Protection of Trade for Innovation: The Roles of Northern and Southern Tariffs

by

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Abstract

Using a North-South trade model with innovation and imitation, we investigate the interaction of intellectual property rights (IPR) protection and trade protection. We show that unlike a Southern tariff, a Northern tariff supplements IPR protection and is not necessarily a beggar-thy-neighbor policy. The globally optimal Northern tariff increases as IPR protection in the North or the South decreases. Global welfare may rise as Northern tariff increases, but necessarily declines as Southern tariff increases. This suggests that pushing for freer trade in the South is more urgent than in the North in innovation-intensive sectors where IPR protections are weak in both regions.

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1. Introduction

Although innovation is conducive to economic growth, it is widely believed that markets do not provide appropriate incentives for innovation.[1] Nonetheless, there are many attempts to solve the problem of under-provision of new products and new production processes. In practice, governments have adopted various mechanisms to encourage innovation, including patents, R&D subsidization and patent buy-out.[2] Among those mechanisms, patents are used most widely and, along with copyrights and trademarks, are the major components of Intellectual Property Rights (IPR) protection. However, perhaps partly due to the myopic concerns of some interest groups over monopoly pricing, it is believed by many that even in developed countries (referred to here as the North) IPR protection is not strong enough from the social point of view, not to mention in less developed countries (referred to here as the South).[3] Thus, there are cries for stronger IPR protection from industries, and cooperative efforts have been made to strengthen IPR protection in many nations.[4] While most countries are strengthening IPR protection laws, there are many obstacles in enforcement. Some other mechanisms are potential supplements for weak IPR protection although they were not originally designed for such

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[1]Throughout this paper, the words innovation and invention are used interchangeably, and so are the words innovate and invent.

[2]However, each of these mechanisms has its own shortcomings. Patents create monopolies and lead to social deadweight losses. Government subsidy of R&D is much better than the patent policy (Spence, 1984), but it cannot escape from the asymmetric information problem and always invites rent-seeking, which leads to inefficient subsidization. Patent buy-out could be potentially superior to the other two mechanisms, but it too may have drawbacks that have not yet come to light due to its short history and the lack of theoretical analysis. Kremer (1997) is one of the recent studies on patent buy-out.

[3]Kremer (1997) has a nice summary of the empirical literature on patents. Given the current patent system, social returns to innovation far exceed the private returns, suggesting that innovation is not encouraged sufficiently.

[4]In many recent international agreements, including the Uruguay Round, the European Union and the North American Free Trade Agreement, signatories are required to strengthen their national IPR protection over the next decade. See Maskus (1998) for some discussions on this.

a purpose. This paper argues that trade policy measures are one of those mechanisms.

The reason why trade policy measures can potentially be used to supplement IPR protection measures is that IPR standards are usually slow to change while trade barriers can be erected relatively quickly. Legislations to change IPR standards usually take a long time to enact because they need more debates, while trade barriers can often be imposed by the administration without going through the legislature, and they are very often non-noticeable to the public (e.g. administrative barriers).

Trade barriers, proxied by tariffs, can affect pricing decisions and profits of firms, which in turn affect incentives to innovate. Hence, tariffs can either supplement or offset IPR protection. It is therefore important to make a close, careful re-examination of tariffs when IPRs are not fully protected. The present study is motivated by this need. To carry out this reexamination, we establish a North-South trade model with innovation and imitation, in which both regions provide some degrees of IPR protection, captured by patent lengths, and trade protection, captured by tariffs. It is evident that the South has much lower inventive ability than the North's. For simplicity, therefore, we make the assumption that innovations originate only from the North.

The focus of the present paper is on the welfare effects of tariffs in the presence of innovation and imitation. Basically, we have obtained three results in this regard. First, there is a new rationale for a Northern tariff, besides terms-of-trade and rent-shifting considerations, which are well-documented in the trade literature.[5] When innovations concentrate in the North, a Northern tariff provides incentives for innovation and thus benefits consumers. Moreover, because of this effect, the optimal Northern tariff rate is always higher in the present model than in models without innovation. The tariff that is designed to capture this third effect is to promote innovation, not protect profits. A corollary of this effect is that a Northern tariff supplements IPR protection. In fact, weaker IPR protection in the North or the South not only calls for higher tariff protection

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[5]There are some other economic justifications for tariffs, such as the infant industry argument and increasing returns to scale. Of course, one can also find arguments for tariffs in political economy.

in the North for the sake of Northern consumer welfare; it also calls for higher Northern tariff for the sake of world welfare.

Second, while a Northern tariff is pro-innovation, a Southern tariff, in contrast, is anti-innovation. This differentiates the two tariffs in an important way: a Southern tariff is a beggar-thy-neighbor policy, but a Northern one may not be. Third, global welfare declines as the South raises its tariff rate, but under some circumstances global welfare rises as the North increases its tariff rate. Hence, Southern tariffs are more detrimental to world welfare than Northern ones in innovation-intensive sectors where innovations concentrate in the North and IPR protection is weak in both regions. An example that comes to mind is internet-related products. [6]

Zigic (2000) finds a similar motive for the North to protect trade, and that a Northern tariff can be globally welfare improving. While he only focuses on the Northern market, our emphasis is the result that weaker IPR protection in the world calls for higher Northern tariffs for the sake of global welfare. Moreover, we emphasize the differing roles of Northern and Southern tariffs in a world where innovation concentrates in the North.

Our results have obvious policy implications. Note that in the real world the South maintains much higher trade barriers in general, and tariffs in particular, than the North. Our results, however, suggest that the opposite would lead to higher global welfare in certain sectors. The message that this study conveys is that it is more harmful to keep a high tariff in the South than in the North, and hence trade liberalization is more urgent and should be carried out at a faster pace in the South than in the North in certain well-defined sectors. From a policy point of view, it would benefit the North to subsidize trade liberalization of the South since Southern tariff reduction improves global welfare, and so the South's loss would be more than offset by the North's gain.

There exists a rich literature on technology and trade, which mainly focuses on the interplay between innovation and international trade.[7] More recently, there have also

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[6]In contrast, if tariffs are designed for the purpose of terms-of-trade improvement or profit-shifting, the Northern tariff and the Southern tariff are not qualitatively different.

[7]Grossman and Helpman (1995) has a comprehensive survey of this literature.

been studies on the effects of IPR protection and trade policy. Taylor (1993), Maskus and Penubarti (1995) and Smith (1999) investigate whether strengthening IPR protection induces more trade flows. Horowitz and Lai (1996) and Lai (1998) analyze the effects of IPR protection on the rates of innovation. Grossman and Helpman (1991, ch.6 and ch.10) examine the response of innovation rates to trade and industrial policy. However, it is notable that studies on the welfare effects of the interaction of trade policy and IPR protection policy in the context of North-South trade are scarce. Chin and Grossman (1990), Diwan and Rodrik (1991), Deardorff (1992), Helpman (1993) and Lai and Qiu (2003) all examine how strengthening IPR protection in the South affects welfare in the North, the South, or both regions. As Grossman and Helpman (1995, p.1327) point out, we still do not have a complete normative analysis of trade policy, especially for a large, open, innovating economy. We attempt to fill a gap in this literature by building a model to analyze the interaction between trade and IPR policies.[8]

The rest of the paper is organized as follows. In Section 2, we construct a North-South trade model with innovation and imitation, and examine the policy effects on equilibrium amounts of innovation and imitation. Section 3 analyzes the Northern tariff. Section 4 compares the role of a Northern tariff with a Southern one. Finally, Section 5 concludes with a discussion of some caveats of the model.

2. The Model

Consider a world comprised of two regions, the North and the South, which differ only in their abilities to invent differentiated products.[9] For analytical simplicity, we confine our study to an extreme case, which is not unrealistic, where innovation only takes place in the North.[10] In any period, there is a set of potential differentiated products to be

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[8]Zigic (2000) is also along this line.

[9]In the literature, it is common that one study focuses only on one type of innovation that either generates new products, improves the quality of existing products, or lowers production costs.

