Trade Policy Mix under the WTO: Protection of TRIPS and R&D Subsidies

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Executive Summary

This paper provides a theoretical framework to explain why governments seek restrictions on IPR protection and allow R&D subsidies through multilateral trade agreements such as the TRIPS Agreement and the Agreement on Subsidies and Countervailing Measures. After 7 years of discussion, the Uruguay Round extends GATT's trade-liberalizing philosophy to worldwide use of subsidies as a secondary means to intervene in international trade. Through the Agreement on Subsidies and Countervailing Measures the WTO tries to preserve one of basic principles of GATT's philosophy: *Fair Competition.* The principle of *Fair Competition* is of particular importance in understanding the WTO. To harness GATT's trade liberalizing philosophy, the WTO as a successor of GATT takes this principle as objectives that are pursued through the enforcement and implementation of other principles, for instance the non-discrimination and reciprocity. As an example of the *fair competition* principle, the WTO prohibited any type of export subsidies through the Agreement on Subsidies and Countervailing Measures, but allowed R&D subsidies. The allowance of R&D subsidies by the WTO is a puzzle because it is well known that R&D subsidization forms the prisoners' dilemma when governments are active to set R&D policy. In order to find any reasonable logic to explain this puzzle, we focus on the interaction between strategic trade policy tools: R&D subsidization and IPR protection. Indeed, at an international level IPR protection has been a major focus of negotiations along with R&D subsidies. The WTO also requires member countries to strongly enforce patent protection through the TRIPS Agreement. In our analysis, it turns out that it is globally optimal to perfectly disseminate knowledge without IPR protection and to subsidize inventive firms by solving a problem that the weak IPR protection

damages firms' incentive to invest in R&D activities. However, current trade agreements do not match with our global optimum. We show that exporting countries may benefit – at the expense of importers – from a trade agreement to demand stronger enforcement on IPR protection because exporting countries experience the prisoner's dilemma problem when both countries free ride on the rival firm's R&D outcome. Therefore we conclude that it is possible to understand the TRIPS Agreement as an inefficient victory of the interests of northern exporting countries over those of southern importing countries.

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Trade Policy Mix under the WTO:

Protection of TRIPS and R&D Subsidies

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I.   Introduction

This paper provides a theoretical framework to explain why governments seek restrictions on IPR protection and allow R&D subsidies through reciprocal trade agreements such as the TRIPS Agreement and the Agreement on Subsidies and Countervailing Measures. We explore the implications of our findings in my previous work for understanding and interpreting these international agreements by considering R&D subsidies and IPR protection in tandem. After 7 years of discussion, the Uruguay Round extends GATT's trade-liberalizing philosophy to worldwide use of subsidies as a secondary means to intervene in international trade. Through the Agreement on Subsidies and Countervailing Measures the WTO tries to preserve one of basic principles of GATT's philosophy: *fair competition*. The principle of *fair competition* is of particular importance in understanding the WTO. To harness GATT's trade liberalizing philosophy, the WTO as a successor of GATT takes this principle as

objectives that are pursued through the enforcement and implementation of other principles, for instance the non-discrimination and reciprocity. As an example of the *fair competition* principle, the WTO prohibited any type of export subsidies through the Agreement on Subsidies and Countervailing Measures, but allowed R&D subsidies. The allowance of R&D subsidies by the WTO is a puzzle because it is known that R&D subsidization forms the prisoners' dilemma when governments are active to set R&D policy. Brander (1995) showed that while each country has an incentive to subsidize its domestic R&D activities, countries are worse off in case that their governments are active to set R&D policy than in case of free trade. This paper provides a theoretical framework to explain the allowance of R&D subsidies in the context of an imperfectly competitive international market where countries set R&D policy and IPR policy in tandem as strategic trade policy tools.

Based on the results from the previous work, *Patent Infringement and Strategic Trade Policies*, we focus on the interaction between strategic trade policy tools: R&D subsidization and IPR protection. We realized that in reality the IPR protection is not perfect and the IPR regime is itself a policy choice that in principle may affect firms' incentive to engage in R&D activities to the same extent that the choice of an R&D subsidy affects these incentives. Indeed, at an international level IPR protection has been a major focus of negotiations along

with R&D subsidies. Thus we will consider optimal choices for these policy tools in tandem rather than examining R&D subsidies in isolation. For IPR protection, the WTO requires member countries to strongly enforce patent protection through the TRIPS Agreement. It requires member countries to make patents available for any inventions in all fields of technology without discrimination. It is also required that patents be available and patent rights enjoyable for 20 years without discrimination as to the place of invention and whether products are imported or locally produced. This paper also provides an answer to understand why governments seek international standards on patent protection enforcement.

It is well known that R&D activity has the public good nature: (1) its stock does not diminish with its consumption and (2) after invention, the marginal cost of an additional use is almost zero. For the optimal allocation of resources, we need to consider several things. From a simple efficiency perspective, knowledge needs to have a zero price, but with a zero price for knowledge investors have no pecuniary incentive to invest in R&D activities. Patents grant an inventor a temporary monopoly over the use of the invention or the reproduction of a work, and prevent competitors from sharing or using their knowledge without payments. However, the degree of IPR protection afforded to innovations has an impact on inventors' profits and therefore one the amount of money invested in R&D activities. Keeping in mind the

interdependence and the trade-off between the need for monopoly and the benefits of free access to knowledge, we could verify that R&D subsidization could be a means to cure the damaged incentives of inventor due to weak enforcement on IPR protection. This is an answer to the question of why the WTO allows R&D subsidies even though they could have a general form of the prisoners' dilemma. To preserve a globally optimal R&D investment level, governments could use R&D subsidies by curing the damaged incentives to invest in R&D activities. However, the TRIPS Agreement is hard to understand because the world as a whole benefits from weaker enforcement on IPR protection provided R&D subsidies cure the damaged incentives for firms to invest in R&D activities. Since the globally optimal R&D investment is achieved through R&D subsidization, the TRIPS Agreement could be useless for global optimum. However, it is possible that stronger enforcement would be attractive to exporting countries. Weak enforcement in an exporting country will damage a foreign rival firm's incentive to invest in R&D activities. As a consequence of this negative externality, exporting countries experience the prisoners' dilemma problem when both countries free ride on the rival firm's R&D outcome. This implies that exporting countries may benefit – at the expense of importers – from a trade agreement to demand stronger enforcement on IPR protection. Thus it is possible to understand the TRIPS Agreement as an inefficient victory

of the interests of northern exporting countries over the interests of southern importing countries.

To show these results, we begin by showing that the Nash equilibrium is not efficient. The global inefficiency comes from (1) public good nature of R&D activities and (2) *strategic* externalities that have arisen in the government-level game. As we have discussed before, R&D activity has public good natures. Based on these natures, incentives to invest in R&D activities are easy to be damaged if the outcome is not perfectly protected. That is why firms are looking for a chance to free ride on rivals' R&D outcome. Secondly, government has an incentive to manipulate strategic relationship between firms in an imperfectly competitive international market by providing subsidies. However, the intervention based on strategic policy forms the prisoners' dilemma, which results in global inefficiency. Therefore we must take account of the global inefficiency to answer to the puzzle of the R&D subsidy allowance. To see the global optimum, we assume that countries cooperate over trade policies to maximize the worldwide welfare including exporting and importing countries' welfare. As an alternative, we will check a possibility where *exporting* countries cooperate over trade policy tools. This optimization problem explains how reciprocal trade agreements are attractive to exporting countries comparing to the global optimum.

