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WELFARE EFFECTS OF INTELLECTUAL PROPERTY RIGHTS UNDER ASYMMETRIC SPILLOVERS

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Classification Code: F13, O34

Key Words: Commercial Policy; Intellectual Property Rights protection; Trade; Innovation; Imperfect competition

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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 2006. The 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.

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. 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]

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 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.

[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.

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. Further, from the analysis, we identify which southern countries could be benefited through tightening IPR protection. We find that more efficient Southern countries have less incentive to increase spillovers than do less efficient Southern countries. But, from a world welfare perspective, it is better that the more efficient countries expand the 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 welfare effects of spillovers and suggests some implications. The last section provides conclusions.

2. The Model and Solution

There exist 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 the IPR protection level. 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 originally used by Chin and Grossman (1988): $C_1 = \alpha - (\gamma\chi)^{1/2}$, where α describes pre-innovation cost, and γ is a parameter denoting the R&D efficiency. The term, $(\gamma\chi)^{1/2}$, represents the R&D production function, which exhibits diminishing returns to scale with respect to R&D investment, χ.[4] The i^{th} southern firm's unit cost function is $C_i = \alpha - \beta_i(\gamma\chi)^{1/2}$, $i = 2,3,\ldots, n$ where $\beta_i \in (0,1)$ denotes the index of spillovers or the strength of inverse IPR protection as in Žigić (1998). The spillover parameter may consist of two terms: the IPR protection level and a country-specific learning characteristic. The country-specific characteristic may include the country's ability to absorb R&D knowledge,[5] or it may reflect imitation ability. Thus, even if southern countries adopt a common IPR protection level, the value of the spillover parameter may differ across southern countries, depending on their ability to absorb R&D knowledge. Without loss of generality, we order the countries such that:[6] $\beta_2 > \beta_3 > \ldots\ldots > \beta_n$. We assume away two extreme cases, $\beta_i \equiv 0$ and $\beta_i \equiv 1$, which may reflect 'perfect protection' and 'no protection' of intellectual property right, respectively.[7]

[4] For more detail, see D'Aspremont and Jacquemin (1988) and Kamien et al. (1992).

[5] Following Cohen and Levinthal (1989), we may call this ability 'absorptive capacity'.

[6] The amount of spillovers could be a choice variable, depending upon firm expenditures as well as local IPR protection policy. However, throughout this paper we assume spillover expansion in any southern country increases only when IPR protection is relaxed.

[7] We could think of the spillover parameter as depending on (inverse) IPR protection, ρ_i, and the country's ability to absorb knowledge (ω_i). If $\beta_i = \rho_i + \omega_i$, then even if IPR protection is perfect ($\rho_i = 0$), spillovers may occur. The results obtained in this paper do not hold if $\beta_i \equiv 0$.

Note that $\beta_1 \equiv 1$ in our set-up. By construction, the sum of spillovers is less than the number of countries, i.e., $\sum_{j=1}^{n} \beta_j < n$. 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: $P = A - Q$, $Q = \sum q_i$.

The game among *n* countries consists of two stages, and we use the subgame perfect Nash equilibrium. In the first stage, the northern firm chooses R&D investment, χ. In the second stage, *given* the northern firm's R&D investment, the *n* firms engage in Cournot-Nash competition. To find the subgame perfect equilibrium, 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:

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

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

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

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

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

Note that the solution has the well-known property (for linear systems) that the aggregate equilibrium price and quantity depend upon the number of firms and average cost per firm, but not on the distribution of the cost vector $\left(\beta_1,...,\beta_n\right)$. Using (2) and (3) yields:

$$q_i^* = \frac{A-\alpha+\left((n+1)\beta_i-\beta^T\right)(\gamma\chi)^{1/2}}{n+1}; \quad \pi_i^* = \left(q_i^*\right)^2; \quad Q^* = \frac{n(A-\alpha)+\beta^T(\gamma\chi)^{1/2}}{n+1}$$
$$P^* = \frac{A+n\alpha-\beta^T(\gamma\chi)^{1/2}}{n+1} \quad \text{where } \beta^T = \sum_1^n \beta_j < n \tag{4}$$

where the "*" indicates the equilibrium value.