[10]The qualitative aspects of our results so derived remain robust even if we allow both regions to innovate and imitate as long as most of the innovation takes place in the North and most of the imitation occurs in the South. We have included a discussion on this in the concluding

invented, indexed by i within the range $[0, +\infty)$. Any differentiated product will become obsolete T periods after its invention. Beyond that, it loses its economic value. The IPR policy of a region is proxied by its patent length. A patent length of T_n, $T_n \leq T$, means that the Northern government prevents a patented product from being imitated or sold in the North within T_n periods after its invention.

Although the Northern government's IPR policy cannot be extended to the South, a differentiated product will not be imitated in the South within T_s periods after its invention, due to a natural imitation lag or the IPR protection by the Southern government. T_s periods after a product is invented, it can be (and will be) imitated and sold in the South.

The two regions trade with each other. The Northern government imposes a uniform specific tariff τ_n on all products imported from the South, and the Southern government imposes a uniform specific tariff τ_s on all products imported from the North.

In the beginning of period 1, the vector of policy instruments $\tau \equiv (T_n, T_s, \tau_n, \tau_s)$ are set by the governments. In each subsequent period, potential innovators then make their investment decisions. We assume that firms and consumers are faced with the same market parameters in all periods, and so the same *number* of products will be invented in every period. Let M be the number of differentiated products invented in the North in each period. The same firm could invent more than one product in every period. Nonetheless, for ease of exposition, we treat different products (whether in the same period or not) as being invented by different firms. All differentiated products are necessarily different in order to be patented. We will show in subsection 2.2 that by making an appropriate ordering the first M products will be invented in every period in equilibrium.

section. In fact, this is a common assumption in the literature, for example, Krugman (1979), Grossman and Helpman (1991, ch.11), and Helpman (1993). Grossman and Helpman (1995, p.1327) also provide several reasons for this, "First, firms in the South have shown only limited ability to develop innovative products of their own. Second, several of the governments of less developed nations have been somewhat lax in their enforcement of foreign intellectual property rights. Finally, the low wage rates of the South make it an especially attractive place for copying some kinds of products, because successful imitators can expect to earn substantial profits in their competition against innovators who bear higher labor costs".

Before period T, the total number of products whose patents have not expired change from one period to the next. After period T, however, the number becomes steady. Therefore, a steady state is attained after period T. To simplify the analysis, we assume that there is no discount of the future. Since there is no discounting, we can focus our attention on the steady-state flow welfare for the purpose of welfare analysis. This can be justified by "overtaking criterion" in dynamic optimization theory.[11] In every steady-state period, there are $T_n M$ products whose patents have not expired in the North, $(T - T_n)M$ economically viable products whose patents have expired in the North, $T_s M$ products still maintaining monopoly power in the South, and $(T - T_s)M$ imitated products sold in the South. Although the number of products is discrete, we treat it as continuous in our mathematical derivation for easier handling.

Define t as the age of a product from the time of invention. Consumers in the two regions have identical utility function. In every steady-state period, consumers in each region j (with $j = n$ for the North and s for the South) derive utility from consuming the differentiated products and a composite traditional product:[12]

$$u_j = \sum_{t=1}^{T} \int_0^M x_j(i,t)^\alpha \mathrm{d}i + X_j, \quad 0 < \alpha < 1, \ \ j = n, s,$$

where $x_j(i,t)$ is the consumption of product i with age t in region j, and X_j is the quantity of traditional good consumed by region j. In what follows, when it is unnecessary to keep the argument t in $x_j(i,t)$, we will drop it. To simplify the notation, we define $\epsilon = 1/(1-\alpha)$ and $A = (1 - \alpha)\alpha^{(1+\alpha)\epsilon}$.

While the price of the traditional good is normalized to one in both regions, the price of differentiated product i with age t in region j is denoted by $p_j(i,t)$. Since there is no lending and borrowing, in each steady-state period, consumers in region j maximize the period's utility under the budget constraint: $E_j \geq \sum_{t=1}^{T} \int_0^M p_j(i,t)x_j(i,t)\mathrm{d}i + X_j$, where E_j is the (exogenous) total income spent on consumption by region j. Hence, the

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[11]See, for example, Burmeister (1980), pp. 249-250.

[12]Specific utility functions are used in many other studies including Krugman (1979), Grossman and Helpman (1991, ch.11) and Helpman (1993).

instantaneous demand for differentiated products of all ages is

$$p_j(i) = \alpha x_j(i)^{\alpha-1}, \;\; j = n, s, .$$

which has constant elasticity equal to ϵ. Note that the specific form of the utility function considered above implies that we confine our analysis to independent products. Allowing substitution among the differentiated products will greatly complicate the analysis without altering the results qualitatively.

2.1. The Market

Let us consider the Northern market first. Suppose product i has been invented by a Northern firm, called it Northern firm i. The firm will be guaranteed a monopoly position in the Northern market for T_n periods and in the Southern market for T_s periods. To sharpen our focus on innovation, we assume that the innovation costs of different products vary (see next subsection), but their production costs are the same. Specifically, and for simplicity, assume identical and constant marginal cost of production, which is equal to c, for all firms in the North. Then, under IPR protection from the North, i.e., for Northern firm i with $t \leq T_n$, its steady-state flow operating profit (i.e., profit not taking into account the innovation costs) in the Northern market is $\pi_{nn} = (p_n - c)x_n$, where subscript nn stands for a Northern firm in the Northern market. In equilibrium (superscript m standing for monopoly),

$$p_n^m = \alpha^{-1}c, \;\; x_n^m = \alpha^{2\epsilon}c^{-\epsilon}, \;\; \text{and} \;\; \pi_{nn}^m = Ac^{-\alpha\epsilon} \;\; \text{for a product with} \;\; t \leq T_n. \qquad (1)$$

After T_n periods, patent for product i expires in the North. Imitators start to enter the Northern market. Imitation is costly.[13] To simplify our analysis, but with little loss in generality, we assume equal imitation cost for all potential imitators and for all products. To focus on innovation and imitation costs, let us assume that the constant

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[13]Empirical evidence indicates that imitation could be very costly, normally higher than 20 percent of the costs of innovation (Mansfield et al., 1981). Glass and Saggi (1999) analyze the theoretical implications of costly imitation for innovation and foreign direct investment.

marginal cost of production in the South is also c.[14] Since the imitators face the same cost and demand for each product, there would be an equal number of entrants in all products.[15] Assume there are H Northern imitators and K Southern imitators for each product in equilibrium. Thus, the Northern innovator in the Northern market will face competition from the K Southern imitators and H Northern imitators after T_n periods. We assume that firms in the same market compete in quantity *à la* Cournot.[16] Consider the product markets for i. Each Southern imitator k has the following per-period export profit: $\pi_{sn} = [(p_n - c - \tau_n)]x_{sn}$, where x_{sn} is Southern imitator k's export volume (subscript sn stands for a Southern firm in the Northern market). The total export is Kx_{sn}. The Northern innovator and H Northern imitators each sells x_{nn} to this market and has a per-period operating profit equal to $\pi_{nn} = (p_n - c)x_{nn}$. Hence, the total supply of product i in the Northern market is $x_n = (H+1)x_{nn} + Kx_{sn}$.

Denote $B(H,K) \equiv \epsilon\alpha^\epsilon(H+K+\alpha)^\epsilon$. The resulting equilibrium in the Northern market for product i is, for $T \geq t > T_n$,

$$
\begin{cases}
p_n = [(H+K+1)c + K\tau_n]/(H+K+\alpha), \\
x_n = \{\alpha(H+K+\alpha)/[(H+K+1)c + K\tau_n]\}^\epsilon, \\
x_{nn} = B(H,K)[(1-\alpha)c + K\tau_n]/[(H+K+1)c + K\tau_n]^{\epsilon+1}, \\
x_{sn} = B(H,K)[(1-\alpha)c - (H+\alpha)\tau_n]/[(H+K+1)c + K\tau_n]\}^{\epsilon+1}, \\
\pi_{nn} = B(H,K)[(1-\alpha)c + K\tau_n]^2/\{[(H+K+1)c + K\tau_n]^{1+\epsilon}(H+K+\alpha)\}, \\
\pi_{sn} = B(H,K)[(1-\alpha)c - (H+\alpha)\tau_n]^2/\{[(H+K+1)c + K\tau_n]^{1+\epsilon}(H+K+\alpha)\}.
\end{cases}
\tag{2}
$$

Clearly, from (2) we see that the Northern tariff reduces π_{sn} (i.e., $\partial\pi_{sn}/\partial\tau_n < 0$). Using

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[14]The qualitative results do not change if we assume different production costs in the two regions, which is the case in our working paper Qiu and Lai (1999).

