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Technical Annex

**The TRIPS Disagreement:
Should GATT Traditions Have Been Abandoned?**

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This document is the technical annex to the full paper “The TRIPS Disagreement: Should GATT Traditions Have Been Abandoned?” which is available separately.

Basic Components of the Model

This annex presents a North-South model of patent protection in which there is a single innovating firm located in North. The model lies within the tradition of Nordhaus’s pioneering work on optimum patent protection (Nordhaus, 1969, 70-90; Kaufer, 1989, 24-32; Gilbert and Shapiro, 1990; Klemperer, 1990). Whereas Nordhaus considered a single country, Chin and Grossman (1990), Diwan and Rodrik (1991), Deardorff (1992), Helpman (1993), Richardson and Gaisford (1996), and Markusen (1998), have introduced various international issues concerning developing countries from a theoretical point of view. Empirical studies by Maskus and Penebarti (1995), Lee and Mansfield (1996), and Smith (1999) have examined how trade volumes and foreign direct investment are linked to property protection.

In order to simplify the interaction between countries in our model, we assume that the probability of successful new-product innovation increases as R&D invest-

ment increases but, in the event of success, the unit cost of production is given. By contrast, in Nordhaus (1969) and most of the other models, the innovation of a new process is certain to be successful, with the unit cost of production falling as R&D expenditure increases. At the first stage of the game the governments of both North and South set patent durations, and at the second stage the firm invests optimally. Since the governments can deduce how the firm will behave prior to setting their patents, it is necessary to solve the game backwards and focus on investment in R&D first.

R&D activity is assumed to be risky. The Northern firm can invest in R&D in order to enhance the probability that a new product will be successfully developed. Given that I denotes the firm's investment in R&D, the probability of a successful innovation occurring is $\pi(I)$. As investment in R&D increases, the probability of a successful innovation increases, but each additional R&D dollar has less impact (i.e., $\pi'(I) > 0$ and $\pi''(I) < 0$). In order to simplify the algebra that follows, it will be assumed that the probability function has the following form.

$$\pi(I) = \begin{cases} \pi_0 + \alpha I^{1/2} & \text{if } I \leq \left(\frac{1-\pi_0}{\alpha}\right)^2 \\ 1 & \text{if } I > \left(\frac{1-\pi_0}{\alpha}\right)^2 \end{cases} \quad (1)$$

where: $0 < \pi_0 < 1$, $\alpha > 0$

Here, π_0 is the probability of spontaneous innovation (i.e., without investment in R&D), and α is an R&D coefficient. If the firm chooses $I = \left(\frac{1-\pi_0}{\alpha}\right)^2$, then $\pi = 1$ and the firm is certain to obtain the innovation.

When an innovation is successful, it will be assumed that the new product has a constant unit cost of production, c , regardless of where it is produced. Thus, there is no producer surplus associated with the competitive provision of the new product in either country. By utilizing this simple cost structure, the model abstracts from any producer-side benefits of enhanced IP protection such as those that might arise from technology transfer and direct foreign investment.

The prices pertaining to the Northern and Southern markets will be represented by p_N and p_S respectively, and the corresponding quantities will be represented by q_N and q_S . It will be assumed that both countries have linear inverse demand functions with the same intercept.

$$p_i = a - b_i q_i, \quad i = N, S \quad (2)$$

Figure 1 shows the Northern and Southern markets. Given that North has a larger market for technology-intensive goods than South, $b_N < b_S$. The competitive and monopoly prices and quantities for this market are as follows:

$$p_i = c, \quad q_i = \frac{a-c}{b_i}, \quad i = N, S ; \quad (3)$$

$$p_i^M = p^M = \frac{a+c}{2}, \quad q_i^M = \frac{a-c}{2b_i}, \quad i = N, S \quad (4)$$

