \omega^T \rho \tag{24}$$

In (24) $\rho_i \in [0,1]$ represents IPR policy in country $i$ ($\rho_i = 0$ representing comprehensive IPR protection), while $\omega_i \in (0,1]$ represents country-specific factors, such as imitation ability, the appropriateness of the Northern innovation for Southern cost conditions, and so forth. Assuming a common IPR policy entails setting $\rho_i = \rho$ for all $i$, which still allows for *ex post* spillover differences. Under this common policy, and using (11) we have:

$$\frac{dq_i^*}{d\rho} = \left( \frac{\gamma H (n+1)^3}{D^2} \right) \left\{ \left( 1 - \gamma \tilde{m}^2 \right) \left[ \tilde{m} \omega_i + (1 - \beta_i) \frac{\omega^T}{n+1} \right] - \frac{2\tilde{m} \omega^T}{n+1} \left( 1 - \gamma \tilde{m} (1 - \beta_i) \right) \right\} \qquad (25)$$

Equation (25) can be rewritten as:

$$\frac{dq_i^*}{d\rho} = \left( \frac{\gamma H (n+1) \omega^T}{D^2} \right) \left\{ \left( 1 + \gamma \tilde{m}^2 \right) \left[ \frac{1 - \kappa_i \rho}{n+1} \right] + \left( 1 - \gamma \tilde{m}^2 \right) \frac{\tilde{m} \kappa_i}{\omega^T} \right\}; \quad \kappa_i \equiv \left( \omega_i (n+1) - \omega^T \right) \qquad (26)$$

From (26) the following can be deduced:

**Proposition 4.** Suppose southern countries export all output to the North, and assume they can coordinate their IPR policy. Then:

  i.    If all southern countries have the same imitation ability, $\omega$, and if $\omega \leq (1/2)$, then their optimal policy is to provide no IPR protection $\left( \rho^* = 1 \right)$.

  ii.   If there are more than 3 southern countries, if they all have the same imitation ability, $\omega$, and if it is sufficiently large $\left( \omega \geq \omega^* \equiv \left[ (3n-1)/(4(n-1)) \right] \right)$, then their optimal cooperative policy is to provide some IPR protection $\left( \rho^* < 1 \right)$ and all southern countries are better off than in the non-cooperative equilibrium.

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[12]If technology is Leontief and the northern innovation economizes on labor, the innovation will lower costs more in high wage countries than in low wage countries. Hence, the *ex post* heterogeneity in the $\beta_i$ is due to the

iii.    If southern countries differ, then - in coordinating policy - the southern countries whose imitation ability is above average will prefer tighter *IPR policy* (smaller $\rho$) then will the countries whose imitation ability is below average.

**PROOF:**

If $\omega_i = \omega \ \forall i \in \{2,...,n\}$ then $\kappa_i = 2\omega$ and $(1 - \kappa_i \rho) = (1 - 2\omega\rho)$. Assumption 1 requires $\gamma \tilde{m}^2 < 1$.

Hence, if $\omega \leq (1/2)$ it is immediate from (26) that $(dq_i^* / d\rho) > 0$ for all $\rho \in [0,1]$, and hence part

(i) follows. For part (ii), note that $\tilde{m} = ((n - (n-1)\omega\rho)/(n+1))$. Hence, again from (26):

$$\left(\frac{dq_i^*}{d\rho}\right) = T\{3n - 1 - 4(n-1)\rho\omega - \gamma\tilde{m}^2(1+n)\}; \quad T \equiv \left(\frac{\gamma H\omega^T}{D^2(n-1)}\right) \tag{27}$$

Since $\gamma\tilde{m}^2 \in [0,1]$, it is immediately apparent that $\left.(dq_i^* / d\rho)\right|_{\rho=0} > 0$ and $\left.(dq_i^* / d\rho)\right|_{\rho=1} < 0$

provided $\omega \geq \omega^* = ((3n-1)/(4(n-1)))$, where $\omega^* < 1$ for $n > 3$. Hence, for $n > 3$, $\gamma > 0$,

$\left.(dq_i^* / d\rho)\right|_{\rho=1} < 0$ provided $\omega \geq \omega^*$. The optimal IPR protection, $\rho^* \leq ((3n-1)/(4\omega(n-1)))$, is

less than 1, completing the proof of part (ii).