[15]This will be the case if imitation cost is not low and competition reduces market profit drastically. Moreover, in this model, if we explicitly allow imitators to choose products for imitation, they will choose to imitate different products. Limited resources also disallow a single imitator to imitate many products. All these tend to support the above assumption. Also imitation requires certain technology not owned by everyone.

[16]Changing from Cournot to Stackelberg model in the product market will not alter any of our results, since the effects of an increase in Northern tariff would be qualitatively the same. The analysis is available upon request.

condition $x_{sn} > 0$ or equivalently $(1 - \alpha)c - (H + \alpha)\tau_n > 0$, we can show that

$$\frac{\partial \pi_{nn}}{\partial \tau_n} = \frac{KB(H,K)[(1-\alpha)c + K\tau_n]}{[(H+K+1)c + K\tau_n]^{2+\epsilon}} \left\{ \frac{\epsilon[2(1-\alpha)c - (H+\alpha)\tau_n] + \alpha c}{H+K+\alpha} \right\} > 0. \quad (3)$$

A Northern tariff shifts profits from the Southern imitators to the Northern innovators and imitators. For products with $t \in (T_n, T]$, there are $H + 1$ identical Northern firms (each with a marginal cost equal to c) and K identical Southern firms (each with a marginal cost equal to $c + \tau_n$) competing in the Northern market. As τ_n increases, the marginal cost for Southern firms increases. It is intuitive that the profits of all Northern firms increase while those of all Southern firms decrease.

We now examine the Southern markets. For products with $t \leq T_s$, Northern firm i, as a monopolist, exports its product to the South. Similar to (1), we have the following equilibrium (subscript ns stands for a Northern firm in the Southern market).

$$p_s^m = \alpha^{-1}(c+\tau_s), \quad x_s^m = \alpha^{2\epsilon}(c+\tau_s)^{-\epsilon}, \quad \text{and} \quad \pi_{ns}^m = A(c+\tau_s)^{-\alpha\epsilon} \text{ for products with } t \leq T_s. \quad (4)$$

A Northern innovator i with $t \in (T_s, T]$ (and with marginal cost $c + \tau_s$) competes against H Northern imitators (each with marginal cost $c + \tau_s$) and K Southern imitating firms (each with marginal cost c) in the Southern market. (Note that Northern firms with $t \in (T_s, T]$ can carry out imitation and sell in the South.)

For a product with $t \in (T_s, T]$, let x_{ns} and π_{ns} denote the steady-state flow output and operating profit, respectively, of the Northern innovator *and* all Northern imitators in the Southern market; while x_{ss} and π_{ss} denote the steady-state flow output and operating profit, respectively, of all Southern imitators in the Southern market. Hence, for a product with $t \in (T_s, T]$,

$$\begin{cases} p_s = [(H+K+1)c + (H+1)\tau_s]/(H+K+\alpha), \\ x_s = \{\alpha(H+K+\alpha)/[(H+K+1)c + (H+1)\tau_s]\}^\epsilon, \\ x_{ns} = B(H,K)[(1-\alpha)c - (K-1+\alpha)\tau_s]/[(H+K+1)c + (H+1)\tau_s]^{\epsilon+1}, \\ x_{ss} = B(H,K)[(1-\alpha)c + (H+1)\tau_s]/[(H+K+1)c + (H+1)\tau_s]^{\epsilon+1}, \\ \pi_{ns} = B(H,K)[(1-\alpha)c - (K-1+\alpha)\tau_s]^2/\{[(H+K+1)c + (H+1)\tau_s]^{1+\epsilon}(H+K+\alpha)\}, \\ \pi_{ss} = B(H,K)[(1-\alpha)c + (H+1)\tau_s]^2/\{[(H+K+1)c + (H+1)\tau_s]^{1+\epsilon}(H+K+\alpha)\}. \end{cases} \quad (5)$$

Clearly, from (5) we see that the Southern tariff reduces π_{ns} (i.e., $\partial \pi_{ns}/\partial \tau_s < 0$). Using condition $x_{ns} > 0$ or equivalently $(1 - \alpha)c - (K + \alpha - 1)\tau_s > 0$, we can show that

$$\frac{\partial \pi_{ss}}{\partial \tau_s} = (H + 1)\frac{B(H,K)[(1 - \alpha)c + (H + 1)\tau_s]}{[(H + K + 1)c + (H + 1)\tau_s]^{2+\epsilon}} \left\{ \frac{\epsilon[2(1 - \alpha)Kc - \alpha \tau_s] + \alpha c}{H + K + \alpha} \right\} > 0.$$

The Southern tariff shifts profits from the Northern innovator and imitators to the Southern imitators. For a product with $t \in (T_s, T]$, there are $H + 1$ identical Northern firms (each with a marginal cost equal to $c + \tau_s$) and K identical Southern firms (each with a marginal cost equal to c) competing in the Southern market. As τ_s increases, the marginal cost for Northern firms increases. It is intuitive that the steady-state flow profits of all Southern firms increase while those of all Northern firms decrease.

In summary, we have derived the steady-state product market equilibria in the North for two distinct kinds of products (i.e., those with $t \le T_n$ and $T \ge t > T_n$, respectively), and also in the South (those with $t \le T_s$ and $T \ge t > T_s$, respectively). In particular, we have calculated each type of firm's steady-state flow operating profit derived from each market.

2.2. Innovation and Imitation

We now turn to innovation and imitation in order to determine the number of products invented in each period. To this end, we examine a firm's profit over T periods. Thus, we will move away from the focus on the steady-state in this subsection. Northern firm i invests in R&D to invent product i if and only if the stream of operating profits over the entire T periods is sufficiently large to cover the innovation costs, and the imitators use the same criterion to decide whether or not to imitate. For convenience, we order the products in such a way that a product with a higher index i has a higher innovation cost. This could be due to the fact that the Northern firm with a higher i is less capable of innovation. Alternatively, this reflects economy-wide diminishing marginal returns to innovation activities or increasing marginal cost of innovation. Without loss of generality, we adopt the simplest possible innovation cost structure for product i: innovation cost

$= bi$ where $b > 0$. We assume that the imitation cost for each imitator in each product is the same, being equal to $e > 0$.

We now consider innovation. Recall that under IPR protection, Northern firm i, if it invests in innovation, earns monopoly profit as given by (1) from its home market in the first T_n periods, and monopoly profit as given by (4) from export to the South in the first T_s periods. Its operating profit in the Northern market in each period after IPR protection expires is π_{nn} as given by (2) and in the Southern market is π_{ns} as given by (5). By definition, Northern firm i's net life-time profit (taking into account innovation costs) is

$$\Pi_n(i) = \pi_n - bi, \tag{6}$$

where the life-time operating profit is equal to

$$\pi_n = AT_n c^{-\alpha\epsilon} + AT_s(c + \tau_s)^{-\alpha\epsilon} + (T - T_n)\pi_{nn} + (T - T_s)\pi_{ns}. \tag{7}$$

Since only firms that earn positive profits would produce, the number of products invented in each period, M, must satisfy

$$\Pi_n(M) = 0. \tag{8}$$

Then all products with index $i \leq M$ will be developed.

2.3. Policy Effects on Innovation

Given policy parameters, the preceding subsection has characterized the possible equilibrium outcomes about innovation. In this subsection, we explore how various policy measures affect the innovation set. Although time is discrete, we treat time as continuous in analyzing the impacts of changing T_s and T_n.