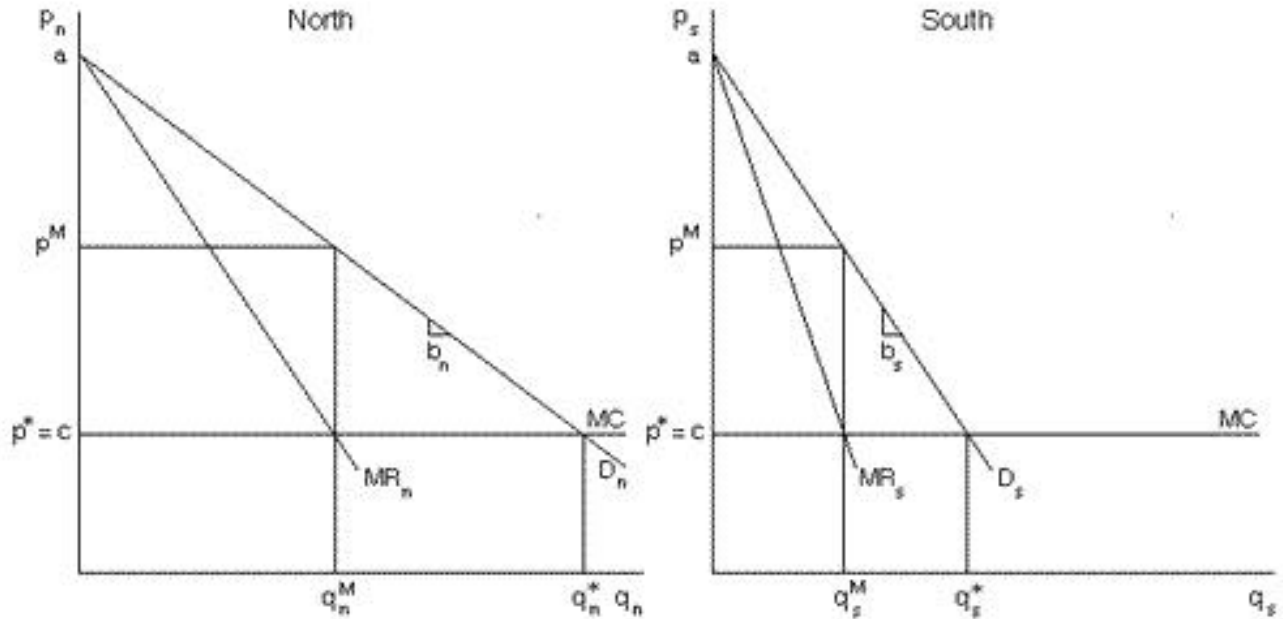


Figure 1 The markets of North and South

Because the intercepts of the linear demand functions are the same, the monopoly prices for each market are the same regardless of whether the two markets are segmented or integrated. This property of uniform, monopoly prices is convenient for two reasons. First, whenever both countries have patents in force, price discrimination is not a consideration and therefore dumping and anti-dumping issues will not arise. Second, in any market that is patent-protected, the price is always the same regardless of the state of patent protection on the other market. While the monopoly price is the same in both markets, the quantity demanded will be larger in North given that North has a larger market for technology-intensive goods than South (i.e., $b_N < b_S$).

Let V_i denote the maximum present value of consumer surpluses that could arise from the new product on country “ i ’s” market (e.g., if the good were produced competitively from the outset), and let r denote the discount rate.

$$V_i = \frac{(a-c)^2}{rb_i}, \quad i = N, S \tag{5}$$

It is useful to define the South-versus-North relative market size parameter, $V_S/V_N = b_N/b_S$. Given that North has a larger market for technology-intensive goods than South, < 1 . It is also helpful to let (i) Y_i denote the present value of monopoly profits on market “ i ” over an infinite horizon, (ii) X_i denote the present value of the consumer surplus generated under monopoly over an infinite horizon, and (iii) Z_i denote the present value of the deadweight loss generated by monopoly over an infinite horizon. Because the demand functions are linear and the unit costs of production are constant, the following relationships must hold:

$$V_i = X_i + Y_i + Z_i = 2Y_i = 4X_i = 4Z_i, \quad i = N, S \tag{6}$$

Since time is to be treated as a continuous variable, it would be accurate to speak of infinitesimally short periods and an instantaneous discount rate. Nevertheless, it is clearer to frame the discussion in terms of one-year periods and annual discount rates.

Suppose that T_N and T_S denote the patent lengths of North and South, while α_N and α_S denote the present value of receiving one dollar for T_N and T_S years respectively.

$$\alpha_i = 1 - e^{-rT_i}, \quad i = N, S \quad (7)$$

Notice that α_N and α_S effectively measure the fraction of the maximum possible patent protection that is effectively extended by North and South. Thus, if country “ i ” provides no patent protection then $\alpha_i = 0$, but if patents are protected forever, then $\alpha_i = 1$ and the fraction of possible patent protection on country “ i ’s” market will be 100 percent. Of course, increases in patent life always serve to increase the fraction of possible protection.

