

# TRIPS, trade, and technology transfer

M. SCOTT TAYLOR University of British Columbia

*Abstract.* A north-south model of unintentional technology transfer is developed where the stringency of southern patent protection provides the institutional backdrop for a strategic game in a high-tech goods market. The appropriability regime is set endogenously and combines elements of imperfect southern patent protection with the protection afforded by market-made northern technology 'masquing.' Less stringent protection of northern intellectual property can 'work' much like other strategic trade policies; therefore, developed countries appear to be right in demanding discussion of intellectual property rights in GATT.

*Droits de propriété intellectuelle reliés au commerce international, commerce international et transfert technologique.* L'auteur développe un modèle Nord-Sud de transfert non-intentionnel de technologie dans lequel le degré de rigueur de la loi des brevets dans le Sud fournit la base d'un jeu stratégique dans un marché de biens de haute technologie. Le régime d'appropriation est défini de façon endogène et combine des éléments de protection imparfaite de la loi des brevets dans le Sud avec la protection engendrée par le 'masquage' de la technologie des produits du Nord engendré par le marché pour éviter les imitations. Une protection moins rigoureuse de la propriété intellectuelle du Nord peut fort bien fonctionner comme les autres politiques commerciales stratégiques; donc les pays développés semblent avoir raison de demander qu'on discute des droits de propriété intellectuelle au GATT.

## 1. INTRODUCTION

The ongoing GATT discussions on Trade Related Intellectual Property Rights, or TRIPS, are the most recent example of an enduring debate over the role of in-

Funding was provided by the Social Sciences and Humanities Research Council, the Killam Foundation, Queen's University, and the Centre for International Business Studies at UBC. I would like to thank R. Harris, J. Brander, J. Mintz, K. McKenzie, and an anonymous referee for helpful comments on earlier drafts. The usual disclaimer applies.

lectual property rights in trade and development.<sup>1</sup> Proponents of less stringent protection suggest further controls on intellectual property would harm imitation-cum-innovation development strategies and constitute a barrier to legitimate trade in imitative products. In contrast, proponents of more stringent protection suggest lax protection distorts natural trading patterns. Unfortunately, neither of these positions follows from any clear prescription of economic theory. Accordingly, this paper presents a simple model to examine how the stringency of intellectual property protection affects international trade in R&D intensive products.

I present a north-south model, where the level of unintentional technology transfers is affected by the stringency of southern patent protection. I focus on unintentional transfers because evidence suggests firms routinely employ reverse engineering (or other less intrusive activities) to learn from the embodied technology in competitor's products.<sup>2</sup> Consequently, the southern firm is assumed to invest in imitative activities, but the northern firm may respond in kind by 'masquing' product technology. The influence of intellectual property rights is captured by assuming imitation costs rise as the stringency of southern patent requirements increase. Therefore, the appropriability regime is set endogenously and reflects both market-made and institutional barriers to imitation.

It has long been recognized that firms rely on more than just patent protection to ensure the appropriability of product and process innovations. These extra efforts are surely needed, given the evidence presented by Levin (1989), Mansfield et al. (1981), and Firestone (1971) documenting the very great difference between patent protection in theory and patent protection in practice. These studies conclude that patenting succeeds in raising imitation costs but fails to provide the perfect protection theory often assumed. Therefore, it is not surprising to find that examples of product 'masquing' abound.

Software programming traps, copy-protect schemes, the encryption of important codes, and the use of special materials to make copying more difficult all are physical masquing techniques designed to prevent reverse engineering and copying efforts. Masquing is also present in actions designed to ensure imitation stops short of patent infringement. These efforts may include maintaining a vigilant legal department, monitoring the imports of similar foreign products, writing restrictive agreements with customers, or creating a web of related patents each covering alternative methods, or necessary steps for producing the innovative product or process. Despite this evidence in support of masquing, the existing literature on technology transfer ignores the incentives existing patent holders have to invest in market-made barriers to imitation. This neglect is especially serious for discussions concerning TRIPS, since the effective protection granted intellectual property varies widely across the globe, and in many countries innovating firms have large incentives to invest in other imitation barring strategies.

1 There are numerous sources discussing the ongoing Uruguay Round and TRIPS. For very recent developments and a synopsis of negotiating positions see the GATT's monthly newsletter *GATT FOCUS*. Many other references are contained in Taylor (1991).

