Patent Protection and Strategic Trade Policy

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Executive Summary

This paper reconsiders the well-worked topic of strategic trade policy, but we approach the topic from a novel and important perspective. We observe that previous work on strategic trade policy with regard to R&D subsidies, starting with the seminal paper by Barbara Spencer and Jim Brander (1983), has proceeded under the implicit assumption that firms have perfect property rights to the results of their R&D investments. In reality, of course, the protection of intellectual property rights (IPRs) is not perfect. So it is natural to consider optimal choices for these policies in tandem rather than examining R&D subsidy policy in isolation. We show that the level of IPR protection can have important implications for a government's incentives to intervene in the R&D decisions of domestic firms.

We treat the level of IPR protection as exogenous, and consider how weak IPR protection may affect the case for an R&D subsidy in an international duopoly setting. When IPR protection is perfect, the model is identical to the original Spencer and Brander setup, and exhibits its well-known features. A firm's profits rise when its rival undertakes smaller amounts of R&D, and so governments seek to reduce the R&D levels of rival firms with their R&D policies. 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 curves slope down), the domestic government will wish to subsidize R&D because, in providing the domestic firm with an incentive to do more R&D, the government is able to discourage R&D activity be the foreign rival firm. However, in the presence of imperfect IPR protection, 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. If IPR protection is sufficiently weak, we show that R&D reaction functions will in fact slope up, so that a prediction of R&D subsidies will again obtain. But now it is fore precisely the opposite reason found in the original Spencer and Brander logic: the domestic government will wish to subsidize its firm's R&D in the presence of sufficiently weak IPR protection, because 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 the greater R&D investments of the foreign rival increase the profits of the domestic firm.

This paper 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. In pointing out the importance of the IPR regime for understanding the incentives to subsidize R&D, and even for predicting the sign of the optimal strategic R&D policy, we also set the stage of future research, which models the joint determination of R&D subsidies and IPR regime.

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I. Introduction

Most countries take a wide variety of measures to stimulate R&D activities. Even though possibilities range from improving finance for high-tech companies to introducing an R&D tax credit, the most favorite measure over countries seems to be an R&D subsidy (see ⟨Table I-1⟩). The US federal government provides approximately 40% of total funds allocated to R&D in the United States, the remainder being spent by the private sector. Especially, federal funds support 61% of basic research, 44% of applied research, and 41% of development work.[1] Economic theories verify this R&D subsidization. As a pioneer work in this field, Spencer and Brander (1983) showed that an exporting country has an incentive to subsidize its domestic R&D activities as long as home and foreign R&D activities are strategic substitutes.

However, US firms could not perfectly benefit from this support if developing countries are weakly enforcing patent protection. Notice that legal methods of protecting intellectual property rights (IPRs) include patents, copyrights, and trademarks. Specifically, a patent is a governmental grant of a property right to the inventor of a product or process (which is new and has industrial application) that gives

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1) See "Trade Policy Review: United States," Vol. 1, 1994, GATT.

the patent holder exclusive right to the invention over a limited period of time.

⟨Table I-1⟩ The Ratio of GERD Financed by Government

	1989	1990	1991	1992	1993	1994	1995	1996
Austria	0.155	0.184	0.197	0.196	0.191	0.208	0.205	0.195
Canada	0.363	0.365	0.358	–	0.335	–	0.293	0.281
France	0.414	0.416	0.418	0.365	0.362	0.343	0.349	–
Japan	0.113	0.110	0.112	0.119	0.133	0.132	0.142	–
Netherlands	0.231	0.229	0.213	0.213	0.212	0.211	0.193	–
Spain	0.341	0.326	0.325	0.304	0.298	0.303	0.306	–
UK	0.292	0.283	0.272	0.267	0.262	0.263	0.262	–
US	0.422	0.408	0.387	0.377	0.377	0.369	0.361	0.346

GERD: Gross Domestic Expenditure on R&D.
Source: *OECD (1997), Basic Science and Technology Statistics.*

However, laws need to be enforced. By loosely enforcing patent protection, some developing countries allow their national firms to copy and use the product or process of the R&D developed in high-tech countries. Because of intellectual property (IP) piracy in some developing countries, inventive firms cannot perfectly appropriate their new technology and cannot perfectly benefit from their government's R&D subsidies. For instance, suppose that *Ford*, a US carmaker, invents an efficient way to produce cars and takes out a patent on the R&D outcome. However, if a foreign country, say South Korea, is loosely enforcing patent protection so that the patent of *Ford* is not fully protected in South Korea, it is then possible that *Hyundai*, a Korean carmaker, copies and benefits from the R&D outcome of *Ford*.