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

$$V_1 = \left(P^*-c_1\right)q_1^*-\chi; \left(\frac{dV_1}{d\chi}\right) = \left[P^*-c_1+P'q_1^*\right]\left(\frac{dq_1^*}{d\chi}\right)+P'q_1^*\left(\sum_{i\neq 1}\left(\frac{dq_i^*}{d\chi}\right)\right)-\left[q_1^*\left(\frac{dc_1}{d\chi}\right)+1\right]=0 \tag{5}$$

By assumption, $P' = (-1)$, and the first term on the RHS of (5) is zero by the FOC for firm (1). The last term on the RHS of (5) reflects the impact of R&D expenditures on firm 1's total costs whereas 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 (4) it is readily seen that:

$$\sum_{i\neq 1}\left(\frac{dq_i^*}{d\chi}\right) = \frac{\left((n+1)\sum_{i\neq 1}\beta_i-(n-1)\beta^T\right)(\gamma/\chi)^{1/2}}{2(n+1)} = \frac{\left(2\beta^T-(n+1)\right)(\gamma/\chi)^{1/2}}{2(n+1)} \tag{6}$$

The sign of (6) depends on β^T, and hence the strategic interaction can increase or decrease firm 1's investment in R&D. If $\beta^T > \left((n+1)/2\right)$, 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 its profits due to the output effect on other firms.[8] Using (4) in (5) and simplifying yields:

$$\left(dV_1/d\chi\right) = \frac{q_1^*\left((n+1)-\beta^T\right)(\gamma/\chi)^{1/2}}{(n+1)}-1=0 \tag{7}$$

It is readily seen that the second order condition holds. Solving (7), using (4), yields:

$$\chi^* \equiv \frac{\gamma\left(A-\alpha\right)^2\Delta^2}{D^2} \text{ where } \Delta \equiv n+1-\beta^T > 1;\ D \equiv \left[\left(n+1\right)^2 - \gamma\Delta^2\right] \tag{8}$$

A meaningful (finite) solution to (8) requires $\left[\left(n+1\right)^2 - \gamma\Delta^2\right] > 0$, which we assume holds. Using equilibrium R&D in (4) yields equilibrium output levels and price:

$$\begin{aligned} q_i^* &= \frac{\left(A-\alpha\right) + \left(\left(n+1\right)\beta_i - \beta^T\right)\left(\gamma\chi^*\right)^{1/2}}{\left(n+1\right)} = \frac{\left(A-\alpha\right)\left(\left(n+1\right) - \gamma\Delta\left(1-\beta_i\right)\right)}{D}; \\ Q^* &= \frac{\left(A-\alpha\right)\left(n\left(n+1\right) - \gamma\Delta\left(n-\beta^T\right)\right)}{D} \end{aligned} \tag{9}$$

The equilibrium R&D level, and hence the aggregate equilibrium, depends on the aggregate spillover $\left(\beta^T\right)$, but not on the distribution of spillovers among firms[9]. For all countries to produce positive amounts, $\gamma < \gamma^n \equiv \dfrac{(n+1)}{(1-\beta_n)\Delta}$ is required, which is equivalent to the condition for the least productive southern country n to produce[10].

It is desirable to compare the condition for the n-firm oligopoly equilibrium to exist in our model with that for the duopoly equilibrium to exist both in Chin and Grossman (1988) and in Žigić (1998). The conditions for the duopoly to exist in Chin and Grossman and in Žigić are $\gamma < 3/2$ and $\gamma < 3/\{(1-\beta)(2-\beta)\}$, respectively. Two countries, the North and the South, are modeled in both papers. Chin and Grossman consider 'perfect protection' of intellectual property right while Žigić assumes that the southern country can take advantage of the benefits from

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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 marginal costs – without R&D – differed across firms $\left(\alpha_i \neq \alpha_j\right)$, the equilibrium level of R&D and thus the aggregate equilibrium would depend on firm 1's cost and average marginal cost, but not the vector of marginal costs.

northern firm's innovation through spillovers. The condition in Chin and Grossman can be recovered in our set-up by setting *n*=2 and $\beta_2 = 0$ while Žigić's condition is obtained by putting *n*=2 and $\beta_2 = \beta$.