A major hurdle in the multilateral trade negotiations of the Uruguay Round was how non-tariff barriers (NTBs) should be controlled. Thus IPR protection became a new area of concern in GATT negotiations, and in the negotiation some leading countries have demanded strong protection for their own industries from other countries that consistently violate trade provisions through the TRIPS Agreement. It was natural that during the Uruguay Round this issue was very critical between North and South countries forming a north-south confrontation. Industrial countries, led by the United States, sought a comprehensive agreement on standards for IPR protection. This demand was of great concern to many developing countries. Led by India, Brazil, Egypt, Argentina, and Yugoslavia, they hoped to draw a firm distinction between work on trade in counterfeit goods and that on TRIPS more broadly defined. However, the final conclusion of the multilateral negotiations was to require member countries (1) to make patents available for any inventors in all fields of technology without discrimination[1] and (2) to strongly enforce IPR protection even though the TRIPS Agreement allowed long transition periods during which developing countries are supposed to come into compliance with increased protection for IPR: a ten-year grace period. Extending GATT's trade-liberalizing philosophy to IPR protection through the TRIPS Agreement, the

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[1] For instance, in India no patents were provided at all for pharmaceutical products before the multilateral negotiations.

WTO makes it possible to harmonize patent laws and patent protection enforcement being a source of international legal convergence toward U.S. standards of protection.[2,3]

In trying to meet those objectives, this paper basically grafts two past research lines together: strategic trade policy and TRIPS. First, a large number of papers have focused on strategic R&D policy after a pioneer work by Spencer and Brander (1983, hereafter SB) who showed that an exporting country has an incentive to subsidize domestic R&D investment. Even though Eaton and Grossman (1986) have pointed out that the SB's result in case of export subsidies is sensitive to the mode of competition: price or quantity, Bagwell and Staiger (1994) showed that R&D choices are strategic substitutes regardless of the competition mode for the case of stochastic R&D effect on cost. Additionally Maggi (1996) has endogenized the mode of competition introducing capacity constraints. Based on our motivation of this paper, we extend this research line by analyzing the interaction between this trade policy mix: patent protection

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[2]   The duration of a patent under the WTO has been standardized to a minimum of 20 years from the date of *filing*. However, it *was* 17 years from the date of *issuance* under the US patent laws. Since it usually takes 2-3 years to issue patents, GATT's requirement is roughly equivalent to US duration. However, under the amended provision (which took effect June 8, 1995) the term is 20 years from the *application*. See US Code: Title 35, Section 154 – (a).

[3]   However, the convergence can be extremely slow due to long transition periods during which developing countries are supposed to come into compliance with increased protection for IPR: a ten-year grace period. See Article 66.1 of TRIPS Agreement.

enforcement and R&D subsidies. Furthermore, this paper extends the discussion to the WTO framework. In the absence of any binding agreement, each government chooses an optimal enforcement level, which maximizes its domestic welfare. However, after being a member of the WTO, each government needs to enforce patent protection at the minimum level, which is required by the TRIPS Agreement. Given the above analysis, we describe the optimal R&D policy in both regimes.

As a pioneer work of the second research line, Chin and Grossman (1988) examined the effect of IPRs protection on R&D incentives and social welfare by using a simple north-south model. Diwan and Rodrik (1991) introduced the difference of technological needs and tastes between the north and the south. Extending this research line, Taylor (1993) examined how a reduction in southern patent protection raises northern incentives to other barriers to imitations. Additionally Taylor (1994) explored the link between IPR protection and growth by considering the ability of firms to transfer technologies. Incorporating the subsidy issue into this research line, this paper sheds light on the effect of IPR protection on R&D policy. Moreover, this paper takes steps further than the above work, focusing on trade agreements and exploring the effect of international legal harmonization.

The rest of this paper proceeds as follows. Section II establishes an extended theoretical model from Spencer and Brander (1983), which enables us to consider R&D subsidies and IPR policy in tandem. Section III describes in detail the TRIPS Agreement and the Agreement on Subsidies and Countervailing Measures, and then in Section IV we provide a theory for both agreements and analyze the interaction between these agreements. Section V then concludes.

II.   The Model

A.   An Extended SB Model to Analyze the Trade Policy Mix

We extend the SB model to a modified one that was presented in my previous work in order to analyze a trade policy mix: R&D subsidies and protection of TRIPS under the WTO. This setup contrasts with Spencer and Brander (1983) that analyzes R&D subsidization considering it as a single trade policy tool. There are two exporting countries, home (no *) and foreign (*), and a third importing country. We assume that each exporting country has a single exporting firm. Both exporting firms play in a two-stage game where firms

choose R&D levels in the first stage, and in the second stage, output levels. The policy choices are considered in several ways. First, the government of one country is allowed to set simultaneously R&D and IPR policy tools in the Nash setup. Secondly, both home and foreign countries cooperate over the policy mix. Finally we explore policy choices from the world point of view. The first two cases are the same as Spencer and Brander (1983), but we will consider R&D subsidies and IPR policy together.

The idea of backward induction helps to find a subgame perfect equilibrium. Thus we start by solving for the optimal choice of firms over each possible situation, and then work backward to compute the optimal choice for the players before. Then the equilibrium output levels will be calculated in the last stage, R&D levels in the second stage, and the optimal policy in the first stage. Now let us begin by analyzing the last stage in order to find a subgame perfect equilibrium. A domestic firm produces output y at cost C, which induces all costs except R&D, and earns revenue R. The R&D level of this domestic firm is denoted x and costs v per unit. The government provides R&D subsidies (tax if negative) at a rate of s. Profit of this firm is then given as follows:

(1) $\boldsymbol{p}(y, y^*, x, x^*; s, \boldsymbol{q}) = R(y, y^*) - C(y, x, x^*, \boldsymbol{q}) - (v - s)x.$

Following Spencer and Brander (1983), outputs y and y^* are substitutes and it is assumed that an increase in the domestic output decreases the marginal revenue of the foreign firm:

(2) $\quad R_y > 0; \qquad R_{y^*} < 0; \qquad R_{yy^*} < 0.$

The production cost of the domestic firm depends on domestic output level as well as domestic R&D level: $C(y, x, x^*, \boldsymbol{q}) = yc(x, x^*, \boldsymbol{q})$, where $c(\bullet)$ is marginal cost. This model is similar to Qiu and Tao (1998), except that we introduce patent protection enforcement. It is assumed that an increase in the foreign R&D activities also reduces the domestic firm's marginal cost if home country is weakly enforcing patent protection. It implies that the patent granted to the foreign firm is not protected in the home country. Each firm has the following marginal cost:

(3) $\quad c(x, x^*, \boldsymbol{q}) \equiv \boldsymbol{a} + c^1(x) + \boldsymbol{q}c^2(x^*);$

(4) $\quad c^*(x^*, x, \boldsymbol{q}^*) \equiv \boldsymbol{a} + c^{1*}(x^*) + \boldsymbol{q}^* c^{2*}(x),$

where $\boldsymbol{a}$ is sufficiently large so that marginal cost is non-negative for all R&D investment levels. Let $\boldsymbol{q}$ and $\boldsymbol{q}^*$ be patent protection enforcement levels of home

and foreign countries, respectively. They are defined between 0 and 1. The home country's government is perfectly enforcing patent protection if $q = 0$, while it enforces nothing and hence the domestic firm can freely copy the foreign firm's R&D if $q = 1$. We make assumptions on marginal cost function as follows:

(5) $c^1, c^2 < 0;$ $c_x^1, c_{x*}^2 < 0;$ $c_{xx}^1, c_{x*x*}^{2*} > 0.$ [4]

When home country is weakly enforcing patent protection, the foreign R&D activities could affect the domestic firm's marginal cost in the same way that the domestic R&D does.