〈Table I-2〉 US – China IPR Dispute: 1979 – 1996

Year	Issues
1979	The 1979 US –China Trade Agreement: Both countries afford each other equal national treatment in the protection of patents, copyrights, and trademarks.
1985	US officials expressed concern over IPR protection in China during talks held under the auspices of the US – Chinese Joint Commission on Commerce and Trade (JCCT).
1989	The USTR placed China on its Special 301 priority watch list.[2]
1990	The USTR placed China on its Special 301 priority watch list.
April, 1991	The USTR designated China as a priority foreign country[3] under Special 301 and launched an investigation of four specific deficiencies in China's IPR practices.[4]
November 26, 1991	The USTR determined that insufficient progress had been made in resolving Chinese IPR violations and issued a draft list of products imported from China, valued at $1.5 billion.

2) Section 182 of the 1974 Trade Act, commonly referred to as Special 301, is one of the primary US trade statues used to protect US IPR in foreign market. The provision directs the USTR to identify countries that deny adequate protection of US IPR, and to initiate investigations against "priority foreign countries," whose IPR practices are considered to be the most serious or harmful to US persons who rely on intellectual property protections. Once a country is identified as a priority foreign country, the USTR begins an investigation and seeks negotiations with that country. If an agreement is not reached within six months (extendable to nine months), the USTR must determine if the foreign practice violated US rights under a trade agreement of was "unreasonable" or "discriminatory". If an affirmative determination is made, the USTR may decide to issue trade sanctions, usually in the form of 100% import tariffs on selected products. See GATT (1994) and Morrison (1996) for details.

⟨Table I–2⟩ continued

Year	Issues
January 16, 1992	However, an agreement was reached. China agreed to strengthen its patent, copyright, and trade secret laws, and to improve IPR protection for US products.
1992	The USTR placed China on its Special 301 watch list.
1993	The USTR placed China on its Special 301 watch list.
June 30, 1994	The USTR designated China as a priority foreign country under Special 301, initiated an investigation, and subsequently began new talk with Chinese officials.
February 4, 1995	The USTR announced that insufficient progress had been made in talks and issued a list of Chinese products, valued at about $1.1 billion, which would be subject to 100% import tariffs. China in turn threatened counter sanctions against US products.
February 26, 1995	An agreement was reached. China agreed to (1) begin a "special enforcement period" over the course of the next several months; (2) establish mechanisms to ensure long–term enforcement of IPR laws; and (3) provide greater market access to US products.
April 30, 1996	The USTR designated China as a priority foreign country under Special 301 for failing to fully implement the 1995 IPR agreement.
May 15, 1996	The USTR published a preliminary list of Chinese products that were under consideration for US sanction (100% prohibitive tariffs). China warned that it would retaliate against US sanctions.

Source: *Morrison (1996)*.

3) Since the enactment of Special 301 (Section 1303 of the Omnibus Trade and Competitiveness Act of 1988, P.L. 100–418), the USTR has issued a three–tier list (beginning in 1989) of countries that are considered to maintain inadequate regimes for the protection of US IPR or deny market access: (1) *priority foreign countries* that are considered to be the worst violators of US IPR and are subject to a USTR investigation and possible US trade sanction; (2) *priority watch list countries* that are considered to have serious deficiencies in their IPR regime, but do not currently warrant an investigation; and (3) *watch list countries* that have been identified

According to a Congressional Research,[5] US and IPR industry officials have charged that IPR piracy in China is costing US firms $ 2.3 billion in lost trade annually, despite trade agreements in January 1992 and February 1995 that pledged China to improve its IPR enforcement regime (see ⟨Table I–2⟩). Baldwin (1988) has pointed out that the US is concerned about these losses, especially *"in view of the increasing competitiveness of other countries as they close the technological and skill gaps that long have been the basis of US cost advantage"*. Given this fact, R&D subsidies financed by the Federal government could flow into a foreign country if the foreign country is loosely enforcing patent protection. In the sense above, a country's R&D subsidies could benefit a foreign rival if that foreign country is weakly enforcing patent protection.