Both Chin and Grossman and Žigić consider two more types of equilibria: monopoly and strategic predation. They show that the northern firm will enjoy the pure monopoly position for a sufficiently high value of R&D efficiency parameter (γ) while it will act strategically to induce southern firm's exit (strategic predation) for an intermediate value of R&D efficiency. These two types of equilibria can exist when there is more than one southern country in the world. The monopoly condition[11] in our set-up is $\gamma > \dfrac{2}{1-\beta_2}$. The same condition for the monopoly is obtained in Žigić where only one southern country is assumed. Note $\gamma > 2$ is the condition for the monopoly in Chin and Grossman where they consider perfect protection of intellectual property rights ($\beta = 0$). The condition for strategic predation is $3/2 < \gamma < 2$ and $3/\{(1-\beta)(2-\beta)\} < \gamma < 2/(1-\beta)$ in Chin and Grossman and Žigić, respectively. In our set-up, $(n+1)\Big/\{(1-\beta_2)(n+1-\sum_{j=1}^{n}\beta_j)\} < \gamma < 2/(1-\beta_2)$ is the condition for strategic predation, which is exactly the same condition as in Žigić if we assume that there exists only one southern country in the market.[12] Even though the outcome comparison among these equilibria is an interesting issue, we do not consider these two equilibria since we are interested in investigating the own and cross welfare effects of spillovers in the southern country.

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[10] Note $\gamma^n \equiv \left[(n+1)\Big/\big((1-\beta_n)\Delta\big)\right] < \left[(n+1)^2/\Delta^2\right]$ if $\beta_n < \left(\beta^T/(1+n)\right)$. Note that $\beta_n < (1/2)$ suffices for this condition to hold.

[11] This happens when 'drastic innovation' takes place, that is, for $i = 2,\ldots\ldots, n$, $p^m < C_i(\chi^m)$ where *m* denotes monopoly outcome. Substituting price and R&D with monopoly outcome yields the condition.

[12] The equilibrium R&D investment for strategic predation can be obtained by setting $q_i = 0$ for $i = 2,\ldots\ldots, n$.

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 (8) yields:

$$\left(\frac{d\chi^*}{d\beta_i}\right) \equiv \left(\frac{-2\chi^*}{\Delta}\right) - \left(\frac{2\chi^*(2\gamma\Delta)}{D}\right) = -2\left(\frac{\chi^*}{\psi}\right) < 0; \quad \psi \equiv \left(\frac{\Delta\left[(n+1)^2 - \gamma\Delta^2\right]}{\left[(n+1)^2 + \gamma\Delta^2\right]}\right) > 0 \tag{10}$$

$$\left(\frac{dC_j}{d\beta_i}\right) = -(\gamma\chi^*)^{1/2}\delta_{ij} - (\beta_j/2)(\gamma\chi^*)^{1/2}\left(\frac{d\chi^*}{\chi^* d\beta_i}\right) = (\gamma\chi^*)^{1/2}\left\{-\delta_{ij} + \left(\frac{\beta_j}{\psi}\right)\right\} \tag{11}$$

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, then if β_i is small enough costs fall. Formally:

$$\left(\frac{dC_i}{d\beta_i}\right) \underset{>}{\leq} 0 \quad \text{as} \quad \beta_i \underset{>}{\leq} \psi. \text{ QED} \tag{12}$$

By construction, $\Delta > 1$; thus, for γ sufficiently small, the inequality $(\beta_i < \psi)$ in (12) will be satisfied for all Southern countries. Further, ψ is a decreasing function of γ, so that the larger the R&D efficacy, the less likely it is that a Southern firm will reduce its costs by increasing its spillover.

It is important to note that the impact of increased spillovers on R&D depends only on the aggregate level of spillovers, and not which country is increasing its spillover. On the other hand, the feedback effect of reduced R&D affects the high spillover firms more so that "low spillover" firms have an incentive to increase their spillovers more than do high spillover firms.