Since (8) determines the equilibrium number of innovation, differentiating with respect to policy variable (parameter) $y = \{\tau_n, \ \tau_s, \ T_n, \ T_s\}$ yields the impact of the policy on innovation according to

$$\frac{\partial M}{\partial y} = \frac{1}{b}\frac{\partial \pi_n}{\partial y}. \tag{9}$$

The innovation set will expand if a policy raises Northern innovator's operating profit π_n. Eventually, we obtain

Proposition 1 : *Innovation is encouraged by raising IPR protection in either region or raising tariffs in the North. Innovation is discouraged by raising tariffs in the South. Mathematically,*

$$\frac{\partial M}{\partial T_s} > 0, \quad \frac{\partial M}{\partial T_n} > 0, \quad \frac{\partial M}{\partial \tau_n} > 0, \quad \frac{\partial M}{\partial \tau_s} < 0.$$

PROOF: See Appendix.   □.

3.   Northern Trade Protection: Protect Profits vs. Promote Innovation

At this point we switch our focus and turn to welfare analysis. In this section, we characterize the optimal Northern tariff and its relation to the degree of IPR protection. In particular, we argue that Northern tariffs not only shift profits but also encourage innovation. In the next section, we will compare and contrast the Northern tariff and the Southern tariff. In both sections, our primary purpose is to derive results that would not be obtained in conventional trade models, i.e., models without product innovation and imitation.

Based on (1) and utility maximization, the steady-state flow Northern utility derived from all the products with $t \leq T_n$ is

$$u_n(t) = T_n \int_0^M x_n^\alpha \mathrm{d}i = T_n M(1-\alpha)\left(\frac{\alpha^2}{c}\right)^{\alpha\epsilon} \tag{10}$$

Similarly, based on (2), the steady-state flow Northern utility derived from all the products with $t \in (T_n, T]$ is

$$\widetilde{u_n}(t) = (T - T_n)M(1-\alpha)\left[\frac{\alpha(H + K + \alpha)}{(H + K + 1)c + K\tau_n}\right]^{\alpha\epsilon} \tag{11}$$

We use V_n to denote the total imports by the North in steady state, and it is given by

$$V_n = \sum_{t=T_n}^T \int_0^M x_{sn}(t)\mathrm{d}i = M(T - T_n)v_n, \quad \text{where } v_n = KB(H, K)\frac{(1-\alpha)c - (\alpha + H)\tau_n}{[(H + K + 1)c + K\tau_n]^\epsilon}.$$

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We now calculate the steady-state flow welfare of the North, denoted by $W_n(\tau)$. It is defined as the sum of steady-state flow consumer utility, producer profits and tariff revenue from all invented products. The steady-state flow profits are the sum of Northern firms' profits derived in a steady-state period, which turn out to be equal to the sum of the life-time profits of all products that are invented in that period plus the sum of the life-time profits of all Northern imitators in both markets in that period. It is clear that this is equal to $\int_0^M \Pi_n(i)\mathrm{d}i + MH\left[\sum_{t=T_n}^T \pi_{nn}(t) + \sum_{t=T_s}^T \pi_{ns}(t) - e\right]$. Hence,

$$
\begin{aligned}
W_n(\tau) &= \sum_{t=1}^{T_n} u_n(t) + \sum_{t=T_n}^T \widetilde{u_n}(t) + \int_0^M \Pi_n(i)\mathrm{d}i + E_n + \tau_n V_n \\
&\quad + MH\left[\sum_{t=T_n}^T \pi_{nn}(t) + \sum_{t=T_s}^T \pi_{ns}(t) - e\right] = Mw_n(\tau) + E_n \qquad (12)
\end{aligned}
$$

$$
\begin{aligned}
\text{where } w_n(\tau) &= T_n(1-\alpha)\left(\frac{\alpha^2}{c}\right)^{\alpha\epsilon} + (T-T_n)(1-\alpha)\left[\frac{\alpha(H+K+\alpha)}{(H+K+1)c + K\tau_n}\right]^{\alpha\epsilon} \\
&\quad + \frac{b}{2}\pi_n + \tau_n(T-T_n)v_n + H\left[(T-T_n)\pi_{nn} + (T-T_s)\pi_{ns} - e\right].
\end{aligned}
$$

The Northern government's objective is to maximize Northern steady-state flow welfare by choosing a non-negative τ_n. Thus, assuming that the optimal tariff rate is an interior solution, it must satisfy the following first-order condition:

$$
\frac{\partial W_n}{\partial \tau_n} = M\frac{\partial w_n}{\partial \tau_n} + w_n\frac{\partial M}{\partial \tau_n} = 0. \qquad (13)
$$

We examine each welfare term of (13) in turn. First,

$$
\frac{\partial w_n}{\partial \tau_n} = (T-T_n)\left[-\alpha K\frac{[\alpha(H+K+\alpha)]^{\alpha\epsilon}}{[(H+K+1)c + K\tau_n]^\epsilon} + \left(H+\frac{1}{2}\right)\frac{\partial \pi_{nn}}{\partial \tau_n} + v_n + \tau_n\frac{\partial v_n}{\partial \tau_n}\right]. \qquad (14)
$$

Equation (14) is the welfare effect of the tariff that we usually see in models with imperfect competition but without innovation and imitation. The Northern tariff reduces consumer surplus, increases firms' profits, and generates government revenue. If import subsidy is not allowed, the optimal tariff could be zero or positive, depending upon whether the terms of trade are improved and how much profit is shifted from the foreign exporters to

the local firms.[17] For the sake of exposition, let $\overline{\tau}_n$ be the optimal tariff rate when changes in innovation are ignored. Then, $\overline{\tau}_n = 0$ if $\partial w_n/\partial \tau_n \leq 0$ at $\tau_n = 0$ and $\overline{\tau}_n > 0$ otherwise.

We now turn to the second term of (13). Since $\partial M/\partial \tau_n > 0$ (by Proposition 1), Northern consumers benefit from larger product variety and more products will be exported by the North. These together raise Northern welfare.

We now combine all the effects discussed above for the first-order condition (13). Let τ_n^* be the optimal tariff rate that satisfies (13). Then, $\tau_n^* = 0$ if $\partial W_n/\partial \tau_n \leq 0$ at $\tau_n = 0$ and $\tau_n^* > 0$ otherwise. From the above analysis, we know $\partial W_n/\partial \tau_n > \partial w_n/\partial \tau_n$, and hence, $\tau_n^* \geq \overline{\tau}_n$. More specifically, whenever $\overline{\tau}_n > 0$, we must have $\tau_n^* > 0$ and $\tau_n^* > \overline{\tau}_n$; and in some cases, $\overline{\tau}_n = 0$, but $\tau_n^* > 0$. We summarize the above results in Proposition 2 below.

Proposition 2 : *There is a new rationale for a Northern tariff. There is one more reason why a Northern tariff can raise Northern welfare above the level attainable by free trade in the present model, as compared with other trade models without innovation and imitation. Whenever it is optimal to impose a tariff, the optimal tariff rate in the presence of innovation and imitation is strictly higher than that in the absence of innovation and imitation.*

What exactly is the new rationale for Northern tariff? Suppose T_s and τ_s are beyond the control of the Northern government. Note also the empirical fact that IPR policies are slow to change (e.g. a seventeen-year patent length has been in place and unchanged for many decades in the US). If the given IPR protection T_n is too low for the existing tariff τ_n, then an increase in τ_n can increase consumer welfare by encouraging innovation and thereby making a larger variety of goods available for consumption.