2 For example, see the survey evidence presented in Mansfield et al. (1980), Levin (1988), and Firestone (1971).

Recent work in this area by Chin and Grossman (1988), Diwan and Rodrik (1990), Dearnford (1991), and Taylor (1993) examines how the stringency of protection affects the incentive to conduct R&D, but in all of this work the appropriability regime is set exogenously by the existing strength of southern patent protection. The approach taken here is quite different. Rather than examining how a reduction in southern patent protection lowers northern incentives to conduct R&D, I examine how a reduction in southern patent protection raises northern incentives to employ other barriers to imitation. Here the focus is on an endogenous appropriability regime and on the degree of substitutability between institutional and market-made barriers to imitation. Just as the earlier literature abstracted from an endogenous appropriability regime to focus on incentive effects in R&D, I shall abstract from R&D decisions to focus on the ability of masquing to offset weak southern patent protection.<sup>3</sup>

I shall follow the earlier literature, however, in examining the stringency of patent protection, rather than its length. This is a natural assumption, because the stringency of protection determines the scope for imitation.<sup>4</sup> For example, a lax patent policy may allow wholesale copying of innovative products with imitators' contributing little in the way of inventive value-added. Conversely, with stringent patent protection less of the information found in innovative products will be useful to the now largely inventive efforts of imitators. Therefore, the protection afforded innovative products provides an institutional backdrop which determines the cost of imitation. Consequently, a measure of patent stringency must be part of any analysis of TRIPS.

The remainder of the paper proceeds as follows. In section II I describe the basic model and derive the southern equilibrium conditions. Following this I derive the complete worldwide equilibrium in section III, and examine the impact of relaxing southern patent protection. Section IV considers questions of national and world welfare, while section V contains a brief conclusion.

## II. THE MODEL

I adopt a simple partial equilibrium static model with one northern and one southern firm. The northern firm produces a good of quality  $q^n$ , whereas the southern firm produces a similar good of quality  $q^s$ . By assumption, quality levels are fixed, and  $q^n > q^s$ . The northern firm chooses output,  $x^n$ , and masquing  $\theta^n$  to maximize profits. The southern firm chooses its own output  $x^s$  and its level of reverse engineering activities  $\theta^s$ . Given the technological asymmetry between north and south,

3 A much longer version of this paper appears as chapter 2 in Taylor (1991), where I allow for endogenous R&D decisions. The results presented here are very similar to those derived within the framework with endogenous R&D.

4 In general most patents require that the innovator submit an enabling disclosure detailing how the innovation works, and then the innovation must pass the novelty, uniqueness, and non-obvious tests in order to gain a patent. Altering any one of these many requirements will affect the cost of imitation. Extreme examples of policies lowering imitation costs are barring from patent protection certain classes of goods such as drugs or food products or requiring compulsory licensing immediately upon granting patent protection.

I adopt a leader-follower framework, with the north moving first in setting both output and masquing.

### 1. Consumers

Consumers in the market for high-quality products number  $N$ , with  $N^i$  of these located in region  $i$ . Consumers are alike in preferring higher-quality products to lower-quality substitutes but differ in their willingness to pay for quality. This heterogeneity is captured by indexing consumers according to the strength of this preference with consumer  $z''$  having a greater willingness to pay for quality than consumer  $z'$ , if  $z'' > z'$ . I assume  $z$  is distributed on  $[0, 1]$  according to the density  $f(z)$ . Consumers purchase at most one unit of the product chosen, and all remaining income is spent on a numeraire. Hence these assumptions describe a utility function:<sup>5</sup>

$$U(z, q^i, y) \equiv zU(q^i) + y \text{ for } z \in [0, 1] \quad U(0) = 0, \quad U' > 0 \quad U'' < 0 \quad (1)$$

$q^i$  represents the quality level of product  $i$ , and  $y$  is the quantity consumed of the numeraire.

