LINKAGES BETWEEN PATENT PROTECTION AND STRATEGIC R&D POLICY: CASE OF THE EXOGENOUS REGIME OF IPR PROTECTION

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This paper explores strategic R&D policy when countries' regimes on protection of intellectual property rights (IPR) are exogenously given under the multilaterally agreed disciplines. Under the weak enforcement regime, domestic and foreign R&D activities are strategic complements rather than strategic substitutes and hence R&D reaction curves are upward sloping. Government wishes to subsidize its domestic firm's R&D in the presence of sufficiently weak IPR protection, because it is able to encourage R&D by the foreign rival firm, and greater R&D investment of foreign rivals increases the profits of the domestic firm.

I. INTRODUCTION

This paper reconsiders the well-known topic of strategic R&D policy from a perspective provided by Kang (2006 and forthcoming) in which intellectual property rights (IPR) are *not* fully protected. It is well known

that enforcement levels on IPR protection are quite diverse over countries, implying that the level of IPR protection has important implications for the government's incentives for intervening the R&D decisions of domestic firms.

Trade conflicts between China and the United States on IPR protection have a long history, even though China keeps putting its efforts on enhancing its regime since its accession to the World Trade Organization (WTO) in 2001. According to the Special 301 report of the United States Trade Representative (2008), the U.S. government puts China into a top IPR enforcement and WTO rules compliance priority – simply on the *priority watch list*. Given this fact, R&D subsidies financed by the U.S. government could flow into a foreign country if the foreign country is loosely enforcing patent protection. In other words, R&D subsidies of country could benefit a foreign rival if that foreign country is weakly enforcing patent protection.

This paper explores optimal choices of strategic R&D policy when countries' IPR regimes are exogenously given. What is the optimal policy for a government to help its domestic firms' R&D activities in circumstances that foreign rival countries are weakly enforcing IPR protection in an implicit manner? Most papers [Spencer and Brander (1983 and hereafter SB), Bagwell and Staiger (1992, 1994), and Maggi (1996)] on R&D subsidization have focused on international R&D rivalry, except papers on spillovers [D'Aspremont and Jacquemin (1988, 1990) and Muniagurria and Singh (1997)]. Kang (2006) explored the strategic relationship between R&D subsidies and IPR protection, providing a theoretical framework for the optimal policy choices of both policy tools. Extending this setup to an international field, Kang (forthcoming) provided economic backgrounds on the Agreements on Trade-Related Aspects on Intellectual Property Rights (TRIPS) and Subsidies and Countervailing Measures (SCM). However, this paper considers IPR protection over countries as exogenous and analyzes the optimal R&D policy.

This modification has two meaningful implications. First, it is *practically* reasonable to consider IPR protection as exogenous even though it could also be a policy tool to change strategic relationship as

shown in Kang (2006). The WTO sets multilaterally agreed disciplines both on IPR protection and on R&D subsidies under the TRIPS and SCM Agreement, respectively. The TRIPS Agreement regulates member countries to meet minimum standards of IPR protection. Even though countries are free to give greater protection on IPR, they usually operate their IPR regimes at the minimum level set by the TRIPS Agreement, enabling us to consider the regimes as exogenous. However, R&D subsidies are *non-actionable* for member countries, implying that they are much free to provide subsidies to R&D-related activities.[1] In that sense, it is quite reasonable to consider R&D subsidies as *endogenous*.

Second, most WTO member countries are also active to sign other IPR-related international treaties in addition to the TRIPS Agreement as shown in [Table 1]. Having multiple international treaties on IPRs, countries *voluntarily* devise multiple channels to lock their system in the multilaterally agreed level, making them unable to reverse it to the previous level. Therefore, a country's IPR regime is practically exogenous because countries' hands are tied up through multiple international treaties on IPRs. Having understood these two implications, this paper explores a country's optimal R&D policy when countries' IPR regimes are exogenously given.