Finally, suppose: $\omega_i = \omega(1 + \lambda_i)$ such that: $\sum\limits_{i=2}^{n} \lambda_i = 0$. Then (26) can be rewritten as:

$$\left(\frac{dq_i^*}{d\rho}\right) = T\left\{\left[3n - 1 - 4(n-1)\rho\omega - \gamma\tilde{m}^2(1+n)\right] + (n+1)\lambda_i\{n - 2(n-1)\omega\rho - \gamma\tilde{m}^2 n\}\right\} \tag{28}$$

Rewrite (28) as:

$$\left(\frac{dq_i^*}{d\rho}\right) = T\left\{\left[3n - 1 - 4(n-1)\rho\omega - \gamma\tilde{m}^2(1+n)\right]\left(1 + \frac{(n+1)\lambda_i}{2}\right) - \frac{(n+1)\lambda_i(n-1)(1 + \gamma\tilde{m}^2)}{2}\right\} \tag{29}$$

---

"appropriateness" of the innovation for each country.

Define $\rho^a$ as the optimal IPR protection for the country with the average spillover rate $(\lambda_i = 0)$.

Since the last term on the RHS of (29) is negative, it immediately follows that $\left(\dfrac{dq_i^*}{d\rho}\right)\bigg|_{\rho^a} \begin{smallmatrix} < \\ > \end{smallmatrix} 0$ as

$\lambda_i \begin{smallmatrix} > \\ < \end{smallmatrix} 0$, which completes the proof of part(iii).                                        QED

Several points need to be made concerning this agreement of southern countries to willingly impose IPR protection.  First, it remains true that any particular member would be better off abandoning the agreement and ending all IPR protection *provided* it believes the other members will maintain the agreement.  *However*, if it believes that its exit from the agreement will lead to a collapse of the agreement (and all countries abandoning IPR protection), then the agreement will be self-enforcing *if all countries are identical*.  Secondly, however, if countries differ and if the IPR protection rate is set at the optimal level for the average member, then countries with lower *imitation* abilities may be better off quitting the agreement *even if* that leads to the collapse of the agreement.  Hence, to ensure that it is in the self-interest of these lower imitation ability countries to remain in the agreement, the coalition might have to settle for weaker IPR protection then its average member wants.  Finally, then, it *may* be the case that - if a low imitation ability country opts out of the agreement - then the remaining countries (assumed identical) *may* choose a stricter level of IPR protection[13].

Finally, we could ask how these results would change if the southern countries also consumed the good.  As discussed earlier, relaxing IPR protection has ambiguous affects on world output (price), and hence on consumer surplus; when the overall level of spillovers is large,

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[13]We cannot be sure that eliminating a low ability country from the agreement will increase IPR protection for two reasons.  First, since the original group was heterogeneous, we need to specify how an agreement was reached.  Secondly, even though the exit of the low ability country raises the average imitation ability of the remaining countries - which leaders to stricter IPR protection - it also reduces the number of countries in the coalition, which reduces the desired IPR protection.  Overall, the impact can be ambiguous.

further relaxation of IPR protection lowers output and consumer surplus, while for low levels of spillovers, relaxing IPR protection may increase world output.

Since we have shown that, absent domestic consumption, an individual southern country has no incentive to offer any IPR protection, adding domestic consumption may not alter this result at all, and the precise impact will depend upon how large the domestic market share is. Rather than consider all such cases, let us restrict attention to the case where the southern countries collective choose an IPR policy (as in Proposition 4). Then, using (17), (29) and (18):

$$\frac{dW^j}{d\rho} = \theta^j Q \left(\frac{dQ}{d\rho}\right) + q_j^* \left(\frac{dq_j^*}{d\rho}\right); \quad \left(\frac{dQ}{d\beta^T}\right) = \left(\frac{(\gamma\chi)^{1/2}}{n+1}\right) \left[\frac{1-2\tilde{\beta}-\gamma\left(1-\tilde{\beta}\right)^2}{\left(1-\tilde{\beta}\right)\left(1-\gamma\left(1-\tilde{\beta}\right)^2\right)}\right] \tag{30}$$

Assuming all southern countries choose the same IPR *policy* and have the same imitation ability:

$$\tilde{\beta} = \frac{1+(n-1)\omega\rho}{n+1}; \quad \text{and} \quad \left(1-2\tilde{\beta}-\gamma\left(1-\tilde{\beta}\right)^2\right) = \left(\frac{(n-1)(1-2\omega\rho)-\gamma\tilde{m}^2(n+1)}{(n+1)}\right) \tag{31}$$

By definition, $\left(d\beta^T/d\rho\right) = \left[(n-1)\omega\right]$. As earlier, let $\rho^a$ represent the solution to (27), which represents the optimal IPR policy if countries are alike and there is no domestic consumption. From (30) and (31) it is immediately clear that $\left(dQ/d\rho\right)\big|_{\rho^a} < 0$. Hence:

**Proposition 5:** Assume all Southern countries are identical and that they collectively choose their *IPR* policy. Then, as their share of world consumption increases, their collectively optimal IPR policy becomes more restrictive (i.e., $\left(d\rho^a(\theta)/d\theta^j\right) < 0$)