Stage 2: Profit-Maximizing R&D Investment

Since both governments anticipate the profit-maximizing actions of the firm, it is necessary to examine the (stage 2) behaviour of the firm before turning to the (stage 1) game between the governments. The innovating firm’s expected profit, E , will be given by its probability-weighted profits in the markets of both North and South minus the investment in R&D.

$$\begin{aligned} E &= (I)[\alpha_N Y_N + \alpha_S Y_S] - I \\ &= 0.5V_N \left[1 + I^{0.5} \right] [\alpha_N + \alpha_S] \end{aligned} \quad (8)$$

Since α_N and α_S are fractions of the maximum patent protection that are given by North and South, $\alpha_N Y_N$ and $\alpha_S Y_S$ are the discounted profits in the Northern and Southern markets for T_N and T_S years respectively. Profit-maximization requires that the marginal benefit of an extra dollar of R&D investment equals the marginal cost of investment, which is one dollar.

$$\frac{V_N}{4I^{0.5}} [\alpha_N + \alpha_S] = 1 \quad (9)$$

This first-order condition can be solved for the firm’s optimal R&D investment level, I^M , which in turn can be substituted back into the probability function.

$$I^M = \frac{V_N [\alpha_N + \alpha_S]^2}{4} \quad (10)$$

$$(I^M) = \frac{2V_N}{4} [\alpha_N + \alpha_S], \text{ where: } \frac{4}{2V_N} \quad (11)$$

The smaller the R&D effectiveness parameter, α , the more powerful the R&D investment relative to spontaneous innovation.

If neither country provided any patent protection, then there would be no R&D investment in this model. An increment of α_N units to α_S is always a perfect substitute for one unit to α_S in terms of increasing the probability of success and stimulating R&D investment by the firm. North and South consider the indirect effects of their patent choices on the probability of successful investment when they determine their patent lengths.

Stage 1: The Patent Game

With a successful innovation North would receive: X_N , which is consumer surplus associated with monopoly; Y_N , which is monopoly profit for the Northern market for the first T_N years and additional consumer surplus thereafter; $(1 - \alpha_N)Z_N$, which is a further addition to consumer surplus after the Northern patent comes off; and $\alpha_S Y_S$, which is monopoly profit earned on the Southern market for the first T_S years. North's expected welfare gain from innovation is obtained by deducting the costs of investment in R&D from the probability-weighted benefits of successful innovation. For simplicity we assume that the countries are risk neutral.

$$\begin{aligned} EW_N &= (I) [X_N + Y_N + (1 - \alpha_N)Z_N + \alpha_S Y_S] - I \\ &= 0.25 (V_N)^2 [(\alpha_N + \alpha_S)(1 - 0.25 \alpha_N + 0.5 \alpha_S) + 0.25 (\alpha_N + \alpha_S)^2] \end{aligned} \quad (12)$$

This equation shows how Northern welfare depends on α_N and α_S , and it is the basis for indifference curves (or iso-welfare curves) such as EW_N^{NE} shown in figure 2. Northern welfare is an increasing function of the extent of Southern protection given that the fraction of maximum protection given by each country must lie within the

In figure 2, the Northern reaction function is R_N . The negative slope of the reaction function arises because of the free-rider problem. If South were to increase its patent length, there would be a positive externality for North. Thus, North would gain from decreasing its patent protection. The bliss point for North is at point *A* in figure 2 because Northern welfare is increasing in Southern patent protection. Here South provides maximum patent protection and North typically provides limited protection. It is reasonable to restrict attention to situations where $\beta < 4$ and the North provides some patent protection even if the South does not.

If innovation occurs, South would receive: X_S , which is the consumer surplus that arises with monopoly, and $(1 - \beta_S)[Y_S + Z_S]$, which is an addition to consumer surplus after the Southern patent comes off. While no monopoly profits accrue in South, it is important to emphasize that no R&D costs are borne by South. Thus, South's expected welfare gain from innovation is simply its probability-weighted benefits from innovation.

$$\begin{aligned} EW_S &= (I) [X_S + (1 - \beta_S)(Y_S + Z_S)] \\ &= 0.25 (\beta_N)^2 [(\beta_N + \beta_S)(1 - 0.75 \beta_S)] \end{aligned} \tag{14}$$

This equation generates indifference curves for South such as EW_S^{NE} in figure 2. Since increases in North's patent protection raise South's welfare, South is better off at all points above indifference curve EW_S^{NE} than it is on the curve.