Given these assumptions, it is straightforward to derive the inverse demand functions facing the northern and southern producers. Choosing units such that  $N = 1$ , these can be written:<sup>6</sup>

$$p^s = U(q^s)g(x^n + x^s) \quad (2)$$

$$p^n = [g(x^n + x^s) - g(x^n)]U(q^s) + U(q^n)g(x^n), \quad (3)$$

where  $g(y)$  is defined by

$$\int_{g(y)}^1 f(z)dz \equiv y, \text{ and } g'(y) = -1/f(g(y)) < 0.$$

### 2. Firms

The northern firm facing the demand conditions in (3) maximizes profits subject to the following specification for costs:

$$CN(x^n, \theta^n) \quad CN_x > 0 \quad CN_\theta > 0 \quad CN_{xx} \geq 0, \quad CN_{\theta\theta} \geq 0, \quad CN_{x\theta} \geq 0 \quad (4)$$

Both output and masquing may exhibit constant marginal costs and the joint-cost component,  $CN_{x\theta}$ , may be zero. If masquing consists in physically altering a product, then rising marginal masquing costs seem appropriate; however, if

5 Many authors take a similar approach in modelling the demand for vertically differentiated products. For a recent example in the trade literature see Das and Donnenfeld (1989).

6 For example, see the derivation in Das and Donnenfeld (1989).

masquing consists of providing greater legal protection or increasing product differentiation, then constant or even declining unit costs are possible. Masquing may affect marginal production costs, however, because physical security systems need to be embedded in the products. Therefore, I assume  $CN_{x\theta} \geq 0$ .

The southern firm's cost function is similar in form but differs in two respects. First, I assume the southern firm can lower its production costs through the careful application of knowledge gained in reverse engineering. Quite naturally, I assume the success of these activities is determined by the knowledge capital  $K^n$  embodied within the northern product under examination. As well, I assume that reverse engineering efforts designed to uncover this knowledge capital and increases in the knowledge capital itself have diminishing returns in terms of lowering southern costs. Second, unlike masquing, which may raise northern production costs, I assume reverse engineering costs are independent of southern production levels. These assumptions describe a southern cost function that can be written as

$$CS(x^s, \theta^s) = D(\theta^s, K^n)CS(x^s) + R(\theta^s)$$

$$CS_x > 0 \quad CS_{xx} \geq 0 \quad R_\theta > 0 \quad R_{\theta\theta} > 0$$

$$D_1 < 0 \quad D_2 < 0 \quad D_{ii} > 0, \quad D_{12} < 0; \text{ and } D(0, K^n) = \alpha > 1 \quad (5)$$

Increases in both output and reverse engineering come at increasing cost, but diffusion of technical knowledge  $D$  can lower the first of these components.

It remains to specify the variables affecting  $K^n$ . In general, the success of the south's reverse engineering efforts depend on many factors, both institutional and technological. Here I assume just three determine the amount of knowledge capital  $K^n$  'available' to southern reverse engineering efforts. These are: (1)  $q^n$ , the leader's product quality level which reflects the scale of R&D embodied within the northern product; (2)  $\theta^n$ , the leader's efforts at masquing product technology; and (3)  $\rho$ , a the measure of the *laxity* of southern patent protection. Hence,  $K^n$  can be written

$$K^n = \phi(q^n, \theta^n, \rho) \quad K_q^n > 0, \quad K_\theta^n < 0, \quad K_\rho^n > 0. \quad (6)$$

It is instructive to view (5)–(6) as defining an implicit production function for 'pirated knowledge.' The production function's fixed factor is given by  $K^n$ , and the production function's output is the cost savings the south enjoys because of its unpackaging efforts. This production function for pirated knowledge can be written formally as

$$P(\theta^s, K^n; x^s) = [\alpha - D(\theta^s, K^n)]CS(x^s) \quad (7)$$

Given the specifications assumed,  $P(\theta^s, K^n; x^s)$  has standard neoclassical properties: the variable-input reverse engineering has a positive, but diminishing, marginal product; increases in northern product quality or increases in the laxity of southern patent protection raise both the marginal and the average product of reverse engineering; conversely, increases in product masquing have just the opposite effect.

Moreover with zero variable input, cost reductions, or output, is zero. Therefore, learning from northern products is costly, inspecting high-quality products is better than inspecting low-quality products, and both institutional and market-made barriers to imitation affect southern costs of production.