**Proof:**

Define $\rho^a(\theta)$ as the collective policy that maximizes $\left(\frac{\theta^j Q^2}{2} + \left(q_j^*\right)^2\right)$ where all southern

countries are identical $\left(\theta^j = \theta^S, \quad q_j = q_s \quad \forall j = 2,...,n\right)$ As shown above, $\left(dQ/d\rho^a\left(\theta\right)\right) < 0$ at

$\theta^s = 0$. Assuming the second order conditions (SOCs) hold, this implies that at $\rho^a\left(\theta\right), \theta > 0$,

$\left(dq^j/d\rho^a\right) > 0 > \left(dQ/d\rho^a\right)$. From (30), this implies that $\left(\partial^2 W^j/\partial\rho\partial\theta\right)\Big|_{\rho^a(\theta)} < 0$. Applying the

SOCs again leads to the conclusion $\left(d\rho^a\left(\theta\right)/d\theta\right) < 0$, as stated in the proposition.          QED

However, even though the southern countries would - if acting collectively - choose some

IPR protection, that does not mean all conflict between north and south has been eliminated.  In

particular, it is apparent that:

**Corollary 5.1:**  The optimal IPR protection level for the north is stricter than the collective rate

chosen by the south $\left(\rho^N\right) < \rho^a\left(\theta\right)$.

**Corollary 5.2:** Assume southern countries must use the same IPR policy.  Then the IPR policy

that maximizes world welfare is in the open interval $\left(\rho^N, \rho^a\right)$

Corollary 5.1 follows immediately from the facts that the northern firm's profits are a

decreasing function of $\rho$ and that consumer surplus is also a decreasing function of $\rho$ at $\rho^a$.

Corollary 5.2 follows from the fact that maximizing world welfare means maximizing the sum of

northern and southern welfare.  Both corollaries, of course, assume the SOCs hold.

Thus far, we have assumed that the southern countries can coordinate their IPR policy but

have implicitly assumed that no transfers could take place among them.  In order to consider the

role of diversity among these countries, assume that transfers are feasible and that policy is

coordinated in order to maximize the surplus of all southern countries. Hence, define:

$$W^s = \sum_{i=2}^{n} \pi_i = \sum_{i=2}^{n} q_i^2 \tag{32}$$

Furthermore, using (3), (4), (5), and (9):

$$q_i^* = \left(\frac{A-\bar{\alpha}}{n+1}\right) - \varepsilon_i + \left(\beta_i - \tilde{\beta}\right)\left(\gamma\chi^*\right)^{1/2}; \ \beta_i \equiv \omega_i \rho_i; \quad \left(\gamma\chi^*\right)^{1/2} = \frac{\gamma\left(A-\bar{\alpha}-(n+1)\varepsilon_1\right)\tilde{m}}{(n+1)\left(1-\gamma\tilde{m}^2\right)} \tag{33}$$

Assuming a common IPR policy, differences in spillovers reflect differences in imitation ability

$\left(\omega_i\right)$. Since we are interested in variation among the southern countries, define:

$$\varphi_i \equiv \left[\varepsilon_i - \left(\sum_{j=2}^{n} \varepsilon_j \Big/ (n-1)\right)\right]; \ \delta_i \equiv \left[\left(\omega^T/(n-1)\right) - \omega_i\right]; \ \sigma_i \equiv \left(\varphi_i + \delta_i \rho \left(\gamma\chi^*\right)^{1/2}\right); \ \omega^T \equiv \sum_{j=2}^{n} \omega_j \tag{34}$$

From earlier definitions we have:

$$\sum_{j=1}^{n} \varepsilon_j = 0 \rightarrow \sum_{j=2}^{n} \varepsilon_j = \left(-\varepsilon_1\right); \quad \left(\beta_i - \tilde{\beta}\right) = \left(\frac{\left(\omega^T \rho\right)}{n-1} - \frac{\beta^T}{n+1} - \delta_i \rho\right) = \left(\frac{2\omega^T \rho - (n-1)}{n^2 - 1} - \delta_i \rho\right) \tag{35}$$

Note that positive values of both $\varphi_i$ and $\delta_i$ correspond to situations in which that country's costs

lie above the average for southern countries. Using (33), (34) and (35):

$$q_i^* = q_S - \sigma_i; \quad q_S = \left(\frac{A-\bar{\alpha}}{n+1}\right) + \varepsilon_1 + \left(\frac{2\omega^T \rho - (n-1)}{n^2 - 1}\right)\left(\gamma\chi^*\right)^{1/2} \tag{36}$$