[Table 1] Number of Contracting Parties of IPRs-Related Treaties among WTO Members

	1995	1998	2001	2004	2007
WTO	112	133	143	148	151
WIPO	158 (100)	172 (122)	177 (136)	181 (140)	184 (144)
Paris Conv.	136 (88)	151 (111)	162 (129)	168 (133)	172 (138)
Berne Conv.	116 (85)	133 (112)	148 (127)	157 (130)	163 (135)
Rome Conv.	48 (41)	58 (53)	67 (63)	79 (69)	86 (71)

Note: Author's calculation. The figure in parentheses is a number of contracting parties having the WTO membership.
Source: WTO and WIPO

Based on the dependence on IPR protection enforcement, this paper

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[1] For assistance for basic research, subsidies are allowed up to a maximum of 75 percent of the cost, and up to a maximum of 50 percent for pre-competitive development. See Article 8.2(a) of the SCM Agreement.

first parameterizes the IPR protection enforcement and then computes the optimal R&D policy. This analysis is useful in that it succeeds in identifying and characterizing the interesting effects that exogenous variation in the degree of IPR protection can have on standard strategic trade policy arguments. It is shown that each exporting country has an incentive to subsidize R&D activities if *both* countries strongly enforce or weakly enforce patent protection. The first case of R&D subsidies is similar to the result of the standard SB model. If R&D reaction curves slope down and there is negative externality in the R&D game, then an exporting country will subsidize its domestic R&D activities in order to help its national firm. However, the second case interestingly contrasts with the first case. Under a weak IPR protection regime, R&D reaction curves are upward sloping and the R&D game exhibits positive externality. In this case, the optimal R&D subsidy rate is still positive because both countries cooperate to share the R&D outcome developed in both countries.

The remainder of this paper is organized as follows. Following the SB and Kang (2006) model, this paper presents the basic setup in Section II to analyze how IPR protection enforcement affects R&D policies. After providing some implications for externalities and strategic interaction, Section III continues to analyze R&D subsidies, given the patent protection levels of both countries. Section IV Summarizes the results.

II. THE MODEL AND BASIC RESULTS

This section presents the basic framework to analyze the strategic role of R&D subsidies when countries' IPR regimes are exogenously given. This paper adopts a simple model of two exporting countries (Home and Foreign) and one importing country, based on Kang (2006). Foreign variables have an asterisk, but not for Home variables. For simplicity, we assume that there is no domestic competition in either exporting country[2]

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[2] As an anonymous referee pointed out, this paper can be extended by relaxing the assumption of no domestic competition. However, domestic competitors will presumably face the same levels of IPR protection as the domestic firm does, in Home and Foreign, if domestic competitors are also allowed to export their goods to the foreign country. Even though domestic competitors would harm the domestic firm's commercial interests by changing its response to IPR regimes and R&D activities of both foreign and domestic rivals, the main result of the optimal *subsidy* policy in this

and that both exporting firms produce a homogenous product to compete in a Cournot setup. We differ from Kang (2006 and Forthcoming) in assuming that each exporting country's IPR protection level is *exogenous*.

Let θ and $\theta*$ be IPR protection enforcement levels of the Home and Foreign country, respectively. These parameters of IPR protection are defined between 0 and 1. We interpret that IPR protection is *perfectly* enforced by the home government if $\theta = 0$, while the Home government enforces no IPR protection by allowing its domestic firms to copy freely rival firms' R&D outcomes, if $\theta = 1$.

Subgame Perfect Equilibrium
In this setup, there are three stages in which two exporting firms and two governments play.

The Setup of the Basic Game:
R&D Subsidy Stage: Both Home and Foreign governments simultaneously choose a R&D subsidy rate, given each country's IPR regime.
R&D Stage: Observing the subsidy rate of each government, each firm simultaneously chooses a R&D investment level.
Output Stage: Observing the subsidy rate of each government and R&D investment level of each firm, each firm simultaneously chooses an output level.

Given the patent protection levels of both countries, this paper begins by analyzing the output stage in order to find a subgame perfect equilibrium. The domestic firm in Home produces output y at cost C, which includes all costs except R&D, and earns revenue $R(y, y*) = P(y + y*)y$, where $P = a - b(y + y*)$ is the inverse demand function of the final good with $a > 0$ and $b > 0$. We set the cost function as follows: $C(y, x, x*, \theta) = yc(x, x*, \theta) = y[\alpha + c^1(x) + \theta c^2(x*)]$, where α is assumed to be positive and big enough to have non-negative marginal cost for all R&D investment levels.[3] The R&D level of this domestic