Maximizing South's expected welfare with respect to β_S yields South's reaction function, which appears as R_S in figure 2.

$$\beta_S = \frac{2}{3} - \frac{1}{2} - \frac{1}{2} \beta_N \tag{15}$$

South's reaction function also has a negative slope because of the free riding. As North increases its patent length South can take advantage by reducing its protection. The bliss point for South would be point *B* in figure 2. Here North provides infinite patent protection, while South provides a minimal level of protection (or possibly no protection at all).

The Nash Equilibrium in Patents

In figure 2, the Nash equilibrium is at point NE , where the reaction functions of North and South intersect. The configuration of reaction functions and the Nash equilibrium closely resemble situations where public goods are privately provided (Cornes and Sandler, 1986, chapter 5). The parallel arises because free riding is common to both situations. The Nash equilibrium fractions of maximum patent protection for the two countries can also be determined by simultaneously solving the two reaction functions.

$$x_N^{NE} = \begin{cases} \frac{24 - 4 - 3}{21} & \text{if } 16 \geq 12 + 9 \\ 1 - \frac{1}{4} & \text{if } 16 < 12 + 9 \end{cases} \quad (16)$$

$$x_S^{NE} = \begin{cases} \frac{16 - 12 - 9}{21} & \text{if } 16 \geq 12 + 9 \\ 0 & \text{if } 16 < 12 + 9 \end{cases} \quad (17)$$

It is important to note the asymmetry of the equilibrium. Provided that the Northern market is at least as large as that of South (i.e., $\beta \geq 1$), Northern IP protection must exceed that of South (i.e., $x_N^{NE} > x_S^{NE}$). This asymmetry arises because all of the monopoly profits accrue to the Northern firm and, consequently, South has a greater incentive to free ride. There is a possibility that the reaction functions will not intersect in the interior of the diagram and thus boundary equilibria must also be considered. When this occurs, the Nash equilibrium involves zero patent protection in South as shown in figure 3. An internal equilibrium will occur if and only if $16 \geq 12 + 9$.

North's and South's Nash equilibrium expected welfare gains from innovation can be obtained by substituting from equations (16) and (12) into equations (12) and (14).

$$EW_N^{NE} = \begin{cases} \frac{(V_N)^2}{784} [32\beta^2 + 64 - 32\beta^2 + 48 + 48\beta + 32] & \text{if } 16 \geq 12 + 9 \\ \frac{(V_N)^2}{128} [\beta^2 + 24 + 16] & \text{if } 16 < 12 + 9 \end{cases} \quad (18)$$

$$EW_S^{NE} = \begin{cases} \frac{(V_N)^2}{784} [48\alpha^2 + 96\alpha + 27\alpha^2 + 72\alpha + 72 + 48] & \text{if } \alpha \geq 1 \\ \frac{(V_N)^2}{16} [3 + 4\alpha] & \text{if } \alpha < 1 \end{cases} \quad (19)$$

The formulae for Northern and Southern welfare depend upon whether there is an internal or boundary Nash equilibrium.