Since the value of ψ recurs below, it is worthwhile simplifying the expression. Define:

$$\beta^* \equiv \left(\beta^T/(n+1)\right) < \left(n/(n+1)\right); \quad \psi(\gamma) \equiv \left(\frac{(n+1)(1-\beta^*)\left[1-\gamma(1-\beta^*)^2\right]}{\left[1+\gamma(1-\beta^*)^2\right]} \right) \tag{13}$$

Turning to the impact of increased spillovers on that firm's output, it is clear that 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 aggregate cost increase for all firms. Similarly, it is 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 (4):

$$\left(\frac{dq_j^*}{d\beta_i}\right) = \frac{(\gamma\chi)^{1/2}}{(n+1)} \cdot \left[\left((n+1)\delta_{ij} - 1\right) + \left(\frac{\left(\beta^T - (n+1)\beta_j\right)}{\psi} \right) \right] \tag{14}$$

$$\left(\frac{dQ^*}{d\beta_i}\right)=\left(-\frac{dP}{d\beta_i}\right)=\frac{(\gamma\chi)^{1/2}}{(n+1)}\cdot\left[1+\left(\frac{-\beta^T}{\psi}\right)\right]=\frac{(\gamma\chi)^{1/2}}{(n+1)}\cdot\frac{\left(1-2\beta^*-\gamma\left(1-\beta^*\right)^2\right)}{\left(1-\beta^*\right)\left[1-\gamma\left(1-\beta^*\right)^2\right]} \tag{15}$$

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, then the equilibrium output of a low spillover firm may increase as a result of *some* other firm increasing its spillover rate:

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

iii. If the productivity of R&D investment is not too high, then for low aggregate spillover rates an increase in the spillover rate leads to **higher aggregate equilibrium output; i.e.,**

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

Note that the second order condition requires $\gamma<\left(1-\beta^*\right)^{-2}$; hence, condition (iii) must hold for small spillover rates. This implies that over some interval higher spillover rates benefit consumers as well as some firms. Note that for high aggregate spillover rates $\left(\beta^*>1/2\right)$, then further increases in spillover rates must lower aggregate output.

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:

$$W^j = \pi^j + \theta^j CS = \left(P - C^j\right) q_j^* + \theta^j CS; \quad j \neq 1 \tag{16}$$

where CS is aggregate consumer surplus, θ^j is country *j's* consumer share, and hence $\theta^j CS$ is consumer surplus in country *j*. Differentiate (16) with respect to β_i to obtain:

$$\frac{dW^j}{d\beta_i} = \frac{d\pi^j}{d\beta_i} + \frac{dCS^j}{d\beta_i} = \left[\left(P - C^j\right)\frac{dq_j^*}{d\beta_i} + q_j^*\left(\frac{dP}{d\beta_i} - \frac{dC^j}{d\beta_i}\right)\right] - D^j \frac{dP}{d\beta_i}; \quad j \neq 1 \tag{17}$$

Rearranging terms in (17) yields:

$$\frac{dW^j}{d\beta_i} = \left[\left(X^j \frac{dP}{d\beta_i}\right) - \left(q_j^* \frac{dC^j}{d\beta_i}\right) + \left(P - C^j\right)\frac{dq_j^*}{d\beta_i}\right]; \quad X^j \equiv \left(q_j^* - D^j\right); \quad j \neq 1 \tag{18}$$

where D^j is consumption in country *j*. The first term in (18) 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. The firm's profit maximizing conditions imply:

$$P - C^j - q_j^* = 0; \quad \rightarrow \frac{dq_j^*}{d\beta_i} = \left(\frac{dP}{d\beta_i} - \frac{dC^j}{d\beta_i} \right) \tag{19}$$

Substituting (19) into (18) and rearranging yields:

$$\frac{dW^j}{d\beta_i} = \left[\left(X^j \frac{dP}{d\beta_i} \right) + q_j^* \left(\frac{dP}{d\beta_i} - 2\frac{dC^j}{d\beta_i} \right) \right] = \left[2q_j^* \left(\frac{dP}{d\beta_i} - \frac{dC^j}{d\beta_i} \right) - D^j \frac{dP}{d\beta_i} \right]; \quad j \neq 1 \tag{20}$$

where $\left(dP/d\beta_i\right)$ is given by (15) and $\left(dC^j/d\beta_i\right)$ by (11). Since an increase in the spillover rate in some country *i* will lead to increased unit production costs in all other countries, it immediately follows from (20) that:

Proposition 3: An increase in the spillover rate in Southern country *i* that leads to a lower world price will:

(1)lower welfare in all other Southern countries that are net exporters.