The main objective of this paper is to provide a theoretic framework in order to show how IPR piracy in a foreign country affects R&D subsidization. Most papers[6] on R&D subsidization have focused on international R&D rivalry, except papers on spillovers,[7] even though

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because they maintain IPR practices or barriers to market access that are of particular concern, but do not yet warrant higher level designations. See GATT (1994) and Morrison (1996) for details.

4) They are (1) failure to provide product patent protection for chemicals, pharmaceuticals, and agrichemicals; (2) lack of copyright protection for US works not first published in China; (3) deficient levels of protection under Chinese copyright law and regulations; and (4) inadequate protection of trade secrets. See Morrison (1996) for details.

5) See Morrison (1996).

6) See Spencer and Brander (1983), Bagwell and Staiger (1992, 1993), and Maggi (1996).

7) See D'Aspremont and Jacquemin (1988) and Muniagurria and Singh (1997).

it is well known that the optimal R&D subsidies depend on whether R&D activities are strategic substitutes or complements. However, this paper provides a possible story that IPR protection enforcement determines strategic relationship between home and foreign R&D investment levels, and in turn affects strategic roles of R&D subsidy policy.

We begin by showing how IPR protection enforcement affects the strategic relationship. Strategic interaction between firms is at the center of this analysis as Spencer and Brander (1983) showed. They provided a standard model in which domestic R&D subsidies lead profits to be shifted from foreign firms to domestic firms. This profit shifting occurs because strategic trade policy alters strategic relationship between firms. However, in this paper we have realized that the analysis of R&D policy in Spencer and Brander (1983) has proceeded under an implicit assumption that inventive firms have perfect IPR to the outcome of R&D activities. As we have discussed above, in reality the IPR protection is not perfect and the protection enforcement could affect not only firms' incentive to invest in R&D activities but also government's incentive to subsidize R&D activities. When IPR protection is perfect, our model is identical to the original Spencer and Brander (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), the domestic government will wish to subsidize R&D 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 the *lower* R&D investment of the foreign rival *increases* the profits of the domestic firm.

However, in the presence of imperfect IPR protection, a novel force

comes into play in determining government incentives to intervene in firms' R&D choices: a rival's R&D now directly reduces one's own costs as well. Under the weak enforcement regime, domestic and foreign R&D activities are strategic complements rather than strategic substitutes. In contrast with the SB model, R&D reaction curves are upward sloping under the weak IPR protection regime. Under the circumstance above with weak IPR regime, R&D subsidies as a strategic trade policy tool works again, but it is for precisely the opposite reason found in the SB logic: government will wish to subsidize its national firm's R&D in the presence of sufficiently weak IPR protection, because 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 the *greater* R&D investment of the foreign rival *increase* the profits of the domestic firm. It implies that externalities in this R&D game as well as strategic interaction are determined by each exporting country's IPR protection enforcement. In the standard SB model of strategic R&D policy, an increase in foreign R&D investment will reduce a domestic firm's profits because of international R&D rivalry. However, when the home country is loosely enforcing patent protection, an increase in the R&D activities developed abroad will raise a domestic firm's profits because the domestic firm could copy and use the outcome of R&D developed in the rival country. The positive effects of foreign R&D investment on the domestic firm's profits simply imply positive spillovers.

Based on the dependence on IP protection enforcement, this paper first parameterizes the IP protection enforcement and then computes the optimal R&D policy. This paper 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.[8] 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. 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 weak IP 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. Section II discusses general patent systems, foreign patents and treaties, and patent protection enforcement. Following Spencer and Brander (1983), this paper presents the basic setup in Section III to analyze how IP protection enforcement affects R&D policy. After providing some implications on externalities and strategic interaction, Section III continues to analyze R&D subsidies given patent protection levels over both countries. We summarize the results in Section IV.