The Nash equilibrium output levels maximizing profits are characterized by the first order condition: $\boldsymbol{p}_y = R_y(y, y^*) - c(x, x^*, \boldsymbol{q}) = 0$ and the second order condition: $\boldsymbol{p}_{yy} = R_{yy} < 0$. Then the equilibrium output levels are a function of both home and foreign R&D activities: $y = q(x, x^*, \boldsymbol{q}, \boldsymbol{q}^*)$ and $y^* = q^*(x, x^*, \boldsymbol{q}, \boldsymbol{q}^*)$. However, the effects of each R&D activity on output levels depend on each country's patent protection enforcement level:

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[4]   We assume that $c_x^1 = c_x^{2*}$ and $c_{x*}^{1*} = c_{x*}^2$. In the symmetric setup, $c_x^1 = c_x^{2*} = c_{x*}^{1*} = c_{x*}^2$.

(6) $y_x = \dfrac{c_x^1 R_{y^*y^*}^* - q^* c_x^{2^*} R_{yy^*}}{A} > 0$; $y_x^* = \dfrac{q^* c_x^{2^*} R_{yy} - c_x^1 R_{y^*y}^*}{A}$;

(7) $y_{x^*} = \dfrac{q c_{x^*}^2 R_{y^*y^*}^* - c_{x^*}^{1^*} R_{yy^*}}{A}$; $y_{x^*}^* = \dfrac{c_{x^*}^{1^*} R_{yy} - q c_{x^*}^2 R_{y^*y}^*}{A} > 0$,

where $A \equiv R_{yy} R_{y^*y^*}^* - R_{yy^*} R_{y^*y^*}^* > 0$.[5] It turns out that domestic (foreign) R&D activities are always good for domestic (foreign) output level. However, home (foreign) R&D activities are good for foreign (home) output if foreign (home) country's patent protection enforcement level is greater than a critical level: $l_1 \equiv R_{yy^*}/R_{yy}$. The equilibrium output levels are also dependent on each country's patent protection enforcement level. This is because a country's IPR policy would affect how much an increase in a foreign rival's R&D investment reduces the domestic firm's marginal cost. Using the similar method to find (6) and (7), we can identify the effects of each country's IPR policy on output levels:

(8) $y_q = \dfrac{y c_q R_{y^*y^*}^*}{A} > 0$; $y_q^* = \dfrac{-y c_q R_{y^*y}^*}{A} < 0$;

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[5]   Totally differentiating the first order conditions and using Cramer's rule, we can show those effects on output levels.

$$(9) \quad y_{q^*} = \frac{-y * c_{q^*}^* R_{yy^*}}{A} < 0; \quad y_{q^*}^* = \frac{y * c_{q^*}^* R_{yy}}{A} > 0.$$

Given R&D investment levels of both firms, weak enforcement in the home country is good (bad) for home (foreign) production, while weak enforcement in the foreign country is bad (good) for home (foreign) production.

At the second stage, both firms choose R&D levels in order to maximize their own profits: $G(x, x^*, s, \boldsymbol{q}, \boldsymbol{q}^*) \equiv \boldsymbol{p}(q, q^*, x, x^*, s, \boldsymbol{q})$ and $G^*(x, x^*, s^*, \boldsymbol{q}, \boldsymbol{q}^*) \equiv \boldsymbol{p}^*(q, q^*, x, x^*, s^*, \boldsymbol{q}^*)$. Now the equilibrium R&D levels are a function of the trade policy mix: $x = z(s, s^*, \boldsymbol{q}, \boldsymbol{q}^*)$ and $x^* = z^*(s, s^*, \boldsymbol{q}, \boldsymbol{q}^*)$. The key difference between this modification and the SB model is a strategic relationship between home and foreign R&D activities. While they are strategic substitutes in the SB setup, the relationship in this modification depends on both countries' patent protection enforcement levels. If they are weakly enforcing, home and foreign R&D activities are strategic complements rather than substitutes, by implying that signs of G_{zz^*} and $G_{z^*z}^*$ depend on $\boldsymbol{q}$ and $\boldsymbol{q}^*$.[6] This dependence implies that both exporting countries are able to manipulate the strategic relationship between home and foreign R&D activities by setting enforcement policy of TRIPS protection.

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[6] See Proposition 2 and Appendix A in my previous work, *Patent Protection and Strategic Trade Policy.*

The effects of this trade policy mix on R&D activities are defined as follows:[7]

(10) $\quad x_s = \dfrac{-G^*_{x^*x^*}}{B} > 0;$ $\qquad\qquad x^*_s = \dfrac{G^*_{x^*x}}{B};$

(11) $\quad x_{s^*} = \dfrac{G_{xx^*}}{B};$ $\qquad\qquad x^*_{s^*} = \dfrac{-G_{xx}}{B} > 0;$

(12) $\quad x_q = \dfrac{G_{xx^*}G^*_{x^*q}}{B};$ $\qquad\qquad x^*_q = \dfrac{-G_{xx}G^*_{x^*q}}{B} < 0;$

(13) $\quad x_{q^*} = \dfrac{-G^*_{x^*x^*}G_{xq^*}}{B} < 0;$ $\qquad\qquad x^*_{q^*} = \dfrac{G^*_{x^*x}G_{xq^*}}{B},$

where $B \equiv G_{xx}G^*_{x^*x^*} - G_{xx^*}G^*_{x^*x} > 0$ as a stability condition. Each country's IPR policy determines the strategic relationship between home and foreign R&D investment levels $\left(G_{xx^*}, G^*_{x^*x}\right)$. Under the weakly enforced patent protection regime, home and foreign R&D levels are strategic complements $\left(G_{xx^*}, G^*_{x^*x} > 0\right)$.

The domestic R&D subsidies are always good for the domestic R&D activities, while the foreign R&D activities could benefit from the domestic R&D subsidies when home and foreign R&D activities are strategic complements due to the weak enforcement by home country. Strong enforcement of home country is always good for the foreign R&D activities because the foreign R&D

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[7]   See Propositions 3 and 4 in *Patent Protection and Strategic Trade Policy.*

outcome is protected in home country. However, the effect of domestic enforcement level on domestic R&D activities depends on strategic relationship between home and foreign R&D activities.

It turns out that the foreign (home) country's weak IPR policy is bad for the domestic (foreign) firm's R&D investment because weak enforcement damages firms' incentive to invest in R&D activities. The intuition on this relationship is simple: Under the strong enforcement regime, government could help its national firm by a little bit weakly enforcing patent protection because weak enforcement in a country will damage the foreign rival firm's incentive to invest in R&D activities and hence alter strategic relationship between firms. On the other hand, however, weak enforcement will enlarge the free-rider problem for its domestic firm. Under the weak enforcement regime, weaker enforcement will damage its *domestic* firm's R&D investment by allowing it to freely copy the rival's R&D outcome. Thus this effect forms a U-shaped graph implying a trade-off between a strategic advantage and a free-rider problem.