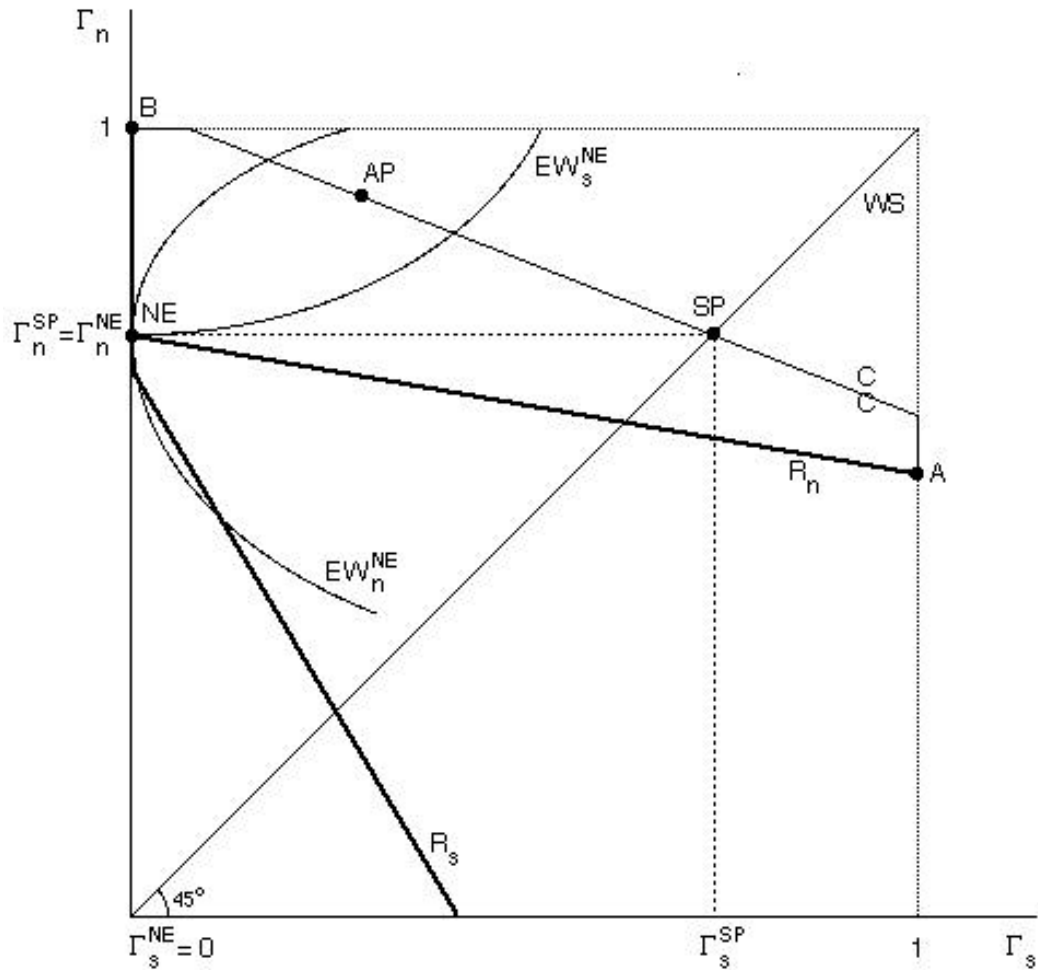


Figure 3 A boundary equilibrium

There is a sense in which the Nash equilibrium favours South. Provided the Northern market is at least as large as the Southern market (i.e., $\alpha \geq 1$), the ratio of South's

Nash equilibrium gain from innovation to that of North must exceed the ratio of South's market size to that of North. In the case of a boundary equilibrium, EW_S^{NE}/EW_N^{NE} , since $\beta < 4$, and for an internal equilibrium, $EW_S^{NE}/EW_N^{NE} > 1$. For example, if North and South have the same market size (i.e., $\beta = 1$), then South's expected welfare at the Nash equilibrium would be greater than that of North (i.e., $EW_S^{NE} > EW_N^{NE}$). This Southern advantage arises because R&D investment is a Northern cost that is greater than the profit earned by the firm in the Southern market given the extent of free riding by South. Thus, there is a potential downside to being the only country with R&D capability.

If both countries agree to simultaneously increase their patent protection, they both can be made better off because they overcome the free-rider problem arising from the public goods feature of patents. In figure 2 or 3, a move into the lens formed by North's and South's Nash equilibrium indifference curves would be beneficial to both nations. This implies the possibility of a mutually beneficial but asymmetric IP agreement. An example of such a mutually beneficial asymmetric position is point *AP* in figure 2.

Pareto Efficient Patent Combinations

When a patent is the only instrument that is available to stimulate R&D investment, world efficiency requires that Northern and Southern patents are set such that Northern expected welfare cannot be increased without reducing Southern welfare, and vice versa. Thus, the fractions of maximum patent protection offered by North and South could be chosen in order to maximize North's expected welfare subject to South obtaining a particular level of expected welfare. This turns out to be equivalent to maximizing the worldwide expected net benefits of innovation, because an increment of β units to β_N is always a perfect substitute for one unit to β_S in terms of increasing probability of success and stimulating R&D investment by the firm.