We demonstrate the above point below. To isolate the new motive for tariff protection, we exclude producer profits and tariff revenue in the Northern welfare function. That is, we focus only on the effect on consumer welfare. This enables us to focus on the case where

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[17]Helpman and Krugman (1989, Chapter 6) have a nice analysis of this issue.

a tariff is not for profit shifting or terms-of-trade improvement. We investigate how the optimal tariff rate τ_n^c, which maximizes Northern consumer welfare $\tilde{W}_n$, depends on the degree of IPR protection. Assume the second-order condition holds, i.e., $\partial^2 \tilde{W}_n / \partial \tau_n^2 < 0$. By totally differentiating the first-order condition (13) (with W_n replaced by $\tilde{W}_n$, see Appendix C), we obtain

$$\frac{\partial \tau_n^c}{\partial T_n} = -\frac{\partial}{\partial T_n}\left(\frac{\partial \tilde{W}_n}{\partial \tau_n}\right) \bigg/ \left(\frac{\partial^2 \tilde{W}_n}{\partial \tau_n^2}\right), \quad \text{which implies} \quad \text{sgn}\left(\frac{\partial \tau_n^c}{\partial T_n}\right) = \text{sgn}\left[\frac{\partial}{\partial T_n}\left(\frac{\partial \tilde{W}_n}{\partial \tau_n}\right)\right].$$

This sign is negative, and a similar relationship holds for τ_n and T_s (see Appendix C). Therefore, we have the following proposition:

Proposition 3 : *The Northern tariff that maximizes Northern consumer welfare is higher if IPR protection in the North or IPR protection in the South is weaker. Mathematically, $\partial \tau_n^c / \partial T_n < 0$ and $\partial \tau_n^c / \partial T_s < 0$.*

PROOF: See Appendix. □

That an increase in import tariff can increase domestic consumer welfare is an interesting point, since most previous arguments for an optimal tariff are based on its effect on increased profits of firms and/or increased tariff revenue. Few previous theories have suggested that a higher tariff can increase consumer welfare.

In fact, an increased tariff to compensate for inadequate IPR protection is only a second best solution as far as the consumer welfare is concerned. The first best solution would be for both a tariff and IPR protection to be jointly optimally chosen to maximize consumer welfare. See Figure 1.

< **Figure 1 about here** >

In the figure, it can be seen that the first best solution is at point A, denoted by (T_n^*, τ_n^*). The curve labeled $\tau_n(T_n)$ represents the optimal value of τ_n as a function of any given T_n. If T_n is lower (higher) than the first best, the optimal τ_n should be higher (lower) than the first best. The curve labeled $T_n(\tau_n)$ represents the optimal value of T_n as

a function of any given τ_n. Again, if τ_n is lower (higher) than the first best, the optimal T_n should be higher (lower) than the first best.

The intersection of the two curves yields the first best solution for maximization of consumer welfare. Note that the first best optimal tariff is not $\tau_n = 0$ and the first best optimal IPR protection is not $T_n = T$. There are interior solutions to both. Suppose there is very little flexibility in the adjustment of T_n. Then curve $\tau_n(T_n)$ is the relevant one for our analysis. If T_n is too low for the existing τ_n, such as in point B, then consumer welfare can be improved with an increased τ_n by shifting to point C.

To understand intuitively how an increased Northern tariff can be used to (partly) supplement weak IPR protection, let us first compare the similar welfare effects resulting from an increase in Northern IPR protection and from a higher Northern tariff. Note that by excluding profits and tariff revenue the welfare is simply the consumer surplus, which decreases if the prices are higher but increases when there is larger product variety (i.e., a greater M). Since we cannot find any (costless) policy that will lower the prices and at the same time stimulate innovation, policy measures that maximize consumer welfare should be combined to strike a balance with prices being not too high and innovations being not too few. First, based on (12), we easily observe the two conflicting effects of increasing T_n. On the one hand, consumer surplus is reduced because all goods are charged at their monopoly prices for a longer period of time. On the other hand, M is larger and hence consumer surplus increases due to larger product variety. Second, those two conflicting welfare effects are also present when τ_n increases: An increase in the tariff results in higher prices paid by consumers for all products during the import periods and thus lowers consumer surplus; however, greater profits for the Northern innovators are assured by a higher tariff and therefore there are more innovations (i.e., M is larger), giving rise to greater consumer surplus. Clearly, the Northern tariff plays a similar role as Northern IPR protection and so the former can be used to supplement the latter when the Northern government has more flexibility to adjust its tariff rate than the patent length. For example, if IPR protection is too weak (T_n too small), meaning that M is

16

not big enough from the consumers' point of view, we should raise the tariff to stimulate innovation. If, however, the IPR protection is already very strong (T_n very big), welfare can be increased by depressing the prices through lowering the tariff rate.

We now turn to the (partial) substitutability of τ_n for T_s. Unlike T_n, T_s has a single effect on Northern welfare through its influence on product variety: an increase of T_s raises M. Thus, as Southern IPR protection becomes weaker, the North can raise its tariff rate to at least partially compensate the Northern innovators, so that their innovations will not decrease too drastically. On the other hand, when Southern IPR protection becomes stronger, the North worries less about innovation incentives but more about high consumer prices, and thus the tariff rate should be lowered to dampen the prices.

To summarize this section, we have demonstrated (in Proposition 2) that there is a pro-innovation element in the optimal Northern tariff. This is a new justification (motive or rationale) for a Northern tariff. This effect of the tariff is to promote innovation, not protect profits. Moreover, in Proposition 3, we have shown that the optimal level of this tariff is higher (lower) if IPR protection, in the North or South, becomes weaker (stronger). Hence, we have identified the pro-innovation role of Northern tariffs, and its (partial) substitutability for IPR protection. In the next section, we shall compare the roles of Northern and Southern tariffs.

4.   Trade Protection: By the North vs. by the South

The pro-innovation feature of the Northern tariff seems to imply that maybe the Northern tariff is desirable not only for the North but also for the world. What about the Southern tariff? If we allow tariff protection, which region should be allowed to use it, the North or the South? To answer these questions, we contrast the different welfare effects of the Northern tariff and the Southern tariff.[18]

First, let us look at the Southern tariff's impact on Northern welfare. Differentiating

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[18]Recall that we have ascertained their different impact on innovation as summarized in Proposition 1.

gives:

$$\frac{\partial W_n}{\partial \tau_s} = M\frac{\partial w_n}{\partial \tau_s} + w_n\frac{\partial M}{\partial \tau_s}. \tag{15}$$

First, note that using (12) we have

$$\frac{\partial w_n}{\partial \tau_s} = \frac{\partial \pi_n}{\partial \tau_s} = (T - T_s)\frac{\partial \pi_{ns}}{\partial \tau_s} < 0.$$

Thus, the first term of (15) is negative. This is the familiar profit-shifting result in the strategic trade literature and it has captured the total effect in the conventional trade model of imperfect competition without innovation and imitation. Thus, a foreign tariff is detrimental to home welfare because it reduces the home producers' profits.

Second, we turn to the second term of (15), which is negative according to Proposition 1. This shows that in the present model with innovation and imitation, the Southern tariff is more harmful to the North than in the conventional model. To see this, recall from Proposition 1 that an increase in τ_s shrinks the innovation set because the Southern tariff reduces Northern firms' profits. As a result, in the North, consumers have a smaller product variety and the government collects less tariff revenue. Northern welfare unambiguously decreases. Based on this analysis we immediately establish the following proposition:

Proposition 4 : *A Southern tariff is a beggar-thy-neighbor policy. Its adverse effect on Northern welfare is more serious in the present model with innovation and imitation than in the conventional model without innovation and imitation.*

We now consider the impact of a Northern tariff on Southern welfare. We first derive the Southern steady-state flow welfare. Similar to (10) and (11), we obtain the steady-state flow utility derived from all products with $t \leq T_s$

$$u_s(t) = T_s M(1 - \alpha)\left(\frac{\alpha^2}{c + \tau_s}\right)^{\alpha\epsilon},$$

and the steady-state flow utility derived from all products with $T \geq t > T_s$

$$\widetilde{u}_s(t) = (T - T_s)M(1 - \alpha)\left[\frac{\alpha(K + \alpha)}{(K + 1)c + \tau_s}\right]^{\alpha\epsilon}.$$

The total import by the South is

$$V_s = Mv_s, \quad \text{where } v_s = T_s A(c+\tau_s)^{-\alpha\epsilon} + (T-T_s)B(H,K)\{\frac{(1-\alpha)c - (K+\alpha-1)\tau_s}{[(H+K+1)c + (H+1)\tau_s]^{\epsilon+1}}\}.$$