B. Non-Cooperative Policy Choices without any Binding Agreement

We first characterize the non-cooperative Nash policy choices without any binding agreement. Then we can define the following game:

The game without any binding agreement in the Nash setup

(Stage I)   Governments: (1) patent protection enforcement levels

(2) R&D subsidy rates

(Stage II)   Firms: R&D levels

(Stage III)   Firms: Output levels

Since we've analyzed the last two stages in the previous subsection, we focus on the first stage in the current subsection. When governments do not cooperate over policies, home government unilaterally set the trade policy mix to maximize its domestic welfare:

(P1) $\max\limits_{s,\,q}\ W(s,\boldsymbol{q};s*,\boldsymbol{q}*) = G(z(s,s*,\boldsymbol{q},\boldsymbol{q}*),z*(s,s*,\boldsymbol{q},\boldsymbol{q}*),s,\boldsymbol{q}) - sz(s,s*,\boldsymbol{q},\boldsymbol{q}*)$

subject to $0 \le \boldsymbol{q} \le 1$.

The foreign country faces the similar problem:

(P1)* $\underset{s^*q^*}{max}$

$$W*(s^*,\boldsymbol{q}^*;s,\boldsymbol{q}) = G*(z(s,s^*,\boldsymbol{q},\boldsymbol{q}^*),z^*(s,s^*,\boldsymbol{q},\boldsymbol{q}^*),s^*,\boldsymbol{q}^*) - s^* z^*(s,s^*,\boldsymbol{q},\boldsymbol{q}^*)$$

subject to $0 \le \boldsymbol{q}^* \le 1$.

Since the main result of these optimization problems are identical to that of my previous work, *Patent Infringement and Strategic Trade Policies*, we report here the key aspects of them as follows:

The symmetric Nash equilibrium without any binding agreement[8]

$$s^N = s^{*N} = G_{z^*}\left(-\frac{G^*_{z^*z}}{G^*_{z^*z^*}}\right) > 0 \text{ and } 1 > \boldsymbol{q}^N = \boldsymbol{q}^{*N} > l_2 \equiv \frac{R_{yy}R_{y^*}}{R^*_{y^*y}R_{y^*} + yA}.$$

This equilibrium implies that each exporting government has an incentive to allow its national firm to copy the rival's R&D investment $\left(\boldsymbol{q}^N = \boldsymbol{q}^{*N} > 0\right)$ and to subsidize its domestic R&D $\left(s^N = s^{*N} > 0\right)$ in the Nash setup. Notice that the Nash enforcement level is greater than the critical level of positive externalities: l_2. When we assume that the demand for the final good is linear, this critical

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[8]   See Appendix A in my previous work, *Patent Infringement and Strategic Trade Policies*.

level is equal to the critical level of strategic relationship, l_1, at ½ Therefore in the Nash setup both governments are weakly enforcing patent protection, making both home and foreign R&D activities strategic complements. Additionally both R&D activities give rise to positive externalities to the rival's profits. On the other hand, this Nash R&D subsidy rate is lower than the Nash rate without consideration of TRIPS issue in the SB model. It implies that each exporting country has a strong incentive to be a free rider on the rival's R&D and it prefers "looking the other way" to subsidizing its R&D investment. Intuitively, by weakly enforcing patent protection the government could help its national firm at the relatively lower cost, while R&D subsidization needs financial support.

The "biased" trade policy preference in the Nash equilibrium stems from the public-good nature of R&D activities: (1) its stock does not diminish with its consumption and (2) after invention, the marginal cost of an additional use is almost zero. That is why each country has an incentive to be a free rider on the rival's R&D outcome. Additionally it could be also due to the absence of domestic competition. If we introduce domestic competition, then the government will enforce more strongly at the Nash equilibrium than in case without it.[9] For simplicity, we keep assuming that there is no domestic

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[9]   Suppose there are N firms in the home country and M firms in the foreign country. Then a domestic firm *i* would have the following marginal cost function depending on domestic

competition, and focus on strategic trade policy. However, it would not be equilibrium for the government to perfectly allow its national firm to copy the outcome of the rival's R&D activities $(q = 1)$ because loose enforcement will hurt its national firm's incentive to invest in R&D activities. Rather, under the weak enforcement regime each firm will try to free ride on the rival's R&D outcome. Thus the Nash equilibrium enforcement level requires balancing these two effects.

Is the Nash policy set internationally efficient, then? By analyzing the slopes of each country's iso-welfare contour, one can show the following:

Proposition 1 (Inefficiency of Nash Equilibrium)

Nash equilibrium enforcement levels and R&D subsidy rates $\left(q^N, q^{*N}, s^N, s^{*N}\right)$ are inefficient.

Proof.   See Appendix A.   ■

There are two sources of the global inefficiency in the absence of any binding agreements: (1) public-good nature of R&D investment, and (2) a

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and foreign rival's R&D levels: $c_i = a + c^1(x_i) + q c^2(x_{-i}) + q c^3\left(\sum x^*\right)$. Under the circumstances, each exporting country will enforce more strongly patent protection to boost the domestic competition.

general form of the prisoners' dilemma on R&D subsidization due to *strategic* externalities. As we have discussed before, R&D outcome often has the characteristics of a public good: its stock does not diminish with its consumption; the marginal cost of disseminating the outcome is almost zero. For this reason, each exporting country has a strong incentive to free ride on the rival's R&D investment, and hence it leads to the global inefficiency.

On the other hand, the Nash equilibrium forms the prisoners' dilemma problem on R&D subsidization that has arisen as in the SB model. As we have discussed in the previous section, while each exporting country has an incentive to subsidize its domestic R&D as Spencer and Brander (1983) showed, both countries will be worse off in case of two active governments than in case of free trade. The active intervention forming the *strategic* externalities distorts the global efficiency. We will check in the next section how we could achieve Pareto improvement through any international agreement.

III. The Agreement on Subsidies and the TRIPS Agreement

Now we are ready to analyze international agreements on these trade policy instruments: R&D subsidies and IPR policy. Before analyzing this issue, we will discuss what the WTO requires member countries in the multinational framework. Through the Agreement on Subsidies and Countervailing Measures the WTO strictly prohibits any type of subsidies on exports, but allows R&D subsidies. Even though R&D subsidies are allowed, however, this Agreement sets upper bounds of R&D subsidies both on industrial research (75%) and on pre-competitive development activity (50%). The TRIPS Agreement under the WTO requires member countries to strongly enforce patent protection enforcement. Thus the agreement makes it possible to harmonize patent laws and patent protection enforcement.

Prior to exploring policy choices under the WTO, we first provide a brief discussion of the Agreement on Subsidies and Countervailing Measures and the TRIPS Agreement.

A.   The Agreement on Subsidies and Countervailing Measures

Governments set industrial policies that affect the allocation of resources in an economy and the distribution of income. These actions may have an impact on the pattern of international trade, and hence may give rise to disputes between countries. Based on the fact above, those policies have been one of major issues in multilateral negotiations such as the Uruguay Round. Before the WTO, the issues of subsidization and countries' response to subsidization (countervailing measures) are handled under two separate GATT Articles: XVI and VI. Article XVI deals with subsidy practices while Article VI concentrates on the domestic legal remedy to those practices: Countervailing Duty Law. Subsidies that are provided by governments directly for exports have always been prohibited in the GATT, although until the Uruguay Round and the formation of the WTO there have been very large exceptions to this prohibition. After 7 years of discussion under the Uruguay Round, the WTO prohibits any kind of export subsidies (Article 3.1-a). Subsidies are a difficult problem. While it is clear that some production subsidies can adversely affect producers in other countries, there exist several reasons why some subsidies are a means of achieving various objectives, for instance, promoting growth of an infant industry. After dealing with this ambiguity by analyzing and classifying subsidies, the WTO allows subsidies of (1) R&D (Article 8.2-a), (2) regional

development (Article 8.2-b), and (3) environmental protection (Article 8.2-c).[10]

Our discussion will focus on R&D subsidies. Even though allowed, the R&D

subsidies have upper limits: each country can pay up to 75% of the costs of

industrial research or 50% of the costs of pre-competitive development activity

(Article 8.2-a). This agreement was greatly based on a change in administration

in the US. Under President Bush, the US position had been that all subsidies

were harmful and must be eliminated. However, Clinton's team took a more

activist approach to government and believed that industry and the economy

could be assisted by selective government intervention. Thus this upper bound

setting is *partly* compatible with the Bush administration's viewpoint, even

though the allowance is mostly based on the Clinton team's viewpoint. Given

the fact that a key principle embodied in the WTO is *fair competition*, the

allowance of government subsidization on R&D activities are believed not to do

harm this key principle.