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paper would not be sensitive to the number of domestic companies.
  [3] The foreign firm has $C*(y*, x, x*, \theta*) = y*c*(x, x*, \theta*) = y*[\alpha + c^{*1}(x*) + \theta*c^2(x)]$ and

firm is denoted x and costs v per unit. The government provides R&D subsidies (tax if negative) at a rate of s. Profits of this firm are then given as follows:

$$
\begin{aligned}
\pi(y, y^*, x, x^*, \theta) &\equiv R(y, y^*) - C(y, x, x^*, \theta) - (v - s)x \\
&= \left[P(y + y^*) - c(x, x^*, \theta) \right] y - (v - s)x \\
&= \left[a - b(y + y^*) - c(x, x^*, \theta) \right] y - (v - s)x .
\end{aligned} \tag{1}
$$

The key features and assumptions are identical to Kang (2006 and forthcoming) so this paper skips those parts and focuses on the optimal R&D policy when countries' IPR protection levels are exogenously given. One can use the idea of backward induction to find a subgame perfect equilibrium. Thus, we start by solving the optimal choice of firms over each possible situation, and then work backward to compute the optimal choice for governments 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. The domestic firm faces in the first stage the following optimization problem:

$$
\begin{aligned}
\max_{y} \quad \pi(y; y^*, x, x^*, s, \theta) &= R(y; y^*) - yc(x, x^*, \theta) - (v - s)x \\
&= \left[a - b(y + y^*) - c(x, x^*, \theta) \right] y - (v - s)x .
\end{aligned} \tag{P1}
$$

The Nash equilibrium output levels are given as follows:

$$
\begin{aligned}
y &= q(x, x^*, \theta, \theta^*) \equiv (a - 2c + c^*)/3b \quad \text{and} \\
y^* &= q^*(x, x^*, \theta, \theta^*) \equiv (a - 2c^* + c)/3b .
\end{aligned} \tag{2}
$$

Totally differentiating the first-order conditions of (P1) with respect to y and y^*, one can verify that outputs are strategic substitutes having a negatively sloped *output* reaction function. However, the effects of each firm's R&D activities on output levels depend on each country's patent

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we assume $c_x^1 = c_x^{*2} \equiv c_x < 0$, $c_{x^*}^{*1} = c_{x^*}^2 \equiv c_{x^*}^* < 0$, $c_{xx} > 0$, $c_{x^*x^*}^* > 0$ and $c_{xx^*} = c_{xx^*}^* = 0$ for simplicity. See Kang (2006) for more information.

protection enforcement level. One can show that when both countries are perfectly enforcing patent protection $(\theta = \theta^* = 0)$, these effects are equal to the result of the standard SB model. In the SB case, the cross effects q_{x*} and q_x^* are negative but with patent infringement $y_{x*}(y_x^*)$ is positive if $\theta > R_{yy*}/R_{y*y*}^* = 1/2$ $(\theta^* > R_{y*y}^*/R_{yy} = 1/2)$.[4] As with the SB, domestic (foreign) R&D activities increase domestic (foreign) output level. However, home (foreign) R&D activities increase foreign (home) output levels if the foreign (home) country is *loosely* enforcing patent protection. Therefore, one can conclude that the domestic firm's Nash equilibrium output is increasing in domestic R&D; and the foreign firm's Nash equilibrium output is increasing in domestic R&D when the foreign government is loosely enforcing patent protection.

We now analyze the preceding stage, R&D stage, in which firms choose R&D levels maximizing their own profits. Firms are aware of the dependence of output on R&D levels and profits can be rewritten as functions of x and x^*. Let G represent the profit function for the domestic firm at the second stage:

$$
\begin{aligned}
\max_x \; G\left(x, x^*, \theta, \theta^*, s\right) &\equiv \pi\left(q\left(x, x^*, \theta, \theta^*\right), q^*\left(x, x^*, \theta, \theta^*\right), x, x^*, \theta, s\right) \\
&= R\left(q\left(x, x^*, \theta, \theta^*\right), q^*\left(x, x^*, \theta, \theta^*\right)\right) \\
&\quad - q\left(x, x^*, \theta, \theta^*\right)c\left(x, x^*, \theta\right) - \left(v - s\right)x .
\end{aligned}
\tag{P2}
$$

Solving (P2) for x,[5] we can find the Nash equilibrium R&D levels as a function of strategic trade policy tools:

$$
x = z\left(s, s^*, \theta, \theta^*\right); \quad \text{and} \quad x^* = z^*\left(s, s^*, \theta, \theta^*\right).
\tag{3}
$$

Totally differentiating the first-order conditions of (P2), we can show the slope of the R&D reaction curve as follows:

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[4] This was found in Kang (2006). See Kang (2006) for more information.