The steady-state flow profits of all Southern imitators are equal to

$$\Pi_s = MK\left[\sum_{t=T_s}^{T}\pi_{ss}(t) + \sum_{t=T_n}^{T}\pi_{sn}(t) - e\right] = MK(\pi_s - e), \quad \text{where } \pi_s = (T-T_s)\pi_{ss} + (T-T_n)\pi_{sn}. \tag{16}$$

The Southern steady-state flow welfare, denoted by $W_s(\tau)$, is defined as the sum of the flow consumer surplus, producer profit and tariff revenue. Hence,

$$W_s(\tau) = \sum_{t=1}^{T_s}u_s(t) + \sum_{T_s}^{T}\widetilde{u}_s(t) + \Pi_s + \tau_s V_s = Mw_s(\tau) + E_s \tag{17}$$

$$\text{where} \quad w_s(\tau) = T_s(1-\alpha)\left(\frac{\alpha^2}{c+\tau_s}\right)^{\alpha\epsilon} + (T-T_s)(1-\alpha)\left[\frac{\alpha(H+K+\alpha)}{(H+K+1)c + (H+1)\tau_s}\right]^{\alpha\epsilon}$$
$$+ K[(T-T_s)\pi_{ss} + (T-T_n)\pi_{sn} - e] + \tau_s v_s.$$

Differentiating with respect to τ_n, we obtain

$$\frac{\partial W_s}{\partial \tau_n} = M\frac{\partial w_s}{\partial \tau_n} + w_s\frac{\partial M}{\partial \tau_n}. \tag{18}$$

The first term on the right-hand side of (18), which is equal to $MK(T-T_n)\partial\pi_{sn}/\partial\tau_n$, is negative, being the result of profit shifting. Because of this, Southern welfare is reduced. However, the second term is positive, which tends to increase Southern welfare. The Northern tariff expands the innovation set, which in turn also gives rise to a larger imitation set. As a result, in the South, consumers enjoy larger product variety, there are more imitators earning positive profits, and the government collects more tariff revenue. All these lead to greater welfare for the South.

It is manifest from the above analysis that because the Northern tariff is pro-innovation, its adverse effect on Southern welfare, if any, is smaller in the present model with innovation and imitation than in the conventional model without innovation and imitation. Depending on the relative degrees of the positive and negative effects, the Northern tariff

may even increase Southern welfare, in which case it is no longer a beggar-thy-neighbor policy.

In fact, it is not only a possibility that the South can benefit from a Northern tariff. We can actually show that it is really true for some values of τ_n. As W_s is a multivariable function including τ_n, whether $\partial W_s/\partial \tau_n > 0$ or not depends on various combinations of many parameters and so finding the necessary and sufficient conditions is intractable. Nevertheless, our purpose is to show that under some meaningful conditions a Northern tariff is beneficial to the South. Proposition 5 below provides some results on this.

Proposition 5 : *Given all other parameter values, there exists a unique $b_0 > 0$ such that $\partial W_s/\partial \tau_n > 0$ if and only if $b < b_0$.*

PROOF: See Appendix. $\square$

It is clear why we need the condition for b. When b is sufficiently small, increasing innovators' market profits will lead to a large increase in innovation M. This benefit to Southern consumers more than offsets the loss of Southern profits due to an increase in the Northern tariff. That is, when b is sufficiently small, the second positive term in (18) is greater than the first negative term in absolute value, leading to an increase in welfare in the South as τ_n increases.

We have found that tariffs imposed by the North and the South have very different consequences on the other region. How, then, are they different in affecting global welfare? A related question is: If we allow just one region to impose a tariff, should it be the North or the South? The above analysis seems to indicate the desirability (or lower undesirability) of the Northern tariff over the Southern tariff. In the rest of this section, we seek an explicit answer to this question.

Steady-state flow global welfare is the sum of Northern welfare and Southern welfare, and so it is defined as

$$W(\tau) = W_n(\tau) + W_s(\tau) \ = Mw(\tau) + E_n + E_s, \quad \text{where } \ w(\tau) = w_n(\tau) + w_s(\tau).$$

Differentiating with respect to the Southern tariff rate, we obtain

$$\frac{\partial W(\tau)}{\partial \tau_s} = M\frac{\partial w}{\partial \tau_s} + w\frac{\partial M}{\partial \tau_s} < 0.$$

The first term on the right-hand side is negative. This is the result from conventional trade models without innovation and imitation, that any region's tariff lowers global welfare even if it may raise the policy-adopting region's welfare. The second term is also negative because the Southern tariff reduces Northern firms' innovation incentives and so is detrimental to both regions. Hence, the Southern tariff unambiguously reduces global welfare, and it reduces global welfare more in the presence of innovation and imitation than in the absence of innovation and imitation.

Differentiating global welfare with respect to the Northern tariff rate, we obtain

$$\frac{\partial W(\tau)}{\partial \tau_n} = M\frac{\partial w}{\partial \tau_n} + w\frac{\partial M}{\partial \tau_n}. \tag{19}$$

The first term on the right-hand side is negative. However, the second term is positive, because Northern protection increases product variety and thus both regions benefit. Therefore, innovation reduces the detrimental effect of the Northern tariff on global welfare. It is even possible that global welfare is improved by raising Northern tariff if the positive innovation effect is sufficiently strong. We show this below.

Suppose τ_n^w (with no restriction on its sign) maximizes global welfare, then $\partial W(\tau)/\partial \tau_n = 0$ at $\tau_n = \tau_n^w$, assuming $\partial^2 W(\tau)/(\partial \tau_n)^2 < 0$. Differentiating this first-order condition with respect to T_s, we obtain

$$\frac{\partial \tau_n^w}{\partial T_s} = -\frac{\partial}{\partial T_s}\left(\frac{\partial W}{\partial \tau_n}\right) \Big/ \frac{\partial^2 W(\tau)}{(\partial \tau_n)^2} \quad \text{and so} \quad \text{sgn}\left(\frac{\partial \tau_n^w}{\partial T_s}\right) = \text{sgn}\left(\frac{\partial}{\partial T_s}\left(\frac{\partial W}{\partial \tau_n}\right)\right).$$

Then using (19), we have

$$\frac{\partial}{\partial T_s}\left(\frac{\partial W}{\partial \tau_n}\right) = M\frac{\partial}{\partial T_s}\left(\frac{\partial w}{\partial \tau_n}\right) + \frac{\partial w}{\partial \tau_n}\frac{\partial M}{\partial T_s} + w\frac{\partial}{\partial T_s}\left(\frac{\partial M}{\partial \tau_n}\right) + \frac{\partial M}{\partial \tau_n}\frac{\partial w}{\partial T_s} < 0$$

since the first term on the RHS is zero (using (6)-(8)) and the third term is also zero (using (6)-(8)), while the second and the last terms are both negative ($\partial w/\partial \tau_n < 0$, $\partial M/\partial T_s > 0$,

$\partial M/\partial \tau_n > 0$, $\partial w/\partial T_s < 0$).[19]

As a result, $\partial \tau_n^w / \partial T_s < 0$. *That is, for weaker IPR protection in the South, the Northern tariff which is required to maximize global welfare should be higher, for otherwise the amount of innovation would be too small. The same result holds for the IPR protection in the North:* $\partial \tau_n^w / \partial T_n < 0$. (proof is the same as the Southern IPR).