Hence, using (36), rewrite (32) as:

$$W^s = \sum_{i=2}^{n} \left(q_S - \sigma_i\right)^2 = \sum_{i=2}^{n} q_S^2 + \sum_{i=2}^{n} \sigma_i^2; \quad \sum_{i=2}^{n} \sigma_i^2 = V_\varphi + 2\rho\left(\gamma\chi^*\right)^{1/2} Cov_{\delta,\varphi} + V_\delta \rho^2 \gamma\chi^* \tag{37}$$

In (37), by construction, $\sum_{i=2}^{n} \sigma_i = 0$, and we define:

$$V_\varphi \equiv \sum_{i=2}^n \varphi_i^2 > 0; \quad Cov_{\delta,\varphi} \equiv \sum_{i=2}^n (\varphi_i \delta_i); \quad V_\delta \equiv \sum_{i=2}^n \delta_i^2 > 0 \tag{38}$$

Next, consider the cooperative IPR policy that maximizes southern welfare:

$$\frac{dW^s}{d\rho} = \frac{2(\gamma\chi^*)^{1/2}}{\psi} \left\{ q_S \left[ \frac{\omega^T (2\psi + n - 1 - 2\omega^T \rho)}{(n^2 - 1)} \right] + \left[ Cov_{\delta,\varphi} + \rho(\gamma\chi^*)^{1/2} V_\delta \right] \left[ \psi - \rho\omega^T \right] \right\} \tag{39}$$

If $\omega^T$ is sufficiently small, there is no interior solution and $\rho^* = 1$; however, for $\omega^T$ large enough, the south benefits from adopting a common IPR policy $(\rho^* < 1)$. Using (37) and (39) we have:

**Proposition 6:** Assume the southern countries adopt a common IPR policy to maximize aggregate welfare (profits) and that transfers among countries are feasible. Then:

    i.   Southern welfare is increasing in the heterogeneity of its members – given average intrinsic cost and imitation ability, greater cost variability implies higher Southern profits. This implies southern welfare is increasing in the variance of instrinsic costs $(\varphi)$, in the variance of imitation ability $(\varphi)$ and in the covariance between these variables.

    ii.   Assuming an interior solution for IPR policy, if $\left[ Cov_{\delta,\varphi} + \rho(\gamma\chi^*)^{1/2} V_\delta \right]$ is positive (negative), then increases in the variance of imitation ability or in the covariance between disadvantages in intrinsic costs and in imitation ability lead to tighter (looser) optimal IPR policy.

**PROOF:** Part (i) follows immediately from (37). For part (ii), note that an interior solution requires $(\psi - \rho\omega^T) < 0$ since, if $(\psi - \rho\omega^T) \geq 0$ then the first term on the RHS of (39) is strictly

positive, while the second is non-negative, implying that welfare is increasing in $\rho$ at the point[14].

Given the second order conditions, part (ii) follows immediate from $\left( \psi - \rho \omega^T \right) < 0$ .          QED


It is well-known that, given a fixed number of firms with constant marginal costs, and given the average (marginal) cost of this set, that aggregate profits increase as the variance of costs increase.  Since positive values of $\varphi$ represent intrinsic costs above average, and positive values of $\delta$ represent a firm with below average imitation ability (hence, higher than average costs), it is clear that aggregate profits are increasing in the covariance of these two variables, as well as in their individual variances.  It is also sensible to expect these variables to be positively correlated as higher costs are likely to reflect lower productivities and less likelihood the country can benefit from northern innovations.  The second part, that greater heterogeneity in the membership leads to stricter IPR policy is less intuitive but essentially reflects the fact that, with more diversity, there is a greater payoff to reducing (average) marginal costs.  From a policy perspective, this would seem to imply that allowing some countries to opt out of an IPR agreement may not be in the interests of either the north or of the remaining southern countries.

Finally, it should be clear that, regardless of whether the objective is maximizing the welfare of the southern countries or world welfare (again, assuming transfers are feasible), that a **common IPR policy can never be optimal**.  The equilibrium R&D rate depends on the aggregate spillover rate, $\beta^T$ , and not on the vector of spillovers.  Hence, it follows that one can think of the optimization process as a two stage process: (1)for any given $\beta^T$ , choose country-

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[14] Even if $\left[ Cov_{\delta,\varphi} + \rho \left( \gamma \chi^* \right)^{1/2} V_\delta \right] < 0$ , upon regrouping the expression in (39), the term multiplying $\left( \psi - \rho \omega^T \right)$ must be positive.

level spillovers (R&D policy) to maximize world welfare (or southern profits); and (2)choose the

optimal $\beta^T$. From (18), (19) and (22) we can write aggregate welfare as:

$$W^T = \Omega + \sum_{i=2}^{n}\left(q_i^*\right)^2 = \Omega + (n-1)q_S^2 + \sum_{i=2}^{n}\left(\sigma_i\right)^2; \quad \Omega \equiv \left[\frac{\left(Q^*\right)^2}{2} + \left(q_1^*\right)^2 - \chi^*\right] \tag{40}$$