(2)raise welfare in all countries that do not produce the good.

From Proposition 2, the increased spillover rate will lead to lower world prices when both the aggregate spillover rate and the R&D productivity parameter are not too large. Lower world prices, *ceteris paribus*, are bad for exporters and good for importers. Clearly, if β_j is sufficiently low so domestic output is low, then the change in world price is the principal determinant of the impact on domestic welfare. If world price increases, then Southern countries with low output relative to demand must be hurt, whereas countries with no domestic demand will be benefited *if* the price increase offsets the cost increase.

Clearly, how price changes relative to the firm's cost is crucial in determining the welfare impact of an increased spillover rate. From the linearity of the system we have, in general:

$$(n+1)P = A + \sum_k c_k \rightarrow \left(\frac{dP}{d\beta_i} - \frac{dc_j}{d\beta_i} \right) = (n+1)^{-1} \left(\sum_k \frac{dc_k}{d\beta_i} - (n+1)\frac{dc_j}{d\beta_i} \right) \tag{21}$$

$$\left(\frac{dP}{d\beta_i} - 2\frac{dc_j}{d\beta_i} \right) = (n+1)^{-1} \left(\sum_k \frac{dc_k}{d\beta_i} - 2(n+1)\frac{dc_j}{d\beta_i} \right) \tag{22}$$

For $j \neq i$, the firm's costs will rise due to decreased R&D; thus, (21) and (22) imply that, if price (average cost) increases, then countries with sufficiently low spillover rates will see their costs rise less than price, and hence those countries will gain provided they are not big consumers of the good. Using (15) and (11), we have, for the specific functional forms:

$$\left(\frac{dP}{d\beta_i} - \frac{dC_j}{d\beta_i} \right) = (\gamma\chi)^{1/2} \cdot \left[-\frac{1}{n+1} + \delta_{ij} + \left(\frac{\beta^* - \beta_j}{\psi} \right) \right]; \;\; \psi^{-1} \equiv \left(\frac{1+\gamma\left(1-\beta^*\right)^2}{\left(1-\gamma\left(1-\beta^*\right)^2\right)(n+1)\left(1-\beta^*\right)} \right) \tag{23}$$

$$\left(\frac{dP}{d\beta_i} - 2\frac{dC_j}{d\beta_i} \right) = (\gamma\chi)^{1/2} \cdot \left[-\frac{1}{n+1} + 2\delta_{ij} + \left(\frac{\beta^* - 2\beta_j}{\psi} \right) \right] \tag{24}$$

Proposition 4: Suppose the spillover rate increases in Southern country *i*; then in **other** Southern countries:

1. If net exports are zero, then domestic welfare will increase, remain unchanged or

decrease as: $$\beta_j \lesseqgtr \left(\frac{2\beta^* + \gamma\left(1-\beta^*\right)^2 - 1}{2\left(1+\gamma\left(1-\beta^*\right)^2\right)} \right)$$

2. If domestic demand is zero, then domestic welfare will increase, remain unchanged or

decrease as: $$\beta_j \lesseqgtr \left(\frac{2\beta^* + \gamma\left(1-\beta^*\right)^2 - 1}{\left(1+\gamma\left(1-\beta^*\right)^2\right)} \right)$$

The proof follows immediately by substitution and rearrangement. Thus, if the countries are net exporters, (only) low spillover countries can benefit from the increased spillover rate in some other country. Note, however, that if price falls, the expression on the RHS of the inequality is negative, and all net exporters must lose.