If innovation occurs, the world would receive: $X_N + X_S$, which is the consumer surplus that arises with monopoly; $Y_N + Y_S$, which is monopoly profit over the lives

of the patents and additional consumer surplus thereafter; and $(1 - \tau_N)Z_N + (1 - \tau_S)Z_S$, which is a further addition to consumer surplus after the patents expire. Thus, the worldwide expected welfare gain from innovation is obtained by deducting the costs of investment in R&D from the probability-weighted benefits.

$$EW_W = (I) [X_N + X_S + Y_N + Y_S + (1 - \tau_N)Z_N + (1 - \tau_S)Z_S] - I$$

$$= 0.25(V_N)^2 \left[(1 + \tau_N + \tau_S)(1 + \tau_N - 0.25\tau_N + 0.25\tau_S) - 0.25(\tau_N + \tau_S)^2 \right] \quad (20)$$

The (same) equation for the contract curve or locus of efficient points can be obtained by maximizing world expected welfare with respect to either τ_N or τ_S .

$$\tau_N = 1 + \frac{-\tau_S}{4} - \tau_S \quad (21)$$

The locus of efficient positions represented by this equation is shown as the contract curve, *CC*, which connects the Northern and Southern bliss points, *A* and *B*, in both figures 2 and 3.

Worldwide Standards for Patent Protection

It is informative to consider the case where there is an agreement on a common worldwide standard for patents such that $\tau_N = \tau_S = \tau_{WS}$. Of course, such points of symmetric patent protection fall on the 45° World Standard (*WS*) line in figures 2 and 3. The Northern and Southern gains from innovation conditional on equal worldwide patent protection, EW_N^{WS} and EW_S^{WS} , can be calculated from equations (12) and (14).

$$EW_N^{WS} = 0.25(V_N)^2 \left[(1 + \tau_{WS} - 0.25\tau_{WS} + 0.5\tau_{WS}^2) - 0.5(1 + 0.5\tau_{WS} - 0.5\tau_{WS}^2) \right] \quad (22)$$

$$EW_S^{WS} = 0.25(V_N)^2 \left[(1 + \tau_{WS} - 0.75\tau_{WS}) - 0.75(1 + \tau_{WS}^2) \right] \quad (23)$$

While South tends to reap more benefits from innovation than North relative to its market size at the Nash equilibrium, the reverse must be true with any agreement on worldwide standards for patents. Regardless of the duration of the standard world-

wide patent, the Southern gain from innovation relative to that of North must be smaller than the size of the Southern market relative to that of North (i.e., $EW_S^{WS}/EW_N^{WS} < 1$). For example, if $\beta = 1$ and consumer surplus were the same on both markets, Northern welfare would have to exceed Southern welfare in any symmetric position because of the presence of positive profits generated by R&D (i.e., $EW_N^{WS} > EW_S^{WS}$).

It is also possible to determine the symmetric efficient position where the two countries have the same patent lengths and world efficiency prevails. The efficient worldwide standard for patent protection, β^{SP} , is calculated by setting $\beta_N = \beta_S$ in the contract curve equation (21).

$$\beta^{SP} = 1 - \frac{1}{4(1 + \beta)} \tag{24}$$

The symmetric efficient position is shown as *SP* in figures 2 and 3. Given that $\beta < 4$, the symmetric efficient position always involves strictly positive patent protection.

The expected welfare levels of North and South in the symmetric efficient position, EW_N^{SP} and EW_S^{SP} , can be obtained by substituting β^{SP} into the expected welfare equations (22) and (23).

$$EW_N^{SP} = \frac{(V_N)^2}{256} (16\beta^2 + 48\beta - 7\beta^2 + 36 + 24) + \frac{1}{1 + \beta} (9 + 12\beta + 12) + 32 \tag{25}$$

$$EW_S^{SP} = \frac{(V_N)^2}{256} (16\beta + 12 + 24) + \frac{1}{1 + \beta} (9 + 12\beta + 12) + 16 \tag{26}$$

Since the symmetric efficient position involves a worldwide standard, South's gain from innovation relative to that of North must be smaller than the size of the Southern market relative to that of North (i.e., $EW_S^{SP}/EW_N^{SP} < 1$). Given that $\beta < 4$, it follows that $36 - 7\beta^2 + 32$ (in equation 25) is greater than $12 + 16$ (in equation 24).