In (40), note that $\Omega$, as defined, and $q_S$ depend only on $\beta^T$, where $q_S$ is defined in (36) with

$\left(\omega^T \rho\right)$ replaced by: $\left(\sum_{i=2}^{n}\beta_i = \left(\beta^T - 1\right)\right)$. Also, $\sigma_i$ is defined as in (34):

$$\sigma_i \equiv \left(\varphi_i + \delta_i\left(\gamma\chi^*\right)^{1/2}\right); \quad \delta_i \equiv \left(\frac{\displaystyle\sum_{j=2}^{n}\beta_j}{n-1} - \beta_i\right) = \left(\frac{\beta^T - 1}{n-1} - \beta_i\right) = \left(\overline{\beta}^S - \beta_i\right) \tag{41}$$

Note that $\overline{\beta}^S$ is the average spillover rate among southern countries and the domain of

$\beta_i \in [0, \omega_i]$ implies $\delta_i \in \left[\overline{\beta}^S - \omega_i, \overline{\beta}^S\right]$. Constrained optimality (i.e., given $\beta^T$) entails

choosing $\{\delta_2, ..., \delta_n\}$ to maximize $\sum_{i=2}^{n}\sigma_i^2$ subject to the domain restrictions on $\delta_i$ and the

condition that $\sum_{i=2}^{n}\delta_i = 0$. Clearly, the objective function is not concave and the corresponding

solution will be a corner solution. Further, the integer programming nature of the problem

makes it difficult to fully characterize the solution. Nevertheless, we have:

**Proposition 7:** Given the intrinsic cost differences $\left(\varphi_i\right)$ and imitation rates $\left(\omega_i\right)$ of each firm

(country), suppose the Southern countries jointly pick a distinct IPR policy $\left(\rho_i \in [0,1]\right)$ for each

country to maximize their aggregate welfare, given that aggregate spillovers are fixed

$\left( \sum_{i=2}^{n} \omega_i \rho_i = \beta^T - 1 \right)$. Then the optimal IPR policy has the following properties:

i.  All countries, except at most one, will have a corner solution with $\rho_i = 0$ or $\rho_i = 1$.

ii.  Assume the optimal solution implies $\rho_s^* = 1$ for country $s$, characterized by intrinsic costs

and imitation rates $(\varphi_s, \omega_s)$; then it is also optimal that $\rho_j^* = 1$ for any country $j$ such that:

$\varphi_j < \varphi_s + \mu Min\left(0, (\omega_j - \omega_s)\right)$.

iii.  Assume the optimal solution implies $\rho_k^* = 0$ for country k, characterized by intrinsic

costs and imitation rates $(\varphi_k, \omega_k)$; then it is also optimal that $\rho_t^* = 0$ for any country $t$

such that: $\varphi_t > \varphi_k + \mu Max\left(0, (\omega_t - \omega_k)\right)$.

**PROOF:** See appendix.

Because of the nature of the problem, it is not possible to fully characterize the solution. Nevertheless, the "spirit" of the solution is intuitive. If it is optimal for a given country to have a completely lax IPR policy, then it should also be optimal for a "more efficient" country to have the same policy – that is, for any country with lower intrinsic costs and higher assimilation ability. Similarly, if the optimal solution entails no spillovers for a given country, then the same logic implies less efficient countries should also adopt a no spillover/strict IPR policy. The following corollaries follow immediately from Proposition 7:

**Corollary 7.1**: Suppose all countries have the same intrinsic costs $(\varphi_i \equiv 0 \; \forall i)$. Without loss of generality order countries so that: $\omega_2 > \omega_3 > ... > \omega_n$. Given $\beta^T$, define $j$ such that:

$$\sum_{i=2}^{j-1} \omega_i < \left(\beta^T - 1\right) \leq \sum_{i=2}^{j} \omega_i .$$ Then the optimal solution entails $\rho_i^* = 1$ for $i=2,...,(j-1;)$ $\rho_k^* = 0$ for

$k = (j+1,...,n)$ and $\rho_j^* \in [0,1]$.

**Corollary 7.2:** Suppose all countries have the same assimilation ability $(\omega_i \equiv \omega \; \forall i)$. Without loss of generality order countries so that: $\phi_2 < \phi_3 < ... < \phi_n$. For given $\beta^T$ define $j$ to be the largest integer no larger than $\left[\left(\beta^T + \omega - 1\right)/\omega\right]$[15]. Then the optimal solution entails $\rho_i^* = 1$ for

$i=2,...,(j);$ $\rho_k^* = 0$ for $k=(j+2),...,n;$ and $\rho_{j+1}^* \in [0,1]$.