The country that increases its spillover rate is likely to benefit, since even though R&D falls, the country appropriates more of the existing stock of knowledge. For a low spillover country, it is fairly clear that it must benefit. Specifically:

Proposition 5: An increased spillover rate in country *i* will have the following impact on that country:

1. If net exports are zero, then domestic welfare will increase, remain unchanged or

decrease as: $$\beta_i \lesseqgtr \hat{\beta}_i = \left(\frac{1 + 2n\left(1-\beta^*\right) - \gamma\left(1-\beta^*\right)^2 \left(2\left(n+1\right)\left(1-\beta^*\right)-1\right)}{2\left(1+\gamma\left(1-\beta^*\right)^2\right)} \right)$$

2. If domestic demand is zero, then domestic welfare will increase, remain unchanged or decrease as: $\beta_i \underset{>}{\leq} \tilde{\beta}_i = \left(\frac{1+(n-1)(1-\beta^*) - \gamma(1-\beta^*)^2((n+1)(1-\beta^*)-1)}{(1+\gamma(1-\beta^*)^2)} \right)$

The proof follows by substitution. Note that both $\hat{\beta}_i$ and $\tilde{\beta}_i$ are decreasing functions of γ; for low R&D productivity, the country increasing its appropriation of foreign technology must gain. However, if γ is large enough it is possible that the country could lose from doing so[13]; since the SOC requires $\gamma(1-\beta^*)^2 < 1$ then a sufficient condition is:

Corollary:

1. If country *i* increases its spillover rate and its net exports are zero, then a sufficient condition for its welfare to improve is: $\beta_i \leq (\beta^*/2)$
2. If country *i* increases its spillover rate and its domestic consumption of this good is zero, then a sufficient condition for its welfare to improve is: $\beta_i \leq \beta^*$

Clearly, then, countries with current low spillover rates have an incentive to increase their absorption of foreign knowledge (i.e., they have less incentive to strengthen IPR).

Next, consider the impact of the increased spillover rate on the Northern country. Rewriting the profit function for the Northern firm:

$$\pi_1 = (P(Q) - c_1)q_1 - \chi \tag{25}$$

Totally differentiating and using the FOC yields:

[13] Of course, if the firm's profits fall – which implies a decline in domestic welfare if there is no consumption, then presumably a rational firm would not increase its spillover rate.

$$\frac{d\pi_1}{d\beta_i} = \left(P - c_1\right)\left(\frac{dq_1^*}{d\beta_i}\right) + q_1^*\left(P'\left(\frac{dQ}{d\beta_i}\right) - \frac{dc_1}{d\chi}\frac{d\chi^*}{d\beta_i}\right) - \frac{d\chi^*}{d\beta_i} \quad \text{where:} \tag{26}$$

$$\frac{dQ}{d\beta_i} = \frac{dq_1^*}{d\beta_1} + \sum_{j\neq 1}\left(\frac{\partial q_j^*}{\partial \beta_i} + \frac{\partial q_j^*}{\partial \chi}\frac{\partial \chi^*}{\partial \beta_i}\right) \tag{27}$$

Substituting (27) into (26) and rearranging yields:

$$\frac{d\pi_1}{d\beta_i} = \left(P - c_1 - q_1^*\right)\left(\frac{dq_1^*}{d\beta_i}\right) - \left(q_1^*\frac{dc_1}{d\chi} + 1 + \sum_{j\neq 1}\left(\frac{\partial q_j^*}{\partial \chi}\right)\right)\left(\frac{d\chi^*}{d\beta_i}\right) - q_1^*\sum_{j\neq 1}\left(\frac{\partial q_j^*}{\partial \beta_i}\right) = -q_1^*\sum_{j\neq 1}\left(\frac{\partial q_j^*}{\partial \beta_i}\right) \tag{28}$$

where the first two terms on the RHS vanish due to the envelope theorem. The impact of an increase in β_i on firm 1's profits is due to the increase in output of all Southern firms, given the level of R&D. From (4), $\sum_{j\neq 1}\left(\partial q_j^* / \partial \beta_i\right) = \left(2\left(\gamma\chi\right)^{1/2} / (n+1)\right) > 0$ so, not surprisingly, the profits of the Northern firm must fall. The impact on welfare then hinges on how consumer surplus changes; a resulting increase in world prices – due to the reduced R&D - must hurt the North, while it might gain if prices fall. Formally:

$$\frac{dW_1}{d\beta_i} = -D^1\frac{dP}{d\beta_i} + \frac{d\pi_1}{d\beta_i} = \left(\frac{\left(\gamma\chi\right)^{1/2}}{(n+1)}\right)\left(D^1 \cdot \left\{\frac{1 - 2\beta^* - \gamma\left(1-\beta^*\right)^2}{\left(1-\beta^*\right)\left(1+\gamma\left(1-\beta^*\right)^2\right)}\right\} - 2q_1^*\right) \tag{29}$$