[5] The first-order conditions and the second-order conditions of (P2) are given as follows: $G_x = R_{q*}q_x^* - qc_x - (v - s) = 0$; and $G_{xx} = \left(R_{q*q}q_x + R_{q*q*}q_x^*\right)q_x^* + R_{q*}q_{xx}^* - q_x c_x - qc_{xx} < 0$.

$$\text{Home } \frac{dx}{dx^*} = -\frac{G_{xx^*}}{G_{xx}}; \text{ Foreign } \frac{dx^*}{dx} = -\frac{G^*_{x^*x}}{G^*_{x^*x^*}}. \tag{4}$$

The key difference between this modification and the SB model is that each country's patent protection enforcement level affects the slopes of the R&D reaction curve. While home and foreign R&D activities are strategic substitutes in the SB model, the relationship in this modification depends on both countries' patent protection regimes. If they are enforced loosely, home and foreign R&D activities become strategic complements rather than strategic substitutes. Analyzing signs of G_{xx^*} and $G^*_{x^*x}$, we can determine the strategic relationship between home and foreign R&D activities depending on each country's IPRs protection regime.

Given the analysis above, one can conclude that Home and Foreign R&D activities are strategic complements when both home and foreign countries are loosely enforcing patent protection $(\theta > 1/2, \theta^* > 1/2)$. Otherwise they are strategic substitutes as in the standard SB.

Under a weak IPR protection regime, Home and Foreign R&D activities are strategic complements because both Home and Foreign firms can share R&D outcomes by copying the rival's outcome of R&D activities. This strategic relationship also affects the effects of R&D subsidies on R&D investment levels. Totally differentiating the first-order conditions of the profit maximization with respect to x, x^*, and s, one can show the effects of R&D subsidies on R&D investment as follows:

$$\begin{bmatrix} G_{xx} & G_{xx^*} \\ G^*_{x^*x} & G^*_{x^*x^*} \end{bmatrix} \begin{bmatrix} x_s \\ x^*_s \end{bmatrix} = \begin{bmatrix} -1 \\ 0 \end{bmatrix}; \text{ and} \tag{5}$$

$$x_s = -\frac{G^*_{x^*x^*}}{B} > 0 \; ; \; x^*_s = \frac{G^*_{x^*x}}{B} \; ; \; x_{s^*} = \frac{G_{xx^*}}{B} \; ; \text{ and } \; x^*_{s^*} = -\frac{G_{xx}}{B} > 0 \; , \tag{6}$$

where $B \equiv G_{xx}G^*_{x^*x^*} - G_{xx^*}G^*_{x^*x} > 0$. Notice that the domestic (foreign) R&D subsidies increase the Foreign (Home) R&D investment $(x^*_s, x_{s^*} > 0)$ when Home and Foreign R&D activities are strategic complements $(G_{xx^*}, G^*_{x^*x} > 0)$. In other words, under a weak IPR protection regime, a country's R&D subsidies could benefit a foreign rival firm's R&D activities. The reason is that strategic complementarity

occurs when both exporting countries are weakly enforcing patent protection.

Proposition 1 (The Effects of R&D Subsidies on R&D Investment)

(1) The domestic R&D subsidies always increase the domestic R&D investment; and

(2) The domestic R&D subsidies increase the foreign R&D investment when both home and foreign countries are loosely enforcing patent protection and hence home and foreign R&D activities are strategic complements.

Proof: From (6), x_s is positive because $G^*_{x^*x^*}$ is negative as the second-order condition. For the second part of Proposition 1, the previous result implies that home and foreign R&D activities are strategic complements when both countries are loosely enforcing patent protection. Then $G^*_{x^*x}$ is positive and it implies that x^*_s is positive. ∎