### III. EQUILIBRIUM

In standard formulations of leader-follower games, the follower takes as given the variables of the leader when maximizing profits. Conducting the required southern maximization results in the following first-order conditions:<sup>7</sup>

$$\begin{aligned} \text{Max}_{\{x^s, \theta^s\}} \prod^s &\equiv p^s(x^s; x^n)x^s - D(\theta^s, K^n)CS(x^s) - R(\theta^s) \\ \prod^s_x &= p^s + [\partial p^s / \partial x^s]x^s - D(\theta^s, K^n)CS_x = 0 \end{aligned} \quad (8)$$

$$\prod^s_\theta = -D_1(\theta^s, K^n)CS(x^s) - R_\theta = 0, \quad (9)$$

where  $p^s(x^s; x^n)$  and  $K^n$  are given by equations (2) and (6) respectively. Totally differentiating (8) and (9) and solving for the follower's response functions shows

$$\begin{aligned} x^s &= f(x^n, K^n) & f_1 < 0, f_2 > 0 \\ \theta^s &= j(x^n, K^n) & j_1 < 0, j_2 > 0 \end{aligned} \quad (10)$$

These results are much as expected. An increase in northern output lowers southern marginal revenues at the previous equilibrium. The consequent reduction in output in turn reduces the south's incentive to invest in reverse engineering, since the potential cost savings fall with output levels. An increase in knowledge capital has just the opposite effect. An increase in  $K^n$  raises the productivity of southern reverse-engineering efforts and leads to an increase in these activities. A reduction in southern costs follows; hence the southern firm finds it profitable to raise output. Masquing, southern patent policy, and the existing level of northern product quality all influence the southern equilibrium but only indirectly through their actions in raising or lowering  $K^n$  as required by equation (6).

The northern firm maximizes profits subject to the southern responses in (10) and the inverse demand function in (3). The first-order conditions for this maximization are

<sup>7</sup> An appendix detailing several subsidiary calculations in the paper is available upon request from the author.

$$\text{Max}_{\{x^n, \theta^n\}} \prod^n \equiv p^n(x^n, \theta^n; \rho)x^n - CN(x^n, \theta^n)$$

$$\prod_x^n = p^n + x^n[\partial p^n / \partial x^n] - CN_x = 0 \quad (11)$$

$$\prod_\theta^n = x^n[\partial p^n / \partial \theta^n] - CN_\theta = 0 \quad (12)$$

Equations (11) and (12) present conventional marginal conditions setting the leader's choice of output and masquing. Before examining the properties of this complete equilibrium, it is necessary to make an assumption on the sign of  $\prod_{x\theta}^n$ .

If masquing is to be effective at the margin in strengthening the north's competitive position, then  $\prod_{x\theta}^n$  must be positive. If we assume  $\prod_{x\theta}^n$  is negative, then a marginal increase in masquing at the previous equilibrium lowers marginal revenues and calls for a reduction in northern output. This is of course contrary to the very purpose of masquing, which is to raise the profitability of output expansion by increasing the appropriability of northern products. This intuition is reinforced when we rearrange  $\prod_{x\theta}^n$  to find

$$\prod_{x\theta}^n = [\partial p^n / \partial \theta^n][1 - 1/\epsilon] + [CN_x / \theta^n][\eta / [\epsilon - 1] - \xi] \geq 0?$$

$$\epsilon \equiv -[\partial x^n / \partial p^n][p^n / x^n], \quad \eta \equiv [\partial \epsilon / \partial \theta^n][\theta^n / \epsilon],$$

$$\text{and } \xi \equiv [CN_{x\theta} \theta^n / CN_x]. \quad (13)$$

hence,  $\epsilon$  is the elasticity of the leader's demand curve,  $\eta$  is the elasticity of  $\epsilon$  with respect to a change in masquing, and  $\xi$  is the elasticity of marginal production costs with respect to a change in masquing. Since  $\epsilon > 1$  in any equilibrium and  $[\partial p^n / \partial \theta^n] > 0$ , the first term in (13) represents the necessarily positive and direct effect of an increase in masquing on northern marginal revenues. The remaining terms in (13) are second-order terms whose sign and size depend on third-order properties of the general functions adopted. In the absence of specific functional forms, it is not possible to determine the sign or size of these terms; consequently I assume the first-order effect dominates and  $\prod_{x\theta}^n$  is positive.<sup>8</sup>

A first step in examining the impact of a fall in southern patent stringency is to determine the northern masquing response. Totally differentiating (11) and (12) and solving for the northern firm's response to an increase in the laxity of southern patent protection ( $d\rho > 0$ ) shows:

<sup>8</sup> However, note that if  $CN_{x\theta} = 0$ , and  $\epsilon$  is large, then  $\prod_{x\theta}^n > 0$ . The condition  $\prod_{x\theta}^n > 0$  is similar to conditions imposed in Salop et al. (1983). In Salop's work these conditions ensure a dominant firm has the ability to use exclusionary practices to raise competitor's costs.