Proposition 6: A sufficient condition for increased spillovers to harm the North is $q_1^* \geq (D^1/2)\cdot((1-2\beta^*)/(1-\beta^*))$. If world price rises, the North must be hurt.

Proof: From (29), the term inside the $\{\ \}$ on the RHS is a decreasing function of γ. Thus, the term inside the parentheses reaches a maximum at $\gamma = 0$, from which the result follows. If world price increases both terms on the RHS are negative and hence $\left(dW_1/d\beta_i\right) < 0$.

QED

Finally, consider the impact of increased spillovers on **world** welfare (the sum of surpluses in all countries). This can be obtained by summing (17) over all Southern countries and adding (29), or directly from the definition of welfare[14]:

$$W^T \equiv \int_0^Q P(y)\,dy - \left(\sum_{j=1}^{n} c_j(\chi, \beta_j) q_j \right) - \chi; \quad Q = \sum_{j=1}^{n} q_j \tag{30}$$

where W^T stands for world ("total") welfare. Differentiating (30) yields:

$$\frac{dW^T}{d\beta_i} \equiv \sum_{j=1}^{n} (P - c_j) \frac{dq_j^*}{d\beta_i} - \sum_{j=1}^{n} \left(q_j^* \frac{dc_j}{d\beta_i} \right) - \frac{d\chi^*}{d\beta_i}; \tag{31}$$

The first term represents the surplus created from increased output since in the original equilibrium price exceeded marginal cost while the second and third terms (collectively) represent the surplus created by the net reduction in production costs. It is well known that in the linear model total output, and hence price, depends only upon average marginal cost of the firm, while total profits depends upon the variance of the cost vector. Hence, **if** all firms were alike, a sufficient condition for total welfare to increase as a result of the increased spillover is that total output did not fall, since expenditures on R&D fall and since total output moves in the opposite direction from average cost. *However*, since the output vector of the firms matters, we are also concerned with whether the proportion of output produced by the low cost firms rises or falls (i.e., whether the variance of the cost vector rises or falls).

Formally, from (3) and (4):

$$P = \left(\frac{A + n\overline{c}}{n+1} \right); Q = \left(\frac{n(A - \overline{c})}{n+1} \right); \quad \overline{q} \equiv \left(\frac{Q}{n} \right); \overline{c} \equiv \frac{\sum_{i=1}^{n} c_i}{n} = \alpha - \overline{\beta} (\gamma\chi)^{1/2}; \; \overline{\beta} \equiv \frac{\sum_{i=1}^{n} \beta_i}{n} = \frac{\beta^T}{n} \tag{32}$$

Define:

[14] Note that the consumption value depends only on total output (consumption) whereas the costs depend on the output vector, not just total output. The reason for the former is that price is equal for all consumers, while the latter

$$\varepsilon_j = \left[\left(\beta_j - \bar{\beta}\right)\left(\gamma\chi\right)^{1/2}\right] \rightarrow c_j = \bar{c} - \varepsilon_j; \quad q_j = \bar{q} + \varepsilon_j \text{ where, by construction: } \sum_{j=1}^{n} \varepsilon_j = 0 \qquad (33)$$

Thus, (30) and (31) can be rewritten as:

$$W^T = AQ - \left(Q^2/2\right) - \bar{c}Q + \sum_j \varepsilon_j^2 - \chi = \left(\left(n+2\right)/2n\right)Q^2 - \chi + \sum_j \varepsilon_j^2 \qquad (34)$$

$$\frac{dW^T}{d\beta_i} = \left(\left(n+2\right)/n\right)\frac{Qd\left(Q\right)}{d\beta_i} - \frac{d\chi}{d\beta_i} + \frac{d\left(\sum_j \varepsilon_j^2\right)}{d\beta_i} \qquad (35)$$