These results are much like the results of a Ricardian trade model with many countries and two goods; that is, when there is heterogeneity in only one dimension then it is much easier to characterize the results. Finally, since the countries can differ in these two dimensions (intrinsic costs and assimilation ability) the obvious question is whether the distribution of these attributes across countries matters. For this we have:

**Proposition 8:** Consider the vectors of attributes, $\vec{\varphi} = (\varphi_2, \varphi_3, ..., \varphi_n)$ and $\vec{\omega} = (\omega_2, \omega_3, ..., \omega_n)$, where $(\varphi_j, \omega_j)$ represents the instrinsic costs, and imitation ability, of country $j$. Suppose for any pair of countries, $k$ and $j$, we have $\varphi_j < \varphi_k$ and $\omega_j < \omega_k$. Consider a rearrangement of the

vector $\vec{\omega}$ to $\vec{\omega}'$ where $\omega'_t = \omega_t$ for all $t \neq j,k$; and $\omega'_j = \omega_k$ and $\omega'_k = \omega_j$. Then, given $\beta^T$, the

aggregate maximized welfare of Southern countries with vector pair $(\vec{\varphi}, \vec{\omega}')$ will be no smaller

(and can be strictly larger) then with vector pair $(\varphi, \omega)$. In words, welfare will be higher (no

lower) when countries with low intrinsic costs also have high imitation abilities.


**Proof:** See appendix.


# 5. Conclusions

This paper has investigated welfare effects of spillovers due to relaxed IPR protection.

Unlike previous studies in which two countries, North and South, are modeled, we consider a

situation where there are many southern countries. We allow these Southern countries to differ

in two attributes, their intrinsic costs and their ability to absorb foreign technology. Using this

framework we reach a number of important results. First, we find, like others, that while there is

North-South conflict over IPR protection, the heterogeneity of the model makes it apparent that

there can also be conflict among the Southern countries themselves. We show, for example, that

an increase in spillovers (a decrease in IPR protection) in any one Southern country will not only

hurt the innovating North, but will also hurt those Southern countries which have a significant

ability to absorb foreign technology. We also show, assuming all output is exported to the North,

that the non-cooperative equilibrium in which each Southern country sets its own IPR policy

leads to maximum spillovers (no protection). However, if the Southern countries can

cooperatively set policy, even without pressure from the North, then it will be in their collective

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[15] The idea, of course, is if the maximum spillover is to be $(\beta^T - 1)$ then no more then $Int\left[(\beta^T - 1)/\omega\right]$ countries

interests to provide some IPR protection, and the resulting equilibrium will be Pareto superior to the non-cooperative equilibrium, provided Southern countries are sufficiently homogeneous.

However, even when the policy is set cooperatively, there will be disagreements among the Southern countries if they are heterogeneous. The countries with the higher ability to absorb Northern innovation will prefer stricter IPR policy then will those countries with lesser imitation ability. This result sounds reminiscent of WTO agreements in which low income countries are, at least initially, excluded from the IPR agreements. However, since Northern innovation depends upon a measure of total protection, and not on how it is distributed across individual nations, somewhat paradoxically welfare will be higher when it is countries with lower intrinsic cost and higher imitation ability that are excluded from this IPR agreement then when the less efficient Southern countries are excluded.

There are some possible extensions of this study. How much each country absorbs the knowledge or information from another country depends on its ability to realize knowledge spillovers. Thus, it will be interesting to introduce endogenous spillovers by having a cost function: $\beta_i(\mu_i, \alpha_i)$ where $\mu_i$ is the cost of reverse-engineering and $\alpha_i$ is a country-specific parameter. Given a vector of $\alpha$, we could model the "spillover" decision without IPR and then have IPR shift the cost function. Second, the existence of spillovers may increase the northern firm's incentive to sell its innovations to the southern countries. Thus, the issue of licensing may be an important topic for future research. Third, it would be worthwhile extending the model to consider the appropriateness of the Northern technology, and in a heterogeneous Southern environment investigate how IPR policy adopted by Southern countries interacts with the type of technology decisions pursued by the North.

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can have maximal spillovers. Since the index set for countries starts at *i=2*, we add 1 to this number.