$$d\theta^n/d\rho = -[K_\rho^n/K_\theta^n] \left[ 1 + \left[ CN_{\theta\theta} \prod_{xx}^n - CN_{x\theta} \prod_{x\theta}^n \right] / \Delta \right] - \Omega \left[ \prod_{xx}^n / \Delta \right]$$

$$\Omega \equiv -x^n U(q^s) g'(x^s + x^n) [dx^s/dK^n] [K_{\theta\theta} K_\rho / K_\theta - K_{\theta\rho}] \geq 0?, \quad (14)$$

where  $\Delta > 0$  by s.o.c. The northern firm's response has three components. The first is a necessarily positive direct response  $d\theta^n = -[K_\rho^n/K_\theta^n]d\rho > 0$ . Totally differentiating (6) shows that this direct response ensures  $dK^n/d\rho = 0$ . Absent the other two components, masquing increases just enough to leave the level of available knowledge capital constant. However, to this first term we must add the second term capturing masquing's indirect effect on northern *marginal* costs. If at the margin an increase in masquing raises either the direct marginal costs of masquing ( $CN_{\theta\theta} > 0$ ), or the marginal costs of production ( $CN_{x\theta} > 0$ ), then this second component is negative.

Finally, consider the last term in (14). This term captures the change in the marginal product of masquing created by the fall in southern patent stringency. In  $\{\rho, \theta^n\}$  space, any equal-knowledge isoquant from (6) is positively sloped. It is positively sloped because an increase in the laxity of patent protection  $d\rho > 0$  must be met by an increase in masquing  $d\theta^n > 0$  if  $K^n$  is to remain constant. Along any equal-knowledge isoquant we can write the marginal product of masquing as  $\bar{K}_\theta(\theta(\rho), \rho)$ , where  $\theta$  is an implicit function of  $\rho$ , since we are holding  $K^n = \bar{K}$ . Differentiating  $\bar{K}_\theta(\theta(\rho), \rho)$  with respect to  $\rho$  shows that *along an equal knowledge isoquant* the marginal product of masquing rises if and only if  $[K_{\theta\theta} K_\rho / K_\theta - K_{\theta\rho}] > 0$ .<sup>9</sup> Therefore, if masquing is more productive in protecting northern intellectual property in environments with less stringent protection,  $\Omega > 0$ . Conversely, if it is less efficient, then  $\Omega < 0$ . Finally, note that if  $K^n$  is linear in  $\theta^n$  and  $\rho$ , then  $\rho$  and  $\theta^n$  are perfect substitutes. As a result  $\Omega = 0$  and the second-order term vanishes completely. Collecting these results:

PROPOSITION 1. *If  $CN_{x\theta} = CN_{\theta\theta} = 0$ , and  $K^n$  is linear in  $\rho$  and  $\theta^n$ , then  $\Omega = 0$  and a fall in southern patent protection is met by an entirely compensating rise in masquing: that is,  $dK^n/d\rho = 0$ . If  $K^n$  is not linear and  $\Omega > 0$ , then  $dK^n/d\rho < 0$ ; if  $\Omega < 0$ ,  $dK^n/d\rho > 0$ .*

Proposition 1 demonstrates that the 'success' of a policy relaxing patent stringency depends on both cost conditions and the substitutability of market-made and institutional barriers to imitation. It should come as no surprise that the leader's output response to a change in protection also hinges on similar considerations. Solving for the leader's output response shows

$$dx^n/d\rho = [K_\rho^n/K_\theta^n] \left[ \left[ CN_{\theta\theta} \prod_{x\theta}^n - CN_{x\theta} \prod_{\theta\theta}^n \right] / \Delta \right] + \Omega \left[ \prod_{x\theta}^n / \Delta \right]. \quad (15)$$

<sup>9</sup>  $\Omega > 0$  is necessary for  $d\rho^2/d\theta^{n2} > 0$ .



Ignore the induced changes in masquing's marginal product for a moment by assuming  $\Omega = 0$ . Then proposition 1 tells us that if  $CN_{\theta\theta} = CN_{x\theta} = 0$  and  $\Omega = 0$ , then  $dK^n/d\rho = 0$ . In this circumstance the southern policy is entirely ineffective, since masquing completely offsets the decline in southern patent protection. The level of unintended technology transfers from north to south remains unchanged. From (15) it is apparent that in this case  $dx^n/d\rho = 0$  as well. With the effective protection for northern intellectual property unchanged, the northern firm leaves its output level constant.