Thus, (34) shows the role played by both average costs and the "variance" of these costs, while (35) reaffirms the claim – if we could ignore the impact of this variance – that if output does not decrease, total welfare must increase since we know $\left(d\chi/d\beta_i\right) < 0$. Using (33):

$$\frac{d\left(\sum_j \varepsilon_j^2\right)}{d\beta_i} = (2\gamma\chi)\left(\left(\beta_i - \bar{\beta}\right) + \sigma_\beta^2\left(\frac{d\chi}{d\beta_i}\right)\left(\frac{1}{2\chi}\right)\right) = (2\gamma\chi)\left(\left(\beta_i - \bar{\beta}\right) - \left(\frac{\sigma_\beta^2}{\psi}\right)\right); \sigma_\beta^2 \equiv \sum_{j=1}^{n}\left(\beta_j - \bar{\beta}\right)^2 \qquad (36)$$

where $\psi > 0$ is defined earlier. Thus, if $\beta_i \leq \bar{\beta}$, the variance in the cost structure is reduced (due to reduced R&D), and this tends to lower welfare, whereas for $\beta_i > \bar{\beta}$ the change on the variance of cost is ambiguous. Turning to the first two terms in (35) we have:

$$\left(\frac{n+2}{n}\right)\frac{Qd\left(Q\right)}{d\beta_i} - \frac{d\chi}{d\beta_i} = \left(\frac{\chi}{\psi}\right)\left\{\left(\frac{n+2}{n+1}\right)\left(\frac{1-\gamma m\left(1-\bar{\beta}\right)}{m}\right)\left(\psi - \beta^T\right) + 2\right\}; \quad m \equiv \left(1-\beta^*\right) \qquad (37)$$

While this expression can be further simplified, there is not much more learned by doing so. Thus, we conclude:

Proposition 7: Given an increased spillover rate in one country, then:

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applies because marginal cost is **not** equalized across firms.

1. Total welfare is more likely to increase when this increase in spillover occurs in a country which already has a high spillover rate.
2. Total welfare will increase when aggregate output increases, provided the dispersion in spillover rates is not too large.

5. Conclusions

This paper has investigated welfare effects of spillovers due to relaxed IPR protection. Unlike previous studies where two countries, North and South, are modeled, we consider the situation where there exist many southern countries in the market. One important feature in the model is to distinguish southern countries according to the absorptive capacity to realize spillovers. This is crucial in analyzing the conflicts among southern countries on the issue of IPR protection. A number of results are obtained from the analysis. 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. It is clear that a firm's output will increase if its unit production costs decrease with spillovers. 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; what matters is how much its costs increase compared to the aggregate cost increase for all firms. Similarly, the output of a "low-spillover" firm may increase as a result of some other firm increasing its spillover rate.

The welfare of each Southern country consists of its firm's profits and consumer surplus. When an increase in the spillover rate leads to a lower world price, Southern countries with high output relative to demand (net exporters) are hurt, whereas southern countries with no domestic demand are benefited. On the other hand, when world price increases with the spillover expansion in a southern country, Southern countries with low output relative to demand must be hurt, whereas countries with no domestic demand will be benefited if the price increase offsets the cost increase. The Northern firm is always hurt whenever the spillover rate in a Southern country increases because it results in the decline of Northern firm's output, but the increase in collective output of all Southern countries. A resulting increase of world price, therefore, must hurt the North, while it might gain if prices fall.

Note that more efficient Southern countries have less incentive to increase the spillover than do less efficient countries. The reason is, as shown above, the feedback effect of reduced R&D impacts the high spillover firms more than low spillover firms. But, from a world welfare perspective, it is better that the more efficient countries expand their spillover. This implies that private and social incentives may not be coordinated. One thing to note is that the one-size fits all agreement is probably not optimal because the ability to absorb the Northern knowledge is different among Southern countries.

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 μ_i is the cost of reverse-engineering and α_i is a country-specific parameter. Given a vector of α, 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, the direct extension of this paper would be to investigate optimal patent policy in terms of domestic welfare or how to reach an agreement on IPR protection that is Pareto improving.

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