## Appendix

**Proof of Lemma 1**:

We must show that, given Assumption 1: $\beta_i < \dfrac{n\psi + \beta^T}{n+1}$ where: $\beta^T \equiv \sum_{k=1}^{n} \beta_k = 1 + \beta^0 + \beta_i$ ;

$\beta^0 \equiv \sum_{k \neq 1,i}^{n} \beta_k$ ; and: $\beta^* \equiv \dfrac{\beta^T}{n+1} = \dfrac{1 + \beta^0 + \beta_i}{n+1}$ . Also:

$$\psi \equiv \frac{\Delta\left[\left(n+1\right)^2 - \gamma\Delta^2\right]}{\left[\left(n+1\right)^2 + \gamma\Delta^2\right]} = \frac{\left(n+1\right)\left(1-\beta^*\right)\left(1-\gamma\left(1-\beta^*\right)^2\right)}{\left(1+\gamma\left(1-\beta^*\right)^2\right)} . \quad \text{Simplifying, this implies demonstrating:}$$

$$H \equiv \left[\frac{n\psi + \beta^T}{n+1} - \beta_i\right] = \frac{nm_T\left(1-\gamma m_T^2\right)}{\left(1+\gamma m_T^2\right)} + m_i - m_T > 0; \quad m_T \equiv \left(1-\beta^*\right); \quad m_i \equiv \left(1-\beta_i\right)$$

By construction, $H > 0$ for $m_i \geq m_T$ (as existence requires $\left(1-\gamma m_T^2\right) > 0$). Also:

$$\frac{d\beta_i}{dm_i} = -1 \quad \rightarrow \frac{dm_T}{dm_i} = \frac{1}{n+1} . \quad \text{Thus:}$$

$$\frac{dH}{dm_i} = \left(\frac{1}{n+1}\right)\left\{\frac{n\left(1-3\gamma m_T^2\right)}{\left(1+\gamma m_T^2\right)} - \frac{2n\gamma m_T^2\left(1-\gamma m_T^2\right)}{\left(1+\gamma m_T^2\right)^2}\right\} + \frac{n}{n+1}$$

Define $\tau = \left(\gamma m_T^2\right)$ and simplifying the above expression yields:

$$\frac{dH}{dm_i} = \left(\frac{n}{n+1}\right)\left\{\frac{\left(1+\tau\right)^2 + \left(1-3\tau\right)\left(1+\tau\right) - 2\tau\left(1-\tau\right)}{\left(1+\tau\right)^2}\right\} = \left(\frac{2n\left(1-\tau\right)}{\left(n+1\right)\left(1+\tau\right)^2}\right) > 0$$

as existence requires $\left(1-\gamma m_T^2\right)>0$. Thus, the minimum value of $H$ for $m_i < m_T$ occurs at

$m_i = 0$:

$$H\left(m_i = 0\right) = \frac{m_T\left[n\left(1-\gamma m_T^2\right)-\left(1+\gamma m_T^2\right)\right]}{\left(1+\gamma m_T^2\right)} \equiv \frac{m_T N}{\left(1+\gamma m_T^2\right)} \quad \text{where } N \text{ represents the term in brackets in}$$

the numerator and sign($H\left(m_i = 0\right)$)=sign($N$). At $\beta_i = 0$, $m_T = \dfrac{1+\beta^0}{n+1}$; $\beta^0 \in [0, n-2]$. Since $N$ is

decreasing in $m_T$, and $m_T \leq \left(\dfrac{n-1}{n+1}\right)$, $\gamma \leq \left(\dfrac{n+1}{n}\right)^2$ this implies:

$$N \geq \left[n-1-\left(n+1\right)\gamma\left(\frac{n-1}{n+1}\right)^2\right] \geq \left(n-1\right)\left[1-\frac{\left(n+1\right)\left(n-1\right)}{n^2}\right] > 0.$$

Thus $H > 0$ for all $\beta_i \in [0,1]$ given Assumption 1. $\hspace{4cm}$ QED

**Proof of Proposition 7:**

A choice of an IPR policy $\left(\rho_2^*, ..., \rho_n^*\right)$ is equivalent to a choice of spillovers $\left(\beta_2^*, ..., \beta_n^*\right)$ such

that $\beta_i \in [0, \omega_i]$. To compare policies that have the same impact on R&D, aggregate output and

price requires that $\displaystyle\sum_{i=2}^{n} \beta_i = \left(\beta^T - 1\right)$. Constrained maximization of welfare is then equivalent to

maximizing $\displaystyle\sum_{i=2}^{n} \sigma_i^2$, where $\sigma_i \equiv \left[\varepsilon_i + \bar{\beta}_s \mu\right] - \beta_i \mu$ where, for simplicity, we define $\mu = \left(\gamma\chi\right)^{1/2}$.