Conversely, assume both  $CN_{\theta\theta}$  and  $CN_{x\theta}$  are positive and  $\Omega = 0$ . Then Proposition 1 tells us  $dK^n/d\rho > 0$ , and equation (15) indicates northern output levels fall. Northern output falls because northern products become less appropriable, and competition in the final output market intensifies.

Finally, consider the importance of  $\Omega$  by assuming  $CN_{\theta\theta} = CN_{x\theta} = 0$ . Here we find that if masquing is more productive at lower levels of patent protection, then  $\Omega > 0$  and  $dK^n/d\rho < 0$ . In this situation equation (15) indicates that northern output levels rise with the increase in appropriability. In contrast, if  $\Omega < 0$ , then  $dK^n/d\rho > 0$ , since northern products become less appropriable, and (15) indicates that northern output levels fall. Finally, if masquing and southern patent protection are perfect substitute, then  $\Omega = 0$  and the second-order terms vanish completely. Collecting these results:

**PROPOSITION 2.** *If  $CN_{x\theta} = CN_{\theta\theta} = 0$ , and  $K^n$  is linear in  $\rho$  and  $\theta^n$  then northern output levels are unaffected by a fall in southern patent protection. If  $\Omega > 0$ , then  $dK^n/d\rho < 0$  and northern output levels rise; conversely, if  $\Omega < 0$ , then  $dK^n/d\rho > 0$  and northern output levels fall.*

Propositions 1 and 2 show that the southern government has only limited control over the pace of unintended technology transfers. Moreover, changes in northern output levels are perfectly correlated with changes in the knowledge stock available to southern reverse-engineering efforts. Given this and the information embodied in southern response functions, the following is also clear:

**PROPOSITION 3.** *If  $CN_{x\theta} = CN_{\theta\theta} = 0$ , and  $K^n$  is linear in  $\rho$  and  $\theta^n$ , then southern output and reverse-engineering efforts are unaffected by the fall in southern patent protection. If  $\Omega > 0$ , southern output and reverse-engineering efforts fall; if  $\Omega < 0$ , southern output and reverse-engineering efforts rise.*

Propositions 1–3 must be amended somewhat when northern marginal costs ( $CN_x$  or  $CN_\theta$ ) are not constant. If additional masquing leads to an increase in marginal costs, then the northern firm may not completely offset the decline in southern patent stringency. Unless the marginal product of masquing is significantly higher in environments with less stringent patent protection, we would expect the appropriability of northern products to fall. It seems likely, however, that strategies to raise imitation costs do have higher marginal products in environments where

patent stringency is already very low. This may be the case because both market-made and institutional barriers to imitation protect the same piece of information. Hence, if protection is already quite good, then there should be diminishing returns to protecting the remaining knowledge. Conversely, if protection is actually quite limited, then the returns to masquing may be high. Nevertheless, unless this second-order effect working through changes in the productivity of masquing is large, the appropriability of northern products will fall with a decline in southern patent stringency. Concomitantly, the amount of available knowledge capital will rise, and southern industry output and reverse engineering will increase.

#### IV. WELFARE ANALYSIS

Thus far I have examined only the case when the southern policy is successful in raising southern industry output and increasing the flow of unintended technology transfers. It is by no means clear that success in these terms implies an increase in southern welfare. Given the quasi-linear form of utility, domestic social welfare in either region is given by the sum of consumer surplus plus profit income. To begin the welfare analysis abstract from home consumption and examine only the profit motive for a change in patent protection. Northern welfare is given by  $\prod^n$  and differentiating  $\prod^n$  with respect to  $\rho$  results in

$$d\prod^n/d\rho = [\partial p^n/\partial\rho]x^n = U(q^s)g'(x^s + x^n)[\partial x^s/\partial K^n]K_p^n < 0. \quad (16)$$

$K_p^n$  is the necessarily positive marginal product of relaxing patent protection. The derivative  $[\partial x^s/\partial K^n]$  is the necessarily positive response found in the follower's problem. Therefore, northern profits always fall when patent protection is relaxed.