B.   The TRIPS Agreement

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[10]   Three categories of subsidy are distinguished under the WTO rules: non-actionable, prohibited, and actionable. R&D subsidies are non-actionable. Non-actionable subsidies are legal and may not be countervailed. See Hoekman and Kostecki (1995) and Deardorff (1996) for more details.

Being effective as of January 1995, the TRIPS Agreement is the first example of successful harmonization of policies under GATT auspices, focusing on intellectual property.[11] The fundamental rules on national treatment (NT) and most-favored-nation (MFN) treatment of foreign nationals are common to all categories of intellectual property covered by the Agreement. These obligations cover not only the substantive standards of protection but also matters affecting the availability, acquisition, scope, maintenance, and enforcement of IPRs. The general goals of the TRIPS Agreement include the reduction of distortions and impediments to international trade, promotion of effective and adequate IPR protection, and ensuring that measures and procedures to enforce IPR protection do not themselves become barriers to legitimate trade. The TRIPS Agreement is unique in the WTO context where it imposes obligations upon governments to pursue specific, similar policies. This is in stark contrast with the GATS and the GATT, which consist of agreements not to use specific policies. Thus the TRIPS Agreement is the first example of successful harmonization of policies under GATT auspices.

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[11]   The areas of intellectual property that TRIPS Agreement covers are: (i) copyright and related rights (i.e. the rights of performers, producers of sound recordings and broadcasting organizations); (ii) trademarks including service marks; (iii) geographical indications including appellations of origin; (iv) industrial designs; (v) patents including the protection of new varieties of plants; (vi) the layout-designs of integrated circuits; and (vii) undisclosed information including trade secrets and test data. See Article 1.2 of TRIPS Agreement.

Patents*:[12]*   In respect of each of the main areas of IPR covered by the TRIPS Agreement, the Agreement sets out the minimum standards of protection to be protected by each member. As we've discussed before, it requires member countries to make patents available for any inventions in all fields of technology without discrimination. It is also required that patents be available and patent rights enjoyable for 20 years without discrimination as to the place of invention and whether products are imported or locally produced (Article 27.1). The exclusive rights that must be conferred by a product patent are defined as the ones of making, using, offering for sale, selling, and importing for these purposes. Additionally, process patent protection must give rights not only over use of the process but also over products obtained directly by the process. Patent owners shall also have the right to assign, or transfer by succession, the patent and to conclude licensing contracts (Article 28). The term of protection available shall not end before the expiration of a period of 20 years counted from the filing date (Article 33). This twenty-year lower limit implies harmonization towards the standards maintained by industrialized countries.

Enforcement of IPRs: The provisions on enforcement are contained in Part III of the Agreement. These provisions have two basic objectives. One is to

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[12]   See my previous work, *Patent Protection and Strategic Trade Policy,* for a general discussion of patents.

ensure that effective means of enforcement are available to right holders. The second is to ensure that enforcement procedures are applied in such a manner as to avoid the creation of barriers to legitimate trade and to provide for safeguards against their abuse. General obligations that all enforcement procedures must meet are notably aimed at ensuring their effectiveness. Such procedures must be fair and equitable, and they may not be unnecessarily complicated or costly, or entail unreasonable time limits or unwarranted delays (Article 41.2).

IV. Trade Policy Mix under the WTO

Now let us consider the main questions that we proposed in this paper: Why do governments seek restrictions on IPR policy and allow R&D subsidies? To answer this question, we first consider global optimization where both exporting countries are assumed to set trade policies to maximize worldwide welfare. Then we will check whether or not results of the global optimization are compatible with the current WTO requirements on IPR policy and subsidies. After analyzing the global optimization, we will then consider other

alternatives to understand why governments seek restrictions on IPR policy and agree to allow R&D subsidies.

A.   Global Welfare Maximization

First consider a global optimization problem in which each country sets the trade policy tools cooperatively to maximize worldwide welfare. Then we will check how results of this optimization problem support those agreements on subsidies and protection of TRIPS. The game based on this consideration is then given as follows:

The game for Global Optimum

(Stage I)   Governments: (1) Patent protection enforcement level and

(2) R&D subsidy rate

(Stage II)   Firms: R&D levels

(Stage III)   Firms: Output levels

Since this model has two exporting countries and the third importing country, the worldwide welfare consists of 3 components: (1) the home country's net welfare, (2) the foreign country's net welfare, and (3) consumer

surplus of the third importing country. The third component not only represents the importing country's welfare but also is compatible with a viewpoint of Deardorff (1992b). As Deardorff has pointed out, a key reason for providing patent protection is to permit inventors to earn a return on their inventions, and therefore to provide an incentive for technology to advance. However, the cost of providing patent protection is that it permits the patent-holder to exercise monopoly power over the market for the new product, and this prevents the benefits of the new product from being enjoyed optimally by consumers. For this reason, the global optimum considers the consumer surplus of the third importing country as one component of the global welfare.

Since the importing country is the only place that consumption occurs in this model, the consumer surplus represents this importing country's welfare:

(14) $CS(s) = \int_0^{q^E(s)+q^{*E}(s)} p(t)dt - p^E(s)[q^E(s) + q^{*E}(s)],$

where (E) represents the equilibrium levels and p(t) is an inverse demand function for the final good. The maximization problem is given as follows:

(P2) $\max_{s,s^*,\boldsymbol{q},\boldsymbol{q}^*} W(s,s^*,\boldsymbol{q},\boldsymbol{q}^*) + W^*(s,s^*,\boldsymbol{q},\boldsymbol{q}^*) + CS(s,s^*,\boldsymbol{q},\boldsymbol{q}^*)$

subject to $0 \leq \boldsymbol{q} \leq 1$ and $0 \leq \boldsymbol{q}^* \leq 1$.