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8) In pointing out the importance of the IPR regime for understanding the incentives to subsidize R&D, and even for predicting the sign of the optimal strategic R&D policy, we set the stage for the future research, which models the joint determination of R&D subsidies and IPR regime.

II. Patent Protection and Enforcement

Before introducing a model, we describe general patent systems, foreign patents and treaties, and patent protection enforcement.

A. Patents

Patents protect the physical embodiment of technological information or inventive activity – invention – rather than abstract thoughts. In the United States, a patent for an invention is a grant of a property right by the government to the inventor, acting through the Patent and Trademark Office. According to the U.S. patent law,[9] the right conferred by the patent grant is *"the right to exclude others from making, using, offering for sale, or selling"* the invention in the United States or *"importing"* the invention into the United States.

The patent laws of the United States don't make discrimination with respect to the citizenship of the inventor. Therefore, any inventor, regardless of his/her citizenship, may apply for a patent on the same basis as an U.S. citizen.

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9) The patent law specifies the subject matter for which a patent may be obtained and the conditions for patentability. The law, which is codified in Title 35, United States Code, establishes the Patent and Trademark Office to administer the law relating to the granting of patents, and contains various other provisions relating to patens.

B. Foreign Patents and Treaties

Since the rights granted by a United States patent extend only throughout the territory of the United States and have no effect in a foreign country, an inventor who wishes patent protection in other countries must apply for a patent in each of other countries or in regional patent offices.[10] Almost every country has its own patent law, and a person desiring a patent in a particular country must make an application for patent in that country, in accordance with the requirements of that country.

There is a treaty relating to patents that is adhered by 140 countries, including the United States, and is known as the Paris Convention for the Protection of Industrial Property. It provides that each country guarantees to the citizens of the other countries the same rights in patent and trademark matters that it gives to its own citizens. Another treaty, known as the Patent Cooperation Treaty, was negotiated at a diplomatic conference in Washington, D.C., in June of 1970. The treaty came into force on January 24, 1978, and is presently adhered to by over 90 countries, including the United States. The treaty facilitates the filing of applications for patent on the same invention in member countries by providing, among other things, for centralized filing procedures and a standardized application format. Thus there is no discrimination to apply for a patent in terms of the citizenship of the inventor.

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10) An example of regional patent offices is the European Patent Office of the European Patent Organization. A European patent granted by the European Patent Convention confers on its proprietor, in each contracting country in respect of which it is granted, the same rights as would be conferred by a national patent granted in that country.

C. Patent Protection Enforcement

Based on the definition of a patent, we can define that infringement of a patent consists of the unauthorized making, using, offering for sale or selling any patented invention within the United States Territories, or importing into the United States of any patented invention during the term of the patent. If a patent is infringed, the patentee may sue for relief in the appropriate Federal court. In general, intellectual property rights in the form of patents, copyrights, and trademarks are granted by national governments and are enforceable only in the country in which they are granted. The scope of intellectual property rights granted, and the degree to which those laws are enforced, closely reflect what a nation considers to be its best interest. Although the United States extends patent protection to seeds and plants, for example, the intellectual property laws of many Latin American countries explicitly or implicitly exclude most agricultural inventions. The enthusiasm with which intellectual property rights are enforced by these governments varies even more than the level and scope of protection. The level of protection in industrialized countries is generally high, whereas intellectual property protection in developing countries varies widely, with many products excluded from protection altogether.

These developing countries have two problems on intellectual property: (1) the lack of formal laws providing an adequate scope of protection, and (2) the failure to enforce existing laws against violators. As we have discussed above, the scope and degree of patents vary in these developing countries. For instance, chemical and pharmaceuticals are not patentable in most developing countries. The failure to enforce formal laws is as bad as the absence of laws altogether. Although

formal protection may be available on paper, enforcement is largely nonexistent and even the best enforcement efforts are weak in some developing countries. For this reason, it is natural that piracy of intellectual property rights has emerged as one of the most important foreign policy issues for many industrialized countries, particularly the United States. The Congressional Research Service estimates that U.S. companies lose one dollar to inadequate protection of intellectual property rights for every three-dollar of revenue gained from exported products.[11] The U.S. government has undertaken efforts to strengthen worldwide protection of intellectual property rights through multilateral forums such as the GATT and bilateral consultations with problem countries.