In contrast, southern profits may rise or fall from the decline in patent stringency depending upon the strategic effect this decline has on northern variables. Employ the envelope theorem to eliminate the indirect effects working through southern variables, to find

$$d\prod^s/d\rho = \left[ \partial \prod^s / \partial x^n \right] [dx^n/d\rho] + \left[ \partial \prod^s / \partial \theta^n \right] [d\theta^n/d\rho] + \partial \prod^s / \partial \rho, \quad (17)$$

and substitute from the southern profit function and from  $K^n$  to obtain

$$d\prod^s/d\rho = U(q^s)x^s g'(x^s + x^n)[dx^n/d\rho] - D_2CS(x^s)[dK^n/d\rho] \geq 0?. \quad (18)$$

The change in southern profits is attributable to two sources: on the revenue side, the south receives a boost to marginal revenue if northern output falls; on the cost side, the south receives a boost to the productivity of reverse engineering if the stock of available knowledge capital grows. Therefore, given our preceding results,

it is apparent that the southern firm experiences an increase in profits whenever  $dK^n/d\rho > 0$ . Collecting these results:

**PROPOSITION 4.** *Northern profits always fall with a decline in southern patent stringency. If  $CN_{x\theta} = CN_{\theta\theta} = 0$ , and  $K^n$  is linear in  $\rho$  and  $\theta^n$ , then southern profit levels are unaffected by the change in patent protection. If  $\Omega > 0$ , southern profits fall; if  $\Omega < 0$ , southern profits rise.*

When a relaxation in southern patent protection 'works,' it does so by altering the initial positions of the follower's response functions. This in turn provides the follower with a strategic advantage in high-tech goods markets and translates into a larger share of worldwide profits. This rent-shifting motive for less stringent patent protection is similar to the strategic trade policy arguments first put forward by Brander and Spencer (1985) concerning export subsidies. Therefore, northern governments appear to be right in demanding discussion of intellectual property rights in the GATT. Both export subsidies and relaxed patent stringency alter the initial conditions of the ensuing game in world markets, and both may be designed to give domestic firms a 'leg up' in international competition.

Nevertheless, in contrast to case of export subsidies, there is no general presumption suggesting the existing level of southern patent stringency is Pareto optimal. Even with the inclusion of domestic consumption effects, it can be shown that as long as southern profits do not fall with a reduction in patent protection, then the south always prefers a less stringent level of protection than the north. Moreover, world welfare is maximized at some intermediate level.

To demonstrate these claims, recall that  $f(z)$  is the same across both countries and  $N^s + N^n = 1$ . Therefore,  $CS^n = N^n CS^w$  and  $CS^s = N^s CS^w$ . Social welfare in the two regions is given by the sum of consumer surplus plus profit income, or  $SW^i = N^i CS^w + \Pi^i$  for  $i = \{n, s\}$ . Assume  $SW^i$  is strictly concave in  $\rho$  so that we can associate  $\rho^n$  and  $\rho^s$  with the north's and south's unique optimal choices for the stringency of southern patent protection. And suppose, to the contrary, that  $\rho^n > \rho^s$  - the north prefers less stringent protection in the south. Then by definition of an optimum  $N^n CS^w(\rho^n) + \Pi^n(\rho^n) > N^n CS^w(\rho^s) + \Pi^n(\rho^s)$ , and  $N^s CS^w(\rho^s) + \Pi^s(\rho^s) > N^s CS^w(\rho^n) + \Pi^s(\rho^n)$ . Then, since  $d\Pi^n/d\rho < 0$ ,  $\Pi^n(\rho^n) < \Pi^n(\rho^s)$ . This would require  $N^n CS^w(\rho^n) > N^n CS^w(\rho^s)$ . But  $N^n CS^w(\rho^n) > N^n CS^w(\rho^s)$  implies  $N^s CS^w(\rho^n) > N^s CS^w(\rho^s)$ , and hence  $\Pi^s(\rho^s) > \Pi^s(\rho^n)$ . However,  $\rho^n > \rho^s$  and  $d\Pi^s/d\rho \geq 0$ ; therefore,  $\Pi^s(\rho^s) > \Pi^s(\rho^n)$  is a contradiction and  $\rho^n < \rho^s$  as required.