Using the theorem of Kuhn-Tucker with inequality constraints, we define the following Lagrangean:

(15) $\quad L \equiv W(s, s^*, \boldsymbol{q}, \boldsymbol{q}^*) + W^*(s, s^*, \boldsymbol{q}, \boldsymbol{q}^*) + \boldsymbol{l}_1\boldsymbol{q} + \boldsymbol{l}_2(1-\boldsymbol{q}) + \boldsymbol{l}_3\boldsymbol{q}^* + \boldsymbol{l}_4(1-\boldsymbol{q}^*),$

where $\boldsymbol{l}_1$, $\boldsymbol{l}_2$, $\boldsymbol{l}_3$ and $\boldsymbol{l}_4$ are multipliers. The first-order conditions are given as follows:

(16) $\quad W_s + W_s^* + CS_s = 0;$

(17) $\quad W_{s^*} + W_{s^*}^* + CS_{s^*} = 0;$

(18) $\quad W_q + W_q^* + CS_q + \boldsymbol{l}_1 - \boldsymbol{l}_2 = 0;$

(19) $\quad W_q + W_q^* + CS_q + \boldsymbol{l}_3 - \boldsymbol{l}_4 = 0;$

(20) $\quad \boldsymbol{q} \geq 0;\ \boldsymbol{l}_1 \geq 0;\ \boldsymbol{l}_1\boldsymbol{q} = 0;$

(21) $\quad 1-\boldsymbol{q} \geq 0;\ \boldsymbol{l}_2 \geq 0;\ \boldsymbol{l}_2(1-\boldsymbol{q}) = 0;$

(22) $\quad \boldsymbol{q}^* \geq 0;\ \boldsymbol{l}_3 \geq 0;\ \boldsymbol{l}_3\boldsymbol{q}^* = 0;$

(23) $\quad 1-\boldsymbol{q}^* \geq 0;\ \boldsymbol{l}_4 \geq 0;\ \boldsymbol{l}_4(1-\boldsymbol{q}^*) = 0.$

Solving this maximization problem and checking corner solutions, we show the following equilibrium:

The Global Optimum[13]

$$q^G = q^{*G} = 1;$$

$$s^G = G_z^* - (q + q^*)\left[\frac{dp}{dq}q_z + \frac{dp}{dq^*}q_z^*\right] > 0 \ and \ s^{*G} = G_{z^*} - (q + q^*)\left[\frac{dp}{dq}q_{z^*} + \frac{dp}{dq^*}q_{z^*}^*\right] > 0.$$

This result of the global optimization expects that both exporting countries will agree to subsidize R&D activities but to eliminate IPR protection. Since no protection on IPRs hurts firms' incentive to engage in R&D activities, R&D subsidies are then required to maintain appropriate incentives for firms to engage in R&D investments. Then why do governments agree to eliminate IPR protection and to perfectly share R&D outcome? This result is difficult to understand, but intuition is given as follows: From (B3), there are two channels in which IPR policy can affect global welfare in both direct and indirect ways. First, by setting IPR policy as well as R&D subsidies each exporting country alters strategic relationship between firms' R&D investment levels, and in turn affects firms' incentive to engage in R&D investments. Through this R&D channel, IPR policies over countries affect global welfare. Second, IPR policy directly affects global welfare by altering output levels and marginal costs as G_q

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and G_q^* in (B3). This direct channel does not consider the R&D incentives or the R&D free riding, but it includes changes in output and marginal cost due to changes in IPR policies. Plugging the globally optimal R&D subsidy rates into (B3) and having (B4), we conclude that R&D subsidies cancel off the R&D channel in which IPR policies indirectly affects global welfare. Even though $G_q > 0$, $G_q^* < 0$, $q_q > 0$ and $q_q^* < 0$, we can show that $G_q + G_q^* > 0$ and $q_q + q_q^* > 0$ implying that the first order condition is positive and the solution is a corner one with $q = 1$.[14]

Then how are the results of the global optimum compatible with the current WTO requirements on IPR policy and R&D subsidies? First, this result verifies that the WTO allows R&D subsidies. At the global equilibrium, R&D subsidies are required to maintain appropriate incentives for firms to engage in R&D investments. In principle, subsidies are justified because of distortions created by market failures or other government policies. In our case, the R&D subsidization is required because the other government policy, IPR protection, distorts firms' incentive to engage in R&D investments. However, elimination of IPR protection is not compatible with the WTO requirements on IPR policy since the WTO requires member countries to strongly enforce IPR protection through the TRIPS Agreement. As a consequence, it turns out that the TRIPS

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[14]   See Appendix B for details.

Agreement is not an outcome of global optimization where countries are supposed to set IPR policy in order to maximize worldwide welfare. We have understood the TRIPS Agreement as a means of providing a proper incentive to inventors to engage in R&D activities, but it turns out that the TRIPS Agreement cannot be understood within the simple framework of the R&D investment incentives. The reason is that in the existence of R&D subsidization, the globally optimal R&D investment level can be achieved using this trade policy instrument, R&D subsidy. R&D subsidies have already considered both the R&D incentives and the R&D free rider problem and hence the globally optimal R&D investment level can be achieved through R&D subsidization. In the sense above, the TRIPS Agreement can be understood as an inefficient outcome in our framework. The main result of the global optimum is summarized in the following proposition:

Proposition 2 (Global Optimum)

The R&D subsidization is required to maintain appropriate incentives for firms to engage in R&D activities. However, the TRIPS Agreement is not an outcome of the global optimization when we consider R&D subsidies and IPR policy in tandem. Since the globally efficient R&D investment level can be achieved through R&D subsidization,

the TRIPS Agreement can be understood as an inefficient outcome of the multilateral negotiations.

Then how can we understand why the TRIPS Agreement requires member countries to strongly enforce IPR protection? In the next subsection we propose an alternative to provide an answer to this question. We consider a framework where both exporting countries cooperate over IPR policy to maximize the joint welfare rather than the global welfare in the absence of R&D subsidies.

B. The Joint Optimum among Exporting Countries in the Absence of R&D Subsidization

Now suppose that R&D subsidies are not available in the sense that countries are unaware or ignore the interdependence between R&D subsidies and IPR policy. Both exporting countries are assumed to cooperate over IPR

policy in order to maximize the joint welfare of the exporting countries.[15] Then

the optimization problem is given as follows:

(P3) $\quad \max_{q,q^*} \; W(q,q^*) + W^*(q,q^*)$

$\quad$ subject to $0 \le q \le 1$ and $0 \le q^* \le 1$.

Plugging zero into R&D subsidies in the first order conditions of the previous

optimization problem and ignoring the consumer surplus part, we can calculate

the right conditions to this optimization with IPR policy as follows:

(24) $\quad G_{z^*}z_q^* + G_q + G_z^*z_q + G_q^* + I_1 - I_2 = 0$.

This condition is different from (B4), the condition of the global optimization

problem with the trade policy mix. As we have discussed before, there are two

channels that IPR policy could affect welfare: (1) the R&D channel in which IPR

policy indirectly affects the joint welfare considering the R&D incentives and

the R&D free rider problem; and (2) the direct channel in which IPR policy

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[15] In the previous version of this paper, I considered the global optimization where both countries cooperatively set IPR policy to maximize the worldwide welfare. However, the result was ambiguous and hence we focus on the joint optimization problem to make a stronger argument.

directly affects considering changes in output levels and marginal costs. It implies that in the absence of R&D subsidies, the jointly optimal IPR policy must consider those channels and balance the R&D investment trade-off between R&D investment incentives and the free rider problem that occurs in this R&D game. Then the optimal IPR policy is:

Jointly Optimal IPR Policy in the absence of R&D Subsidization[16]

$$\frac{R_{qq}R_{q^*}}{R_{q^*q}^*R_{q^*} + qA} < q^C < 1.$$

When exporting countries cooperate over IPR policy to maximize their welfare in the absence of R&D subsidies, they will agree to enforce IPR protection more strongly than the globally optimal level. In my previous work, we have discussed the joint optimum where exporting countries cooperate over the trade policy mix: R&D subsidies and IPR policy. The above result is different from that of the previous work because at the joint optimum in the previous work exporting countries will agree to subsidize R&D activities but to eliminate IPR protection and hence perfectly share R&D outcome: $q = 1$.[17] This was not

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[16]   See Appendix C.