The Impact of Moving to an Efficient Worldwide Standard

The patent protection that is provided by South at the symmetric efficient position must be greater than that which prevails at the Nash Equilibrium, but Northern IP protection at the symmetric point could be higher or lower than at the Nash Equilibrium. Notice that the symmetric efficient point must lie to the right of North's Nash Equilibrium indifference curve and, thus, a move to this position would be welfare enhancing for North. Yet, this symmetric position may well be below South's Nash equilibrium indifference curve as shown in figures 2 and 3. In such cases, a move from the Nash equilibrium to the efficient point would have a negative impact on South's welfare. Suppose that the level of patent protection that North offers at the symmetric efficient point happens to be less than or equal to that at the Nash equilibrium. This is a sufficient, but by no means necessary, condition for South to be worse off at the symmetric efficient point than at the Nash equilibrium. Since the move to common world standards in the TRIPS agreement does not involve significant increases in IP protection by the developed countries of the North, it is very likely that the Southern countries as a group will lose.

There are no plausible parameter values for which South would gain from a move to the symmetric efficient position. Table A.1 indicates that South's expected gain from innovation at the symmetric efficient position relative to the Nash equilibrium is always less than one given plausible ranges for the parameters (i.e., if $0 < \beta < 2$ and $0 < \gamma < 4$, then $EW_S^{SP}/EW_S^{NE} < 1$). Given that North would always wish to impose positive patents, β must be less than 4. Since it is reasonable to presume that North has a larger market for technology-intensive goods than South, γ is most certainly less than 2.

Perhaps the most reasonable value of the relative market size parameter is $\gamma = 0.25$, while that of the R&D effectiveness parameter is $\beta = 1.84$. Suppose that North consists of all countries that had a per-capita GNP of more than US \$ 12,000 in 1988, while South consists of all other countries. If the ratio of total GNP of the Southern group of countries to that of the Northern countries were used as a proxy

Table A.1 South's "Gains" from a Move to the Symmetric Efficient Position

(EW_S^{SP}/EW_S^{NE} ; 1.0 = 100%)

$\phi \setminus \theta$	0.00	0.25	0.50	0.75	1.00	1.5	2.0	2.5	4.0
0.00	0.25	0.30	0.34	0.39	0.44	0.53	0.63	0.72	1.00
0.25	0.31	0.35	0.38	0.42	0.46	0.53	0.60	0.68	0.90
0.50	0.38	0.40	0.43	0.45	0.48	0.54	0.60	0.66	0.84
0.75	0.44	0.45	0.47	0.49	0.51	0.56	0.60	0.65	0.81
1.00	0.51	0.51	0.51	0.53	0.54	0.57	0.61	0.65	0.78
1.25	0.57	0.57	0.57	0.57	0.57	0.60	0.63	0.66	0.77
1.50	0.61	0.61	0.61	0.61	0.61	0.62	0.64	0.67	0.76
1.75	0.65	0.65	0.65	0.65	0.65	0.65	0.66	0.68	0.75
2.00	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.69	0.75

The values in the shaded area represent internal equilibria, while all other values are boundary equilibria.

The most plausible values appear in the unshaded box.

for the South-to-North market size ratio, then θ would be equal to 0.248 based on data from Husted and Melvin (1993, table 1.1). Now suppose that the 20-year patent lengths in the TRIPS agreement happen to be efficient. If the discount rate were 0.05 and ϕ were equal to 0.248, then θ would be equal to 1.84. Under such circumstances the model indicates that South's expected gains from innovation at the symmetric ef-

ficient position would only be between 53 percent and 60 percent of the expected gains at the Nash equilibrium.

Since the underlying analysis has overstated the North-South differences in innovative capability and abstracted from possible producer-side gains from technology transfer and direct foreign investment, these quantitative results may overstate the reduction in Southern benefits from innovation. Further research could introduce additional firms that are potential innovators (Stoneman, 1987). If at least a small proportion of innovating firms were located in South, the degree of asymmetry in Northern and Southern interests would be reduced. Further research might also address the effect of differing production cost structures between North and South. With increased levels of Southern protection, the Northern firm might locate in South in order to take advantage of a cost differential. Such foreign direct investment and technology transfer could possibly provide additional production-side benefits to South. The degree of North-South asymmetry would be reduced further if the multinational ownership of innovating Northern firms were recognized. While the model may exaggerate the differences between Northern and Southern interests concerning IP protection, the main results of the model remain highly instructive.

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