Through the TRIPS provisions, the Uruguay Round extends GATT's trade-liberalizing philosophy to the protection of intellectual property. One of the important objectives is that TRIPS mandate that the standard of intellectual property protection be raised in developing countries. By providing clear and enforceable rules plus dispute settlement mechanisms through the WTO framework, TRIPs are also a source of international legal convergence. Nevertheless, the legal convergence toward U.S. standards of protection can be extremely slow. TRIPs have long transition periods during which developing countries are supposed to come into compliance with increased protection for intellectual property rights.[12] As a result, patent protection enforcement still varies widely even though TRIPs are a

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11) See Buscaglia and Long (1997).

12) TRIPS allow developing countries a ten-year grace period in which to extend intellectual rights to categories of inventions that were previously unprotected. See Article 66(1) of the TRIPs agreement.

pressure to enact intellectual property law harmonization. We can summarize why patent protection enforcement varies widely over countries as follows:

(1) The lack of formal laws providing an adequate scope of protection,

(2) The failure to enforce existing laws against violators, and

(3) Long transition periods: a ten–year grace period

In future research, we will provide a theoretical framework to analyze the global issue of IPR policy enforcement and R&D subsidization.

III. The Model

A. Overview

We present in this section our basic framework to analyze the strategic role of R&D subsidies when countries are *loosely* enforcing patent protection. Following Spencer and Brander (1983), we assume that there are two exporting countries and a third importing country. One exporting country will be referred to as the home (no *) country, while the other is called the foreign (*) country. Each exporting country has a single exporting firm. It is also assumed that both firms produce a homogenous good and compete in a third market by setting quantity (Cournot competition).

We differ from the SB model in realizing the fact that in reality inventive firms do not have perfect protection on their R&D outcome. In other words, a firm's R&D outcome could benefit a foreign rival firm if that foreign country is loosely enforcing patent protection. Each country's patent protection level is assumed to be *exogenous* in this model.

Let θ, θ^*, and θ^I be patent protection enforcement levels of home, foreign, and third importing country, respectively. The parameter of patent protection θ is defined between 0 and 1. Patent protection is *perfectly* enforced by the home government if $\theta = 0$, while the home government enforces nothing about patent protection by allowing its national firms to copy freely rival firms' R&D outcome if $\theta = 1$. Without loss of generality, assume that $\theta \leq \theta^*$ implying that the home country's patent protection enforcement is stronger than the foreign country. There will then be three possible cases over three patent protection

enforcement levels: (Case 1) $\theta \leq \theta^* \leq \theta^I$, (Case 2) $\theta \leq \theta^I \leq \theta^*$, and (Case 3) $\theta^I \leq \theta \leq \theta^*$.

In Case 1, a domestic firm will take out a patent in the home country because the home government is strongly enforcing patent protection. This domestic firm will also take out a patent in the foreign country because it wants to exclude a rival in the foreign country from using its invention. Thus the third importing country's enforcement level θ^I is irrelevant in this case. In Case 2, the foreign country's level θ^* is irrelevant because the domestic firm will take out a patent in the importing country rather than the foreign country. By holding a patent, the domestic firm can exclude a rival in the foreign country from using and selling the product based on its invention in the third importing country. In Case 3, the home and foreign levels, θ and θ^*, are irrelevant because the third importing country's enforcement is the strongest among three countries.

Based on these possibilities, this game is subsequently extended in several ways. First, this paper provides a general model where both firms are facing two relevant enforcement levels, including Case 1 and 2. Then we will move to Case 3 in which only one enforcement level matters. The unique level of patent protection enforcement is reasonable in the following senses: (i) Case 3: Exports to a developed country with strong patent protection enforcement, (ii) A symmetric model, (iii) An international agreement, such as the TRIPS Agreement, and (iv) MNEs who have R&D subsidiaries in the same country. This paper will discuss these cases in Section III-F.

B. Subgame Perfect Equilibrium

This model is based on a three-stage game where two exporting

firms and two governments play.

The Basic Game:

R&D Subsidy Stage: Both home and foreign governments simultane-ously choose R&D subsidy rate, given each country's IPR regime.