Assume $\left(\beta_2^*, ..., \beta_n^*\right)$ is the optimal solution to this problem and consider any variation to

$\tilde{\beta}_i = \beta_i^* + \eta_i$. For this variation to satisfy the spillover constraint, $\displaystyle\sum_{i=2}^{n} \eta_i = 0$; for it to satisfy the

restrictions on domain, $\eta_i \in \left[ -\beta_i^*, \omega_i - \beta_i^* \right]$. If $\vec{\beta}^*$ is optimal then the following inequality has to

hold for all feasible $\vec{\eta}$:

$$V\left( \vec{\eta}, \vec{\beta}^* \right) \equiv \sum_{i=2}^{n} \left[ \sigma_i^2 \left( \beta_i^* \right) - \sigma_i^2 \left( \tilde{\beta}_i \right) \right] = \sum_{i=2}^{n} \left[ \mu \eta_i \left( 2 \left( \phi_i + \mu \left[ \overline{\beta}_s - \beta_i^* \right] \right) - \mu \eta_i \right) \right] \geq 0 \qquad \text{(A1)}$$

To prove part (i), assume there exist $\beta_i^* \in \left( 0, \omega_i \right)$, $\beta_j^* \in \left( 0, \omega_j \right)$; let $\eta_k = 0 \ \forall k \neq i, j$ and let

$\eta_j = -\eta_i$. See $\beta_i^*, \beta_j^*$ are interior, $\eta_i$, if sufficiently small, can take on positive or negative

values. Using these assumptions (A1) simplifies to:

$$V = 2\mu \eta_i K_i - 2\mu \eta_i^2; \quad K_i \equiv \left[ \left( \phi_i - \mu \beta_i^* \right) - \left( \phi_j - \mu \beta_j^* \right) \right] \qquad \text{(A2)}$$

But it is apparent that there exist feasible values of $\eta_i$ such that $V < 0$. Thus. if $K_i > 0$, choose

$\eta_i < 0$; if $K_i < 0$ choose $\eta_i > 0$; and if $K_i = 0$ any small variation in $\eta_i$ will suffice. But $V < 0$

contradicts the assumption that both $\beta_i^*, \beta_j^*$ are optimal and interior.

Given part (i), it immediately follows that the solution can be characterized by dividing

the set of countries into 3 sets: for countries in set I, $\rho_i^* = 1$; for countries in set II, $\rho_j^* = 0$; and

there is at most one country such that $\rho_k^* \in \left( 0,1 \right)$.

To prove part (ii), assume $\rho_s^* = 1 \left( \beta_s^* = \omega_s \right)$ and take any country $j$ and assume $\rho_j^* = 0$.

Consider a variation to $\tilde{\beta}$ which changes spillovers only for countries $s$ and $j$. In particular,

using the earlier notation, let $\eta_j = Min \left( \omega_j, \omega_s \right)$ and $\eta_s = -\eta_j$. This choice is feasible because the

sum of spillovers is preserved and since, after the variation, $\beta_s = \left(\omega_s - \eta_j\right) \geq 0; \ \beta_j = \eta_j \leq \omega_j$

(note that $\eta_j < 0$ would not be feasible). Following our earlier procedure, with this variation we have:

$$V\left(\vec{\eta}, \vec{\beta}^*\right) \equiv \sum_{i=2}^{n} \left[\sigma_i^2\left(\beta_i^*\right) - \sigma_i^2\left(\tilde{\beta}_i\right)\right] = 2\mu\eta_j \left(\left(\phi_j - \phi_s\right) + \mu\omega_s - \mu\eta_j\right) \tag{A3}$$

But, if $\phi_j < \phi_s - \mu\omega_s + \mu Min\left(\omega_j, \omega_s\right) = \phi_s + \mu Min\left(\left(\omega_j - \omega_s\right), 0\right)$ then $V < 0$, contradicting the

assumption of optimality. Hence, if $\rho_s^* = 1$ and $\phi_j < \phi_s + \mu Min\left(\left(\omega_j - \omega_s\right), 0\right)$, then $\rho_j^* = 1$. That

completes the proof of part (ii)

Part (iii) is proved in the same manor. Assume $\rho_k^* = 0$ and take any other country $t$, and

assume $\rho_t^* = 1$. Consider any variation $\eta_t = -Min\left(\omega_t, \omega_k\right)$ and let $\eta_k = -\eta_t$. This variation

guarantees aggregate spillovers are unchanged and all domain constraints are satisfied. Again,

calculate the change in welfare associated with this change:

$$V\left(\vec{\eta}, \vec{\beta}^*\right) \equiv \sum_{i=2}^{n} \left[\sigma_i^2\left(\beta_i^*\right) - \sigma_i^2\left(\tilde{\beta}_i\right)\right] = \left[2\mu\eta_t \left(\left(\phi_t - \phi_k - \mu\omega_t\right) - \mu\eta_t\right)\right] \tag{A4}$$

If $V < 0$, then the original program cannot have been optimal; given $\eta_t < 0$ then:

$$V < 0 \leftrightarrow \phi_t > \phi_k + \mu\omega_t + \mu\eta_t = \phi_k + \mu Max\left(\left(\omega_t - \omega_k\right), 0\right) \tag{A5}$$

Hence, if the inequality is satisfied then $\rho_k^* = 0 \rightarrow \rho_t^* = 0$, proving part (iii). \hspace{2em} QED

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