To demonstrate that World welfare must be maximized at some intermediate value, assume world welfare is any positively weighted sum of northern and southern welfare. Evaluate this sum at  $\rho = \rho^n$  and ask whether welfare rises as  $\rho$  falls and southern protection becomes more stringent. Clearly northern welfare falls, since  $\rho^n$  was a maximum. Southern welfare also falls, since  $\rho^s \geq \rho^n$ . Next, evaluate the sum at  $\rho = \rho^s$  and ask whether welfare could rise if we increased  $\rho$ . Here again northern welfare falls, as does southern, since  $\rho^s$  is a maximum. Therefore, the worldwide optimum  $\rho^w$  must lie somewhere  $\rho^w \in [\rho^n, \rho^s]$ .

These two results follow because of the different trade-offs facing north and south. Northern and southern consumer surplus expressions differ by only a factor of proportionality, reflecting their population sizes. As a result, their consumer surplus gains or losses from relaxing protection are perfectly, and positively, correlated. Conversely, if southern profits never fall from a relaxation in protection, then southern and northern profit gains and losses always move in opposition. Consequently, the south always prefers less stringent protection, and world welfare is maximized at some intermediate value.

#### V. CONCLUSIONS

The transfer of technology has always played a leading role in economic development. While an acceleration of north-south technology transfers would foster competition and raise the productivity of resources employed in the south, unilateral attempts to magnify unintended transfers via weak patent policy call forth defensive responses by innovating firms. These defensive responses can limit, and may eliminate, the benefits from such a policy. Nevertheless since less stringent patent protection can 'work' like other strategic trade policies, a continuation of this rent-seeking activity is to be expected. Despite this rather gloomy forecast, the analysis also suggests that both north and south have much to gain by moving away a Pareto-inferior position, where northern resources are employed in masquing technology and southern resources are subsequently employed in unpackaging it. Since an intermediate level of patent stringency in world welfare maximizing, multilateral negotiations concerning intellectual property rights hold promise for a settlement benefiting both north and south.

Finally, it is of course necessary to remain sceptical of conclusions drawn from a duopoly model with no entry. Apart from the usual caveats, it is important to note that the model abstracts from impacts on other southern industries, on technology-licensing agreements, and on foreign investment. Nevertheless, while the specific results developed here may not survive the move to more general environments, the major insights seem clear enough.

#### REFERENCES

- Brander, J., and B.J. Spencer (1985) 'Export subsidies and international market share rivalry.' *Journal of International Economics* 18, 83-100
- Chin, J.C., and G.M. Grossman (1988) 'Intellectual property rights and north-south trade.' Mimeo
- Das, S.P., and S. Donofield (1989) 'Oligopolistic competition and international trade: quantity and quality restrictions.' *Journal of International Economics* 27, 299-318
- Deardorff, A.V. (1991) 'Should patent protection be extended to all countries?' *Economica*
- Diwan, I., and D. Rodrik (1991) 'Patents, appropriate technology, and north-south trade.' *Journal of International Economics* 29, 27-48
- Firestone, O.J. (1971) *Economic Implications of Patents* (Ottawa: University of Ottawa Press)

- Levin, R.C. (1988) 'Appropriability, R&D spending, and technological performance.' *American Economic Review Papers and Proceedings*, 424-8
- Levin, R.C., A.K. Klevorick, R.R. Nelson, and S.G. Winter (1989) 'Appropriating the returns from industrial research and development.' Discussion Paper No. 714, Cowles Foundation
- Mansfield, E., and A. Romeo (1980) 'Technology transfer to overseas subsidiaries by u.s. based firms.' *Quarterly Journal of Economics* 737-50
- Mansfield, E., M. Schwartz, and S. Wagner (1981) 'Imitation costs and patents: an empirical study.' *Economic Journal*, 907-18
- Salop, S.C., and D.T. Scheffman (1983) 'Raising rivals' costs.' *American Economic Review papers and proceedings* 73, 267-71
- Stalson, H. (1987) *Intellectual property rights and U.S. competitiveness in Trade* (Washington, DC: National Planning Association Committee on Changing International Realities)
- Taylor, M.S. (1991) 'Three essays on the international diffusion of technology.' Unpublished doctoral Dissertation, Queen's University
- (1993) 'TRIPS, trade and growth.' *International Economic Review* (forthcoming)

Copyright of Canadian Journal of Economics is the property of Wiley-Blackwell and its content may not be copied or emailed to multiple sites or posted to a listserv without the copyright holder's express written permission. However, users may print, download, or email articles for individual use.