[17]   See Proposition 2 and Appendix B in my previous work, *Patent Infringement and Strategic Trade Policies.*

compatible with the current WTO requirement on IPR protection, either. However, when both exporting countries cooperate over IPR policy in the absence of R&D subsidies, they will agree to more strongly enforce IPR protection than the globally optimal level and the jointly optimal level in the previous work, *Patent Infringement and Strategic Trade Policies.*

It would imply that it is possible to understand the TRIPS Agreement as representing an inefficient victory of the interests of Northern (exporting) countries over the interests of Southern (importing) countries by demanding stronger enforcement on IPR protection. This result is based on two things: (1) Unawareness or ignorance of the interdependence between R&D subsidies and IPR policy and (2) Exporting countries' cooperation. When we consider R&D subsidies and IPR policy in tandem, exporting countries would agree to eliminate IPR protection and then to subsidize R&D activities in order to maintain appropriate incentives for firms to engage in R&D investments: $s > 0$ and $q = 1$. However, both exporting countries will agree to enforce IPR protection more strongly than the globally optimal level in the absence of R&D subsidies. It implies that exporting countries would be better off at the joint optimum in the existence of both trade policy tools – R&D subsidies and IPR policy - than at the joint optimum in the absence of R&D subsidies. In other words, the joint optimum in the absence of R&D subsidies is not globally

efficient and there is a way for exporting countries to be better off by allowing R&D subsidies. The reason is that we can think of the joint optimum in the absence of R&D subsidies as a sub-optimal policy set of $(s = 0, q \in (l,1))$ in the previous optimization problem, where l is the critical point of the strategic externality. This set provides lower welfare for exporting countries than the jointly optimal trade policy set in the existence of both trade policy tools: $(s > 0, q = 1)$. Due to unawareness or ignorance of the interdependence between R&D subsidies and IPR policy, both exporting countries could be worse off.

In addition, while the world as a whole benefits from weaker enforcement of IPR protection it is possible that stronger enforcement would be attractive to exporting countries. Weaker enforcement in an exporting country will damage a foreign rival firm's incentive to invest in R&D activities. As a consequence of this negative externality exporting countries experience the prisoners' dilemma problem when both countries free ride on the rival firm's R&D outcome. This implies that exporting countries may benefit – at the expense of importers – from a trade agreement to demand stronger enforcement on IPR protection. Thus it is possible to understand the TRIPS Agreement as an inefficient victory of the interests of northern countries over the interests of southern countries. This result is summarized in the following proposition:

Proposition 3 (The TRIPS Agreement)

The TRIPS Agreement is an inefficient victory of the interests of North countries over the interests of Southern countries by ignoring the link between R&D subsidies and IPR policy. This result is based on two things: (1) Unawareness or ignorance of the interdependence between R&D subsidies and IPR policy and (2) Exporting countries' cooperation.

The WTO requires member countries to strongly enforce IPR protection probably because stronger enforcement would protect inventors' incentives from the free rider problem. However, we can cure the damaged incentives by subsidizing the creative activities. Since R&D outcomes have the public good nature, the free rider problem always exists. From the analysis so far, R&D subsidization has been justified because of distortion created by market failures of the public good nature. In the sense above, the TRIPS Agreement overrides the issue of the free rider problem in the R&D. This result provides new implication on the conclusion of Bagwell and Staiger (1999b). Considering a new proposal of the WTO to include negotiations over labor and environmental standards, they conclude that there is no need for the WTO to expand the scope of its negotiations in that way, if the use of those domestic standards is understood as a secondary trade barrier. The reason is that there is only one

source of global inefficiency that a trade agreement can cure, given the understanding of the use of domestic standards in the way above. Since the current WTO rules are well equipped to handle the problems associated with choices over labor and environmental standards focusing on the market access, therefore these rules can achieve globally efficient outcomes with relatively modest changes. Our result is very similar to that of Bagwell and Staiger (1999b). Even though R&D activities might provide an additional channel of the global inefficiency (the public-good nature of R&D activities) because incentives to invest in R&D can be easily damaged if IPR protection is not perfect, a single trade policy instrument would be enough to cure the inefficiency. It is unnecessary to add a trade policy when we understand the link between R&D subsidies and IPR policy.

V. Conclusion

Why does the WTO allow R&D subsidies through the Agreement on Subsidies and Countervailing Measures? To answer this question, we considered the link between R&D subsidies and IPR policy as we have proposed in our previous work. The Nash equilibrium trade policy set was globally inefficient.

There are two channels of global inefficiency in the absence of any binding agreement: (1) public-good nature of R&D activities and (2) *strategic* externalities. At the non-cooperative game, each government has an incentive to manipulate strategic relationship between firms in an imperfectly competitive international market, by choosing either R&D subsidies or TRIPS protection enforcement policy. While the world as a whole benefits from weaker enforcement on IPR protection by sharing R&D outcome, it is possible that stronger enforcement would be attractive to exporting countries. Weak enforcement in an exporting country will hurt a foreign rival firm's incentive to invest in R&D activities. As a consequence of this negative externality, exporting countries experience the prisoners' dilemma problem when both countries free ride on the rival firm's R&D outcome. This implies that exporting countries may benefit from a trade agreement that demands stronger enforcement on IPR protection. Thus it is possible to understand the TRIPS Agreement as representing an inefficient victory of the interests of Northern countries over the interests of Southern countries. In addition, R&D subsidization can solve the damaged incentive problem that occurred in the R&D game. Since R&D activities have public good nature, the free rider problem always exists. To cure the damaged incentives of inventors, each country must subsidize R&D activities. In the sense above, the TRIPS Agreement is an unnecessarily

duplicated restriction on the IPR policy over countries. These results might be very strong so that readers could feel difficult to find the role of the TRIPS Agreement in the multilateral negotiation framework. However, during the Uruguay Round we have faced a lot of issue linkages related to this topic, TRIPS. For example, some of less-developed countries tried to tighten their domestic protection of IPRs unilaterally so as to attract foreign direct investment and technology from high-tech countries. Or in exchange for progress on TRIPS poor nations and transition economies could seek more open markets for their agricultural products and better market access for their textile exports. Therefore many issues are linked each other including TRIPS and R&D subsidies, and we leave this issue linkage for future research.

Appendix A: Proof of Proposition 1

Plugging first-order conditions of the non-cooperative Nash setup into those of the global optimum, (16) – (19), we can show that Nash equilibrium policy levels are inefficient. Even though $W_s = W_{s^*}^* = W_q = W_{q^*}^* = 0$, the Nash policy set doesn't satisfy the first-order conditions of the global optimization:

(A1) $\quad W_s^* + CS_s \neq 0$;

(A2) $\quad W_{s^*} + CS_{s^*} \neq 0$;

(A3) $\quad W_q^* + CS_q \neq 0$;

(A4) $\quad W_{q^*} + CS_{q^*} \neq 0$.