It remains to show that τ_n^w is positive under certain conditions. While general conditions are difficult to obtain, by focusing on the following parameter values as an example: $\alpha = 0.5$, $T = 30$, $T_n = 20$, $b = 2$, $e = 1$, $c = 1$, $H = K = 1$ and $\tau_s = 0$, we obtain,

$$\frac{\partial W}{\partial \tau_n} = \frac{25}{16(3+\tau_n)^4}[(9-2\tau_n)(1+2\tau_n)w+(39-384\tau_n-224\tau_n)M] > 0 \ \text{ at } \tau_n = 0 \text{ and for all } T_s.$$

This shows $\tau_n^w > 0$. When τ_n is sufficiently large, it is sure that increased Northern tariff will reduce global welfare. But the above results have shown that for a range of $\tau_n \in [0, \tau_n^w)$, global welfare continue to increase as the North raises its tariff. This range is larger if the IPR protection is weaker (T_s is smaller or T_n is smaller). Hence, we have

Proposition 6 : *A higher Northern tariff supplements weak IPR protection in the world, in the sense that a weaker IPR protection in the North or the South raises the globally optimal Northern tariff.*

A corollary of the above proposition is that, starting from a point of optimal Northern tariff for given levels of T_s and T_n, an increase in Northern tariff will be globally welfare-improving in the face of a decrease in IPR protection in one of the regions. This result is in sharp contrast to the role of an increase in Southern tariff, which always reduces global welfare. Therefore, we conclude that Southern tariffs are more detrimental to world welfare than Northern ones in innovation-intensive sectors where innovations concentrate

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[19]The last inequality, $\partial w/\partial T_s = AT_s(c+\tau_s)^{-\alpha\varepsilon}/2 - (H+1/2)\pi_{ns} + (1-\alpha)[\alpha^2/(c+\tau_s)]^{\alpha\varepsilon} - (1-\alpha)[\alpha(H+K+\alpha)/[(H+K+1)c+(H+1)\tau_s]^{\alpha\varepsilon} - K\pi_{ss} + A\tau_s(c+\tau_s)^{-\alpha\varepsilon} - B(H,K)\tau_s \{[(1-\alpha)c-(K+\alpha-1)\tau_s]/[H+K+1)c+(H+1)\tau_s]^{(\varepsilon+1)} < 0$, can be confirmed by intuition: given that innovation is not changed (i.e., M is fixed here), increasing patent length increases patent holders' profits, reduces imitators profits, reduces consumer surplus, and *reduces* social welfare.

in the North, and IPR protections are weak in both regions. One example that comes to mind is internet-related products.

The (partial) substitutability of the two instruments, Northern IPR protection and Northern tariff, for the sake of world welfare is apparent, since the effects of the two policies are very similar. A stronger IPR protection in the North increases the profits of the Northern innovators at the expense of Northern consumer welfare, and results in an increase in deadweight loss in the North. This is the marginal cost of Northern IPR protection. The marginal benefit of Northern IPR protection is the increase in the number of innovations, which benefits both Northern and Southern consumers. The optimal Northern IPR protection would strike a balance between the two effects. An increase in Northern tariff protection increases the profits of Northern innovators and Northern imitators, and increases the deadweight loss in the North. This is the marginal cost of Northern trade protection. The marginal benefit of Northern trade protection is again an increase in number of innovations. An optimal Northern tariff would strike a balance between the two effects. Therefore, the two policies have similar effects on world welfare. A Northern tariff should be a less effective tool for encouraging innovation, in the sense that for the same increase in deadweight loss, the increase in innovator profits is smaller, since some increase in profits go to Northern imitators as well. Thus, the optimal Northern tariff may not be positive, but it is more likely so when T_n and T_s are both small.

5. Concluding Remarks

In a North-South trade model with innovation and imitation, we have shown how trade policy and IPR policy in the two regions affect innovation and imitation. The central message from this study comes from its answers to the question: what are the differing roles of Northern and Southern tariffs in a world with innovation and imitation, where innovations concentrate in the North? We have argued that unlike conventional trade models without innovation and imitation, the Northern tariff protects not only profits but also innovation and thus supplements weak IPR protection as a second best

23

policy. Because of the consideration of innovation and imitation, the effects of Northern tariff and Southern tariff are qualitatively different. The former may not be a beggar-thy-neighbor policy but the latter is. Global welfare declines as the South raises its tariff, but under some circumstances it rises as the North raises its tariff. Hence, Northern tariffs are less harmful to world welfare than Southern ones in innovation-intensive sectors where innovations concentrate in the North, and IPR protection in the world is weak. Moreover, it would benefit the North to subsidize trade liberalization of the South in these sectors, since the South's loss would be more than offset by the North's gain.

Under imperfect competition, if we take into account innovation and imitation, there is one more motive for tariff protection in the North — improving consumer welfare by encouraging more innovation. This is an interesting finding since few previous analyses have pointed out that tariff protection can improve consumer welfare through encouraging more innovations. The underlying point is that, from the consumer welfare point of view, taxing at least some of the imitators can serve as a partial substitute for strengthening a weak IPR protection regime. This general principle holds in a closed economy as well as a global economy with trade.

What about the robustness of the results? As any other economic model, this one is built upon a number of assumptions. Among these, those deserving attention are the specific utility function, the absence of price competition between products, and the location where innovation takes place. Let us focus our discussion on the implications of allowing innovation to take place in the South. We conjecture that the qualitative aspects of our results would continue to hold if (a) IPR protection is much stronger in the North than in the South, (b) the ability to innovate is much higher in the North than in the South. Condition a alone would have resulted in much more innovation in the North than in the South even if both regions have an equal ability to innovate. Their difference in innovative ability described in b further widens the gap. Therefore, we would have the situation in which the North does most of the innovation and the South does only a little bit. Then, the effects of a Northern tariff and a Southern tariff would be similar to what

have been presented in this paper. Finally, assuming the South has lower imitation cost would not alter our results.

There are two more caveats worth mentioning. First, our model is set in a partial-equilibrium environment, with expanding-variety type of innovation. This analysis is appropriate for certain purposes, yet may not be appropriate for others. When innovation is of the quality-improvement kind, a tariff increases the profits of an existing vintage, whose patent has expired, more than it increases the profits of a new (yet to be invented) vintage, whose profits are unaffected by the tariff. As a result, Arrow's "replacement effect" becomes more severe with a tariff, which reduces the incentive to innovate by the innovator of the existing vintage. Therefore, a tariff can reduce innovation. Second, if tariffs are imposed on a sufficiently large segment of the economy so that general-equilibrium effect cannot be ignored, a Northern import tariff can possibly deter innovation. This is because more production will stay in the North, which competes for resources (workers) for R&D, raising wage and lowering the returns to innovation, thus reducing innovation. Despite these caveats, however, we believe the model can apply to certain important sectors of the economy.

We should reiterate that in this paper we are not trying to argue for increasing trade protection. Rather, the message we would like to convey is that trade protection by the South is more detrimental to world welfare than by the North in innovation-intensive sectors where IPR protection in both regions are weak, such as the internet-related products. Therefore, the North should perhaps subsidize trade liberalization in the South.

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Appendix

A. Proof of Proposition 1.

Based on (6) and (8) we have

$$M = \frac{\pi_n}{b}, \tag{A1}$$

where π_n is given in (7). From (A1), differentiating M with respect to T_n and T_s, respectively, yields

$$\frac{\partial M}{\partial T_n} = \frac{\pi_{nn}^m - \pi_{nn}}{b} > 0 \quad \text{and} \quad \frac{\partial M}{\partial T_s} = \frac{\pi_{ns}^m - \pi_{ns}}{b} > 0.$$

The inequalities hold because the Northern innovator's monopoly profit is greater than its profit from oligopolistic competition.