R&D Stage: Observing the subsidy rate of each government, each firm simultaneously chooses R&D investment level.

Output Stage: Observing the subsidy rate of each government and R&D investment levels of each firm, each firm simultaneously chooses output level.

Given patent protection levels over both countries, this paper begins by analyzing the output stage in order to find a subgame perfect equilibrium. A domestic firm produces output y at cost C, which includes 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) $\quad \pi\left(y, y^*, x, x^*, \theta\right) \equiv R\left(y, y^*\right) - C\left(y, x, x^*, \theta\right) - (v - s)x$.

Following Spencer and Brander (1983), outputs y and y^* are substitutes and it is assumed that an increase in the foreign output reduces the marginal revenue of the domestic firm. Using subscripts to denote partial derivatives, this implies:

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

The production cost of a domestic firm depends on domestic output

level, domestic and foreign R&D levels, and domestic patent protection enforcement level: $C(y,x,x^*,\theta) = yc(x,x^*,\theta)$, where $c > 0$ is marginal cost. Each firm has the following marginal cost:[13]

$$(3) \quad c(x,x^*,\theta) \equiv \alpha + c^1(x) + \theta c^2(x^*); \, c^*(x,x^*,\theta^*) \equiv \alpha + c^{1^*}(x^*) + \theta^* c^{2^*}(x),$$

where α is sufficiently large so that marginal cost is non-negative for all R&D investment levels. For simplicity, we assume that *potential* effects of any increase in domestic R&D investment on domestic and foreign marginal costs are the same: $c_x = c_x^1 = c_x^{2^*} < 0$ and $c_{x^*} = c_{x^*}^{1^*} = c_{x^*}^2 < 0$. In other words, domestic R&D investment could *potentially* reduce the foreign marginal cost at the same extent that it reduces the domestic marginal cost. However, the *actual* effects depend on the foreign country's IPR protection enforcement level: $dc^*/dx = \theta^* c_x^{2^*}$. As you might expect, when countries are perfectly enforcing patent protection ($\theta = \theta^* = 0$), this model goes back to the SB setup. Additionally the rate of decrease is assumed to decline as R&D investment increases: $c_{xx} = c_{xx}^1 = c_{xx}^{2^*} > 0$ and $c_{x^*x^*} = c_{x^*x^*}^{1^*} = c_{x^*x^*}^2 > 0$ for the concavity of cost functions. It is also assumed that the domestic marginal cost is decreasing when the home country's enforcement is getting weaker given home and foreign R&D activities:

$$(4) \quad c_\theta = c^2 < 0; \quad c_{\theta^*}^* = c^{2^*} < 0; \quad c^1, c^{1^*} < 0.$$

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

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13) For simplicity, we assume $c_{xx^*} = c_{x^*x}^* = 0$.

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:

$$(P1) \quad \max_{y} \quad \pi(y; y^*, x, x^*, s, \theta) = R(y; y^*) - yc(x, x^*, \theta) - (v - s)x$$

The Nash equilibrium output level that maximizes profits is characterized by the first-order condition and the second-order condition as follows:

$$(5) \quad \pi_y = R_y - c(x, x^*, \theta) = 0;$$

$$(6) \quad \pi_{yy} = R_{yy} < 0.$$

Then the solutions to the first-order conditions can be written as:

$$(7) \quad y = q(x, x^*, \theta, \theta^*); \quad y^* = q^*(x, x^*, \theta, \theta^*).$$

Totally differentiating the first-order conditions with respect to y and y^*, we can show the slope of the *output* reaction function, which is negative from (2) and the second-order conditions:

$$(8) \quad \text{Home} \quad \frac{dy}{dy^*} = -\frac{R_{yy^*}}{R_{yy}} < 0; \quad \text{Foreign} \quad \frac{dy^*}{dy} = -\frac{R^*_{y^*y}}{R^*_{y^*y^*}} < 0.$$