Appendix B: Global Optimum

First using a derivative of an integral, one can show the derivative of consumer surplus with respect to the subsidy:

$$\text{(B1)} \quad CS_s = p\frac{d(q+q^*)}{ds} - p\frac{d(q+q^*)}{ds} - (q+q^*)\frac{dp}{ds} = -(q+q^*)\left[\frac{dp}{dq}\frac{dq}{ds} + \frac{dp}{dq^*}\frac{dq^*}{ds}\right]$$

$$= (q+q^*)\left(q_z z_s + q_{z^*} z_s^* + q_z^* z_s + q_{z^*}^* z_s^*\right).$$

Plugging (B1) into (16) and using (17), we can show the optimal subsidy rate over countries as follows:

$$\text{(B2)} \quad s^G = G_z^* - (q+q^*)\left[\frac{dp}{dq}q_z + \frac{dp}{dq^*}q_z^*\right] \text{ and } s^{*G} = G_{z^*} - (q+q^*)\left[\frac{dp}{dq}q_{z^*} + \frac{dp}{dq^*}q_{z^*}^*\right].$$

The signs of optimal R&D subsidies depend on IPR policy over home and foreign countries. To calculate optimal IPR policy, we can rewrite (16) as follows:

$$\text{(B3)} \quad \begin{aligned} &G_{z^*}z_q^* + G_q - sz_q + G_z^* z_q + G_q^* - s^* z_q^* \\ &- (q+q^*)\left[\frac{dp}{dq}\left(q_z z_q + q_{z^*} z_q^* + q_q\right) + \frac{dp}{dq^*}\left(q_z^* z_q + q_{z^*}^* z_q^* + q_q^*\right)\right] + \boldsymbol{I}_1 - \boldsymbol{I}_2 = 0 \end{aligned}$$

Plugging optimal R&D subsidy rates from (B2), we can rewrite (B3) again as follows:

(B4) $\quad G_q + G_q^* - (q + q^*)\left[\dfrac{dp}{dq} q_q + \dfrac{dp}{dq^*} q_q^*\right] + \boldsymbol{1}_1 - \boldsymbol{1}_2 = 0$.

Checking the corner solutions for IPR policy, we can conclude that the worldwide-welfare maximizing IPR policy is no protection: $\boldsymbol{q}^G = \boldsymbol{q}^{*G} = 1$. These IPR policies over countries determine the signs of optimal R&D subsidies. Since there is a positive externality in the R&D game due to no protection on TRIPS, we can conclude $G_{z^*} > 0$. Then we conclude in turn that optimal R&D subsidies are positive.

Appendix C: The Joint Optimum in the Absence of R&D Subsidization

Case 1: $q = 0$.

Then the slackness condition implies that $l_2 = 0$ and $l_1 \geq 0$. Using these results, we can rewrite (24) as follows:

$$(C1) \quad l_1 = -G_{z^*}z_q^* - G_z^* z_q - G_q - G_q^*.$$

Checking signs of components when $q = 0$, we can show that l_1 is negative. It violates the slackness condition, which means that it has a contradiction.

Case 2: $q = 1$.

Then the slackness condition implies that $l_1 = 0$ and $l_2 \geq 0$. Using these results, we can rewrite (24) as follows:

$$(C2) \quad l_2 = G_{z^*}z_q^* + G_z^* z_q + G_q + G_q^*.$$

Checking signs of components when $q = 1$, we can show that the sign of l_2 is ambiguous because $G_{z^*} > 0$, $G_z^* > 0$, $z_q^* + z_q < 0$, and $G_q + G_q^* > 0$.

Case 3: $0 < q < 1$.

Then the slackness condition implies that $l_1 = l_2 = 0$. Using this result, we can rewrite (24) as follows:

(C3) $\quad G_{z^*} z_q^* + G_z^* z_q + G_q + G_q^* = 0$.

Since $z_q^* + z_q < 0$ and $G_q + G_q^* > 0$, we can conclude that G_{z^*} and G_z^* must be positive to satisfy (C3). According to Appendix 2-A, the optimal IPR policy will be given as $\dfrac{R_{qq} R_{q^*}}{R_{q^*q}^* R_{q^*} + qA} < q^C < 1$.
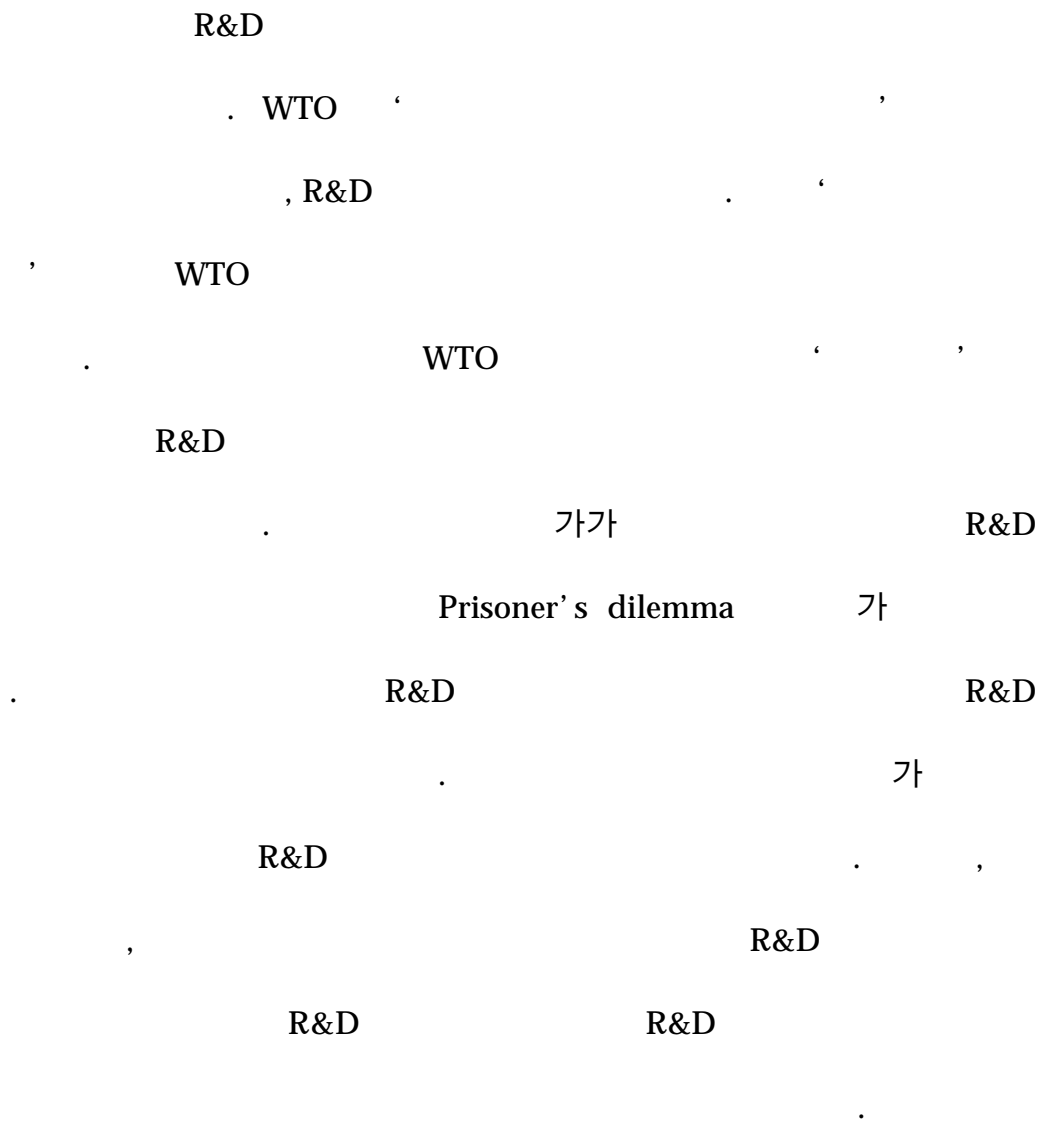
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R&D

. WTO '   '

, R&D   . '

'   WTO

.   WTO   '   '

R&D

.   R&D

Prisoner's dilemma

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R&D   .   ,

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R&D   R&D

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