Using a similar method we can identify the effects of IPR policy on R&D levels:

$$\begin{bmatrix} G_{xx} & G_{xx^*} \\ G^*_{x^*x} & G^*_{x^*x^*} \end{bmatrix}\begin{bmatrix} x_\theta \\ x^*_\theta \end{bmatrix} = \begin{bmatrix} 0 \\ -G^*_{x^*\theta} \end{bmatrix}; \tag{7}$$

$$x_\theta = \frac{G_{xx^*}G^*_{x^*\theta}}{B}; \quad x^*_\theta = \frac{-G_{xx}G^*_{x^*\theta}}{B} < 0; \quad x_{\theta^*} = \frac{-G^*_{x^*x^*}G_{\theta x^*}}{B} < 0; \text{ and}$$

$$x^*_{\theta^*} = \frac{G^*_{x^*x}G_{x\theta^*}}{B}. \tag{8}$$

The results are interpreted in the following proposition:

Proposition 2 (The Effects of IPR Policy on R&D Investment)

(1) Weak IPR protection in the foreign country decreases the domestic firm's R&D investment; and

(2) Weak home country's enforcement increases the domestic R&D investment under a strong enforcement regime, but decreases under a weak enforcement regime.

Proof: The first argument (1) is obvious from (8) because $G_{x^*\theta}^* = R_q^* \dfrac{c_{x^*}^* R_{q^*q^*}^*}{A} < 0$. However, the sign of $x_\theta(x_{\theta^*}^*)$ depends on the sign of G_{xx^*} $(G_{x^*x}^*)$ because $G_{x^*\theta}^*$ is negative. Under a strong enforcement regime in the home country $(G_{xx^*} < 0)$, the sign of x_θ is positive, implying that weaker enforcement increases domestic R&D investment. However, under a weak enforcement regime $(G_{xx^*} > 0)$, the sign of x_θ is negative, implying that weaker enforcement decreases the domestic R&D investment. ∎

The first result is straightforward. The foreign country's weak IPR policy will damage the domestic firm's incentive to invest in R&D activities. The second result is interesting, but the intuition is simple: under a strong enforcement regime, a government can help its domestic firm by weakly enforcing patent protection slightly because weaker enforcement in the home country will damage the foreign rival firm's incentive to invest in R&D activities, and hence, alter the strategic relationship between firms. However, weak enforcement will enlarge a free-rider problem for its domestic firms. In other words, weaker enforcement causes the domestic firm to free-ride on the rival's R&D outcome. Thus, this effect forms a reverse U-shaped graph implying a trade-off between a strategic advantage and a free-rider problem.

Nash Equilibrium

Now, we are ready to analyze each country's strategic trade policy focusing on the first stage. We assume that each government maximizes domestic welfare: that is, the domestic firm's profits less R&D subsidy costs. Each country's optimization problem will be given as follows:

Home: $\max_s \ W(s, s^*; \theta, \theta^*)$

$\equiv G\big(z(s, s^*; \theta, \theta^*), z^*(s, s^*; \theta, \theta^*), s; \theta, \theta^*\big) - sz(s, s^*; \theta, \theta^*);$

Foreign: $\max_{s^*} \ W^*(s, s^*; \theta, \theta^*)$

$\equiv G^*\big(z(s, s^*; \theta, \theta^*), z^*(s, s^*; \theta, \theta^*), s^*; \theta, \theta^*\big);$ and

$$-s*z*\left(s,s*;\theta,\theta*\right).\tag{P3}$$

The first-order conditions are given as follows:

$$G_z z_s + G_{z*} z_s^* + G_s - z - sz_s = 0\,;\text{ and}\tag{9}$$
$$G_z^* z_{s*} + G_{z*}^* z_{s*}^* + G_{s*}^* - z* - s*z_{s*}^* = 0.\tag{10}$$

Since $G_z = 0$ $(G_{z*}^* = 0)$, $G_s = z$ $(G_{s*}^* = z*)$, and $z_s^*/z_s = dx*/dx$ $(z_{s*}/z_{s*}^* = dx/dx*)$, one can show that the optimal R&D subsidies are given as follows:

$$s = G_{z*}\frac{dx*}{dx}\,;\text{ and }\quad s* = G_z^*\frac{dx}{dx*}\,.\tag{11}$$

They have the same formula as the standard SB model, but the logic is totally different. The sign of domestic optimal R&D subsidy (tax if negative) rate depends on two terms: G_{z*} and the slope of the foreign R&D reaction curve $(dx*/dx)$. The R&D reaction curve is upward (downward) sloping when home and foreign R&D activities are strategic complements (substitutes). The other term represents externalities. If G_{z*} is positive (negative), then the foreign R&D activities increase (decrease) for the domestic firm's profits implying positive (negative) externalities. One has shown that each country's IPR policy determines the strategic relationship between home and foreign R&D investment levels. In addition, IPR policy of both countries determines strategic externalities in this R&D game. Under weak enforcement regime in a country, the rival foreign firm's R&D outcome increases profits of the domestic firm, implying that the R&D game exhibits positive externalities.