Thus each firm's *output* reaction curve is downward sloping because outputs are substitutes. However, effects of each R&D activities on output levels depend on each country's patent protection enforcement level:

$$(9) \quad \begin{bmatrix} R_{yy} & R_{yy^*} \\ R_{y^*y}^* & R_{y^*y^*}^* \end{bmatrix} \begin{bmatrix} y_x \\ y_x^* \end{bmatrix} = \begin{bmatrix} c_x \\ \theta^* c_x^* \end{bmatrix};$$

$$(10) \quad y_x = \frac{c_x \left(R_{y^*y^*}^* - \theta^* R_{yy^*} \right)}{A} > 0; \qquad y_x^* = \frac{c_x \left(\theta^* R_{yy} - R_{y^*y}^* \right)}{A};$$

$$(11) \quad y_{x^*} = \frac{c_{x^*}^* \left(\theta R_{y^*y^*}^* - R_{yy^*} \right)}{A}; \qquad y_{x^*}^* = \frac{c_{x^*}^* \left(R_{yy} - \theta R_{y^*y}^* \right)}{A} > 0;$$

where $A \equiv R_{yy} R_{y^*y^*}^* - R_{yy^*} R_{y^*y}^* > 0$ as a stability condition. Notice that when both countries are perfectly enforcing patent protection $(\theta = \theta^* = 0)$, these effects are equal to the result of Spencer and Brander (1983). In the SB case the cross effects q_{x^*} and q_x^* are negative but with patent infringement q_{x^*} (q_x^*) is positive if $\theta > R_{yy^*} / R_{y^*y^*}^*$ $(\theta^* > R_{y^*y}^* / R_{yy})$. As Spencer and Brander (1983), 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 level if foreign (home) country is *loosely* enforcing patent protection. Proposition 1 summarizes these results:

Proposition 1 (The Effects of Domestic R&D Activities on Output Levels)

(1) *The domestic firm's Nash equilibrium output is increasing in the domestic R&D;*

(2) *The foreign firm's Nash equilibrium output is increasing in the domestic R&D when the foreign government is loosely enforcing patent protection.*

Proof.   Since the positive term A implies that own effects of output on marginal revenue dominate cross effects: $(R_{y^*y^*}^* < R_{yy^*} < 0)$, we can

show that y_x is positive over θ^*. For (2), we can show that y_x^* is positive if $\theta^* > R_{yy^*}/R_{y^*y^*}^*$. ∎

Totally differentiating the first-order conditions with respect to y, y^*, and θ, we can show the effects of IPRs protection on output levels as follows:

$$
(12) \quad \begin{bmatrix} R_{yy} & R_{yy^*} \\ R_{y^*y}^* & R_{y^*y^*}^* \end{bmatrix} \begin{bmatrix} y_\theta \\ y_\theta^* \end{bmatrix} = \begin{bmatrix} c_\theta \\ 0 \end{bmatrix};
$$

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

Weak enforcement of the home country is good for the domestic output, but not for foreign production. For the total effect of IPRs protection on output, however, we must consider these effects on R&D activities: $\frac{dy}{d\theta} = y_\theta + y_x x_\theta + y_{x^*} x_\theta^*$. We will discuss it later.

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. Then profits can be rewritten as functions of x and x^*. Let G represent the profit function for the domestic firm at the second stage:

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

The Nash equilibrium R&D levels are characterized by the first-order conditions and the second-order conditions:

$$
(14) \quad G_x = R_q \cdot q_x^* - qc_x - (v-s) = 0;
$$

(15) $G_{xx} = \left(R_{q^*q}q_x + R_{q^*q^*}q_x^*\right)q_x^* + R_{q^*}q_{xx}^* - q_x c_x - q c_{xx} < 0$.

Then the solutions to the first-order conditions can be written as a function of strategic trade policy tools:

(16) $x = z(s, s^*, \theta, \theta^*)$; $x^* = z^*(s, s^*, \theta, \theta^*)$.

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

(17) Home $\dfrac{dx}{dx^*} = -\dfrac{G_{xx^*}}{G_{xx}}$; Foreign $\dfrac{dx^*}{dx} = -\dfrac{G_{x^*x}^*}{G_{x^*x^*}^*}$.

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 loosely enforcing, home and foreign R&D activities are 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.