Again, differentiating (A1) with respect to τ_n and τ_s, respectively, yields

$$\frac{\partial M}{\partial \tau_n} = \frac{(T - T_n)}{b} \frac{\partial \pi_{nn}}{\partial \tau_n} > 0 \quad \text{and} \quad \frac{\partial M}{\partial \tau_s} = \frac{(T - T_s)}{b} \frac{\partial \pi_{ns}}{\partial \tau_s} < 0. \quad \square$$

B. Proof of Proposition 3.

Since the profit term and tariff revenue term do not show up in the welfare function we define consumer welfare as

$$\tilde{W}_n = M(1 - \alpha)\tilde{w}_n + E_n \quad \text{where} \quad \tilde{w}_n = T_n \left(\frac{\alpha^2}{c} \right)^{\alpha \epsilon} + (T - T_n) \left[\frac{\alpha(H + K + \alpha)}{(H + K + 1)c + K\tau_n} \right]^{\alpha \epsilon}.$$

Then the first order condition for an optimal Northern tariff τ_n is equivalent to

$$M \frac{\partial \tilde{w}_n}{\partial \tau_n} + \tilde{w}_n \frac{\partial M}{\partial \tau_n} = 0. \tag{A2}$$

Moreover,

$$\epsilon \frac{\partial}{\partial T_n} \left(\frac{\partial \tilde{W}_n}{\partial \tau_n} \right) = M \frac{\partial}{\partial T_n} \left(\frac{\partial \tilde{w}_n}{\partial \tau_n} \right) + \tilde{w}_n \frac{\partial}{\partial T_n} \left(\frac{\partial M}{\partial \tau_n} \right) + \left(\frac{\partial \tilde{w}_n}{\partial \tau_n} \right) \left(\frac{\partial M}{\partial T_n} \right) + \left(\frac{\partial \tilde{w}_n}{\partial T_n} \right) \left(\frac{\partial M}{\partial \tau_n} \right). \tag{A3}$$

Note that

$$\frac{\partial \tilde{w}_n}{\partial \tau_n} = -\alpha \epsilon K (T - T_n) \frac{[\alpha(H + K + \alpha)]^{\alpha \epsilon}}{[(H + K + 1)c + K\tau_n]^\epsilon}, \quad \frac{\partial}{\partial T_n} \left(\frac{\partial \tilde{w}_n}{\partial \tau_n} \right) = - \left(\frac{1}{T - T_n} \right) \frac{\partial \tilde{w}_n}{\partial \tau_n}.$$

From (7) and (8) we can obtain

$$\frac{\partial M}{\partial \tau_n} = \left(\frac{T - T_n}{b}\right)\frac{\partial \pi_{nn}}{\partial \tau_n} > 0, \quad \frac{\partial}{\partial T_n}\left(\frac{\partial M}{\partial \tau_n}\right) = -\left(\frac{1}{T - T_n}\right)\frac{\partial M}{\partial \tau_n}.$$

Substituting these into (A3) and using the first order condition (A2), we can immediately see that the sum of the first two terms of (A3) is equal to zero.

Recall from Proposition 1 that $\partial M/\partial \tau_n > 0$ and $\partial M/\partial T_n > 0$. And also note that consumer surplus decreases as T_n or τ_n increases, that is $\partial \tilde{w}_n/\partial T_n < 0$ and $\partial \tilde{w}_n/\partial \tau_n < 0$. We know that the third and fourth terms of (A3) are negative. The rest of the proof becomes obvious.

The proof of $d\tau_n^c/dT_s < 0$ is the same as above and so is omitted. $\quad\square$

C. Proof of Proposition 5.

Let

$$\begin{aligned}
\Phi \;\equiv\; \frac{\partial w_s}{\partial M} &= T_s(1-\alpha)\left(\frac{\alpha^2}{c + \tau_s}\right)^{\alpha\epsilon} + (T - T_s)(1-\alpha)\left[\frac{\alpha(H + K + \alpha)}{(H + K + 1)c + (H + 1)\tau_s}\right]^{\alpha\epsilon} \\
&\quad + K[(T - T_s)\pi_{ss} + (T - T_n)\pi_{sn} - e] + \tau_s v_s > 0.
\end{aligned}$$

Using (6) and differentiating (8) with respect to M, gives $\partial M/\partial \tau_n = (1/b)(T - T_n)(\partial \pi_{nn}/\partial \tau_n)$. Then differentiating (17) with respect to τ_n yields

$$\frac{\partial W_s}{\partial \tau_n} = MK(T - T_n)\frac{\partial \pi_{sn}}{\partial \tau_n} + \frac{1}{b}(T - T_n)\Phi\frac{\partial \pi_{nn}}{\partial \tau_n}. \tag{A4}$$

From (2), we obtain

$$\begin{aligned}
\frac{\partial \pi_{sn}}{\partial \tau_n} &= -\frac{B(H, K)[(1-\alpha)c - (H + \alpha)\tau_n]}{[(H + K + 1)c + K\tau_n]^{2+\epsilon}} \\
&\quad \cdot \left\{\frac{2\alpha[(H + K + 1)c + K\tau_n] + (1 + \epsilon)K[(1-\alpha)c - (H + \alpha)\tau_n]}{H + K + \alpha}\right\} \\
&< 0.
\end{aligned}$$

Using this and (3) in (A4), we obtain that

$$\frac{\partial W_s}{\partial \tau_n} > 0 \;\text{ iff }\; b < b_0 \quad \text{where}$$

$$b_0 \equiv \frac{[(1-\alpha)c + K\tau_n]\{\epsilon[2(1-\alpha)c - (H + \alpha)\tau_n] + \alpha c\}\Phi}{M[(1-\alpha)c - (H + \alpha)\tau_n]\{2\alpha[(H + K + 1)c + K\tau_n] + (1 + \epsilon)K[(1-\alpha)c - (H + \alpha)\tau_n]\}} > 0.$$

This completes the proof. $\quad\square$

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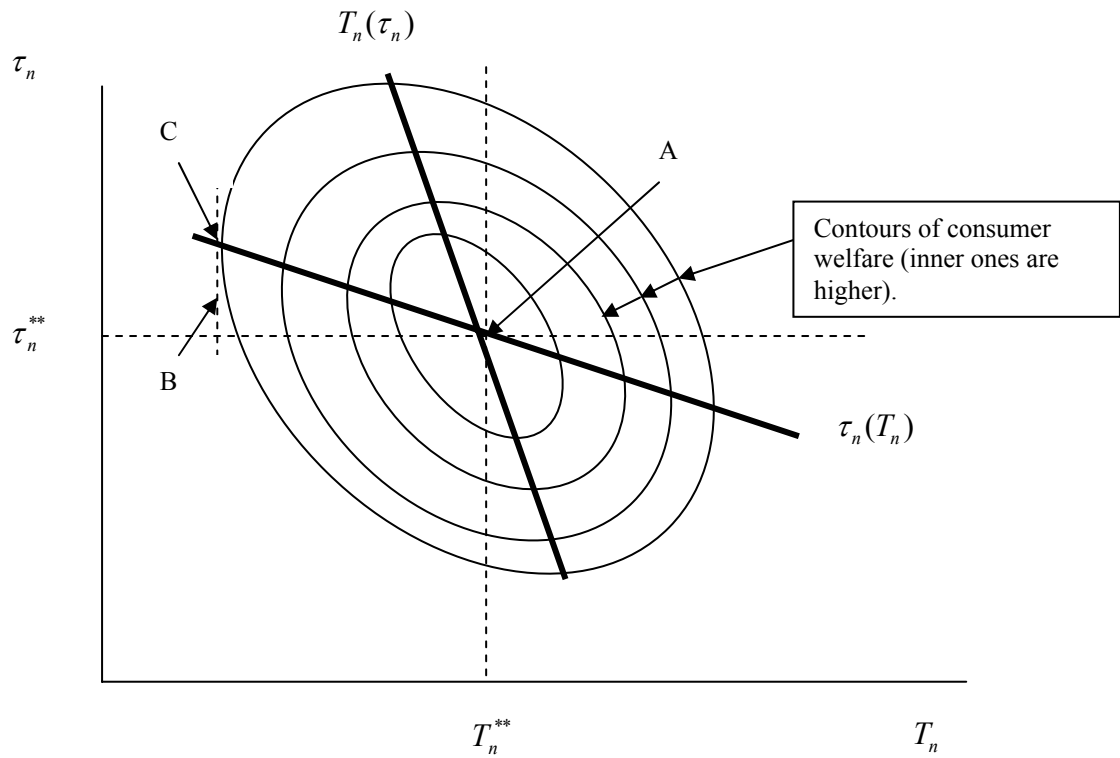
Figure 1. Optimal combination of T_n and τ_n for consumer welfare. $T_n(\tau_n)$ **is the locus of all points with horizontal slopes.** $\tau_n(T_n)$ **is the locus of all points with vertical slopes.**