Proposition 3 (Externalities)
*There is a positive externality in the R&D game when both countries loosely enforce patent protection.*

Proof: By differentiating the domestic firm's profit function with respect to the foreign R&D level, one can show the following: $G_{x*} = R_{q*}q_{x*}^*$

$-q\theta c_{x*}$. One can rewrite $G_{x*} = \frac{c_{x*}}{A}\left[\left(R_{qq} - \theta R^{*}_{q*q}\right)R_{q*} - \theta q A\right]$. Thus, we can show that the sign of G_{x*} is positive if $\theta > \dfrac{R_{qq}R_{q*}}{R^{*}_{q*q}R_{q*} + qA} = \dfrac{2b^2 q}{b^2 q + 3b^2 q} = \dfrac{1}{2}$. ∎

III. OPTIMAL R&D SUBSIDIES

Now let us go back to the optimal R&D subsidy issue. The SB model showed that the exporting country has an incentive to subsidize its domestic R&D activities. However, when the foreign rival firm's R&D outcome could affect the domestic firm's marginal cost, the optimal R&D subsidies were different. From (22), the sign of the optimal R&D subsidy (tax if negative) for the home country depends on: (a) whether or not positive externalities arise in the home country; and (b) whether or not the foreign R&D reaction curve is upward sloping. The home country's optimal R&D subsidy rate depends on both home and foreign country's IPR enforcement levels because the home country's IPR policy determines the externality in the home country, and the foreign country's IPR policy determines the slope of the foreign R&D reaction curve. [Figure 1] shows the signs of optimal R&D subsidy of both countries' IPRs protection regime.

Strategic interaction between firms is at the center of this analysis as the SB showed. When IPR protection is perfect, our model is identical to the original SB setup and exhibits its well-known features. As a firm's best response to an increase in R&D by its rival is to reduce its own R&D (i.e., R&D reaction curve is negatively sloped: $dx*/dx < 0$), the domestic government will wish to subsidize R&D. This is because, in providing the domestic firm with an incentive to do more R&D, the government is able to *discourage* R&D activity by the foreign rival firm, and *lower* R&D investment of the foreign rival *increases* the profits of the domestic firm. This explains Case 1 and was verified in Spencer and Brander (1983).

[Figure 1] The Optimal R&D Subsidy
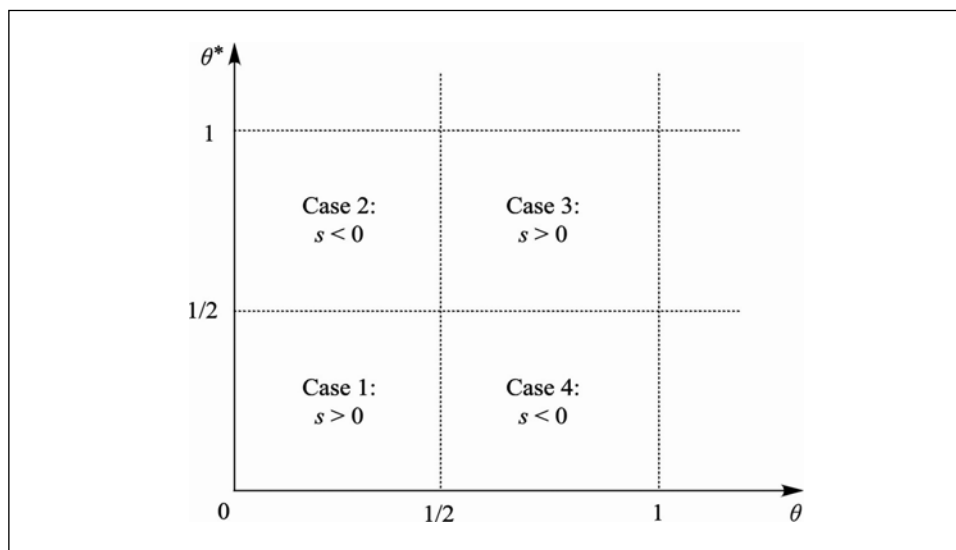
In Case 2, where the home country has relatively strong enforcement on IPR protection ant the foreign country has loose enforcement, the optimal subsidy is negative: that is, the optimal intervention is to impose taxes. In this case, a foreign firm's best response to an increase in the domestic R&D investment is to raise its own R&D $(dx^*/dx > 0)$. However, an increase in foreign R&D is still harmful to the domestic firm's profits because the home government is relatively strong in enforcing IPR protection $(G_{z^*} < 0)$. By imposing a tax on R&D activities the home government can help its domestic firm because an R&D subsidy to encourage domestic R&D investment will help its foreign rival under the circumstance where the foreign country is weakly enforcing IPR protection.

In Case 3, where both countries are loosely enforcing IPR protection, each government has an incentive to subsidize R&D activities but for a very different reason than the SB model. When loosely enforcing patent protection, both countries cooperate to share R&D outcome by allowing firms to *freely* use the rival's R&D activities. This case forms a striking contrast to Case 1: both countries cooperate with each other in enforcing *strong* patent protection. Positive externalities are a key reason in Case 3, while rivalry matters in Case 1. In the presence of imperfect IPR

protection like in Case 3, a novel force comes into play in determining government incentives to intervene in firm R&D choices: a rival's R&D now directly reduces one's own costs as well. In Case 3, R&D reaction curves will in fact slope up (strategic complements) so that a prediction of R&D subsidies will again obtain. In providing the domestic firm with an incentive to do more R&D, the government is able to *encourage* R&D activity by the foreign rival firm, and *greater* R&D investments of the foreign rival *increase* the profits of the domestic firm (positive spillover).

As contrasted with Case 3, Case 4 still has a positive effect of foreign R&D on the domestic profits but the foreign country is strongly enforcing patent protection: $(dx^*/dx < 0)$ and $(G_{z^*} > 0)$. Thus, the home government has an incentive to impose a tax on domestic R&D activities. The results are summarized in the following proposition:

Proposition 4 (Optimal R&D Subsidies)
The optimal domestic R&D subsidy is positive (i) if both countries strongly enforce, or (ii) loosely enforce patent protection.

IV. CONCLUDING REMARKS

This paper has reconsidered the R&D policy issue, which has been a hot topic since the SB model. By showing that IPR protection is related to R&D policy, we have shown how each country's IPR protection regime affects the strategic relationship between R&D activities and the nature of externalities. This externality can be interpreted as a spillover. When both exporting countries cooperate to share R&D outcome by weakly enforcing IPR protection, positive spillovers arise in the R&D game. There are several cases where exporting countries have an incentive to subsidize their domestic R&D activities. One is the case of the standard SB model, but we have provided another possibility where both countries weakly enforce patent protection. In this case, positive externalities arise in the R&D game and R&D reaction curves are positively sloped.

This study has explored strategic R&D policy without any consideration of the patent race process. To acquire a patent, a firm has to win the race, expecting to earn a monopolistic profit stream. However, harnessing the race process into the model is unlikely to provide any

further implications for the strategic role of R&D policy. The reason is that the strategic role of R&D policy is determined by the interaction among firms rather than by the dynamic process of an R&D patent race.

The fact that this study does not consider a worldwide welfare issue is a limitation. Under the General Agreement on Tariffs and Trade, members can negotiate an optimal patent protection level that maximizes worldwide welfare, including the third consuming country. This level would imply GATT-type unique patent protection enforcement. Comparing this level to the discriminatory protection level based on Section 337 of the U.S. trade law, we will provide an important extension of this paper. To compare them, we should let governments choose their patent protection level in order to maximize each country's net benefit. After finding the optimal level of patent protection in a non-cooperative setup, one can allow both countries to cooperate with each other in terms of harmonizing patent protection or designing a cooperative R&D subsidy-tax policy. This extension would produce some implications for trade policy instruments - patent protection enforcement, R&D subsidies, and R&D taxes.

Additionally, motivated by Maggi (1996, 1999) one can consider an asymmetric information problem in which government has no idea of whether the R&D game exhibits *strategic substitutability* or *complementarity* while firms do. This consideration is another logical extension of this paper. However, we leave it for future research.

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