Proposition 2 (Strategic Relationship between Home and Foreign R&D Levels)

Home and foreign R&D activities are strategic complements when both home and foreign countries are loosely enforcing patent protection ($\theta > R_{yy^*} / R_{y^*y^*}^*$, $\theta^* > R_{y^*y}^* / R_{yy}$). Otherwise they are strategic substitutes as Spencer and Brander (1983).

Proof.   See Appendix A.   ■

Under a weak IPR protection regime, home and foreign R&D activities are strategic complements because both home and foreign firms could 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:

$$(18) \quad \begin{bmatrix} G_{xx} & G_{xx^*} \\ G_{x^*x}^* & G_{x^*x^*}^* \end{bmatrix} \begin{bmatrix} x_s \\ x_s^* \end{bmatrix} = \begin{bmatrix} -1 \\ 0 \end{bmatrix};$$

$$(19) \quad x_s = -\frac{G_{x^*x^*}^*}{B} > 0; \qquad x_s^* = \frac{G_{x^*x}^*}{B}; \qquad x_{s^*} = \frac{G_{xx^*}}{B}; \qquad x_{s^*}^* = -\frac{G_{xx}}{B} > 0,$$

Where $B \equiv G_{xx}G_{x^*x^*}^* - G_{xx^*}G_{x^*x}^* > 0$. Notice that the domestic (foreign) R&D subsidies are good for the foreign (home) R&D investment $(x_s^*, x_{s^*} > 0)$ when the 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 3 (The Effects of R&D Subsidies on R&D Investment)
(1) The domestic R&D subsidies are always good for the domestic R&D investment;
(2) The domestic R&D subsidies are good for 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 (19), x_s is positive because $G^*_{x^*x^*}$ is negative as the second-order condition. For (2), Proposition 2 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 the similar method we can identify the effects of IPR policy on R&D levels:

$$(20) \quad \begin{bmatrix} G_{xx} & G_{xx^*} \\ G^*_{x^*x} & G^*_{x^*x^*} \end{bmatrix} \begin{bmatrix} x_\theta \\ x^*_\theta \end{bmatrix} = \begin{bmatrix} 0 \\ -G^*_{x^*\theta} \end{bmatrix};$$

$$(21) \quad x_\theta = \frac{G_{xx^*}G^*_{x^*\theta}}{B}; \quad x^*_\theta = \frac{-G_{xx}G^*_{x^*\theta}}{B} < 0; \quad x_{\theta^*} = \frac{-G^*_{x^*x^*}G_{\theta x^*}}{B} < 0; \quad x^*_{\theta^*} = \frac{G^*_{x^*x}G_{x\theta^*}}{B}.$$

The results are interpreted in the following proposition:

Proposition 4 (The Effects of IPR Policy on R&D Investment)
(1) *Weak IPR protection in the foreign country is bad for the domestic*
    firm's R&D investment;
(2) *Home country's weak enforcement is good for the domestic R&D*
    investment under strong enforcement regime but bad under weak
    enforcement regime.

Proof. The first argument (1) is obvious from (21) because $G^*_{x^*\theta} = R^*_q \frac{c_{x^*}R_{q^*q^*}}{A} < 0$. However, the sign of x_θ ($x^*_{\theta^*}$) 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 is good for the domestic R&D investment. However, under a weak enforcement regime$(G_{xx^*} > 0)$, the sign of x_θ is negative implying that weaker enforcement is bad for 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: the home country's weaker enforcement is good for the domestic R&D investment under a strong enforcement regime, but bad under a weak enforcement regime as shown in ⟨Figure III-1⟩. The intuition is simple: Under a strong enforcement regime government could help its national firm by a little bit weakly enforcing patent protection because weaker enforcement in the home country will damage the foreign rival firm's incentive to invest in R&D activities and hence alter strategic relationship between firms. However, weak enforcement will enlarge a free-rider problem for its domestic firm. In other words, weaker enforcement makes the domestic firm free ride on the rival's R&D outcome. Under a weak enforcement, weaker enforcement is bad for its domestic firm because the free-rider problem is getting greater. Thus this effect forms a U-shaped graph implying a tradeoff between a strategic advantage and a free-rider problem.

〈Figure III-1〉 The Effect of the Home Country's IPR Policy
on its Domestic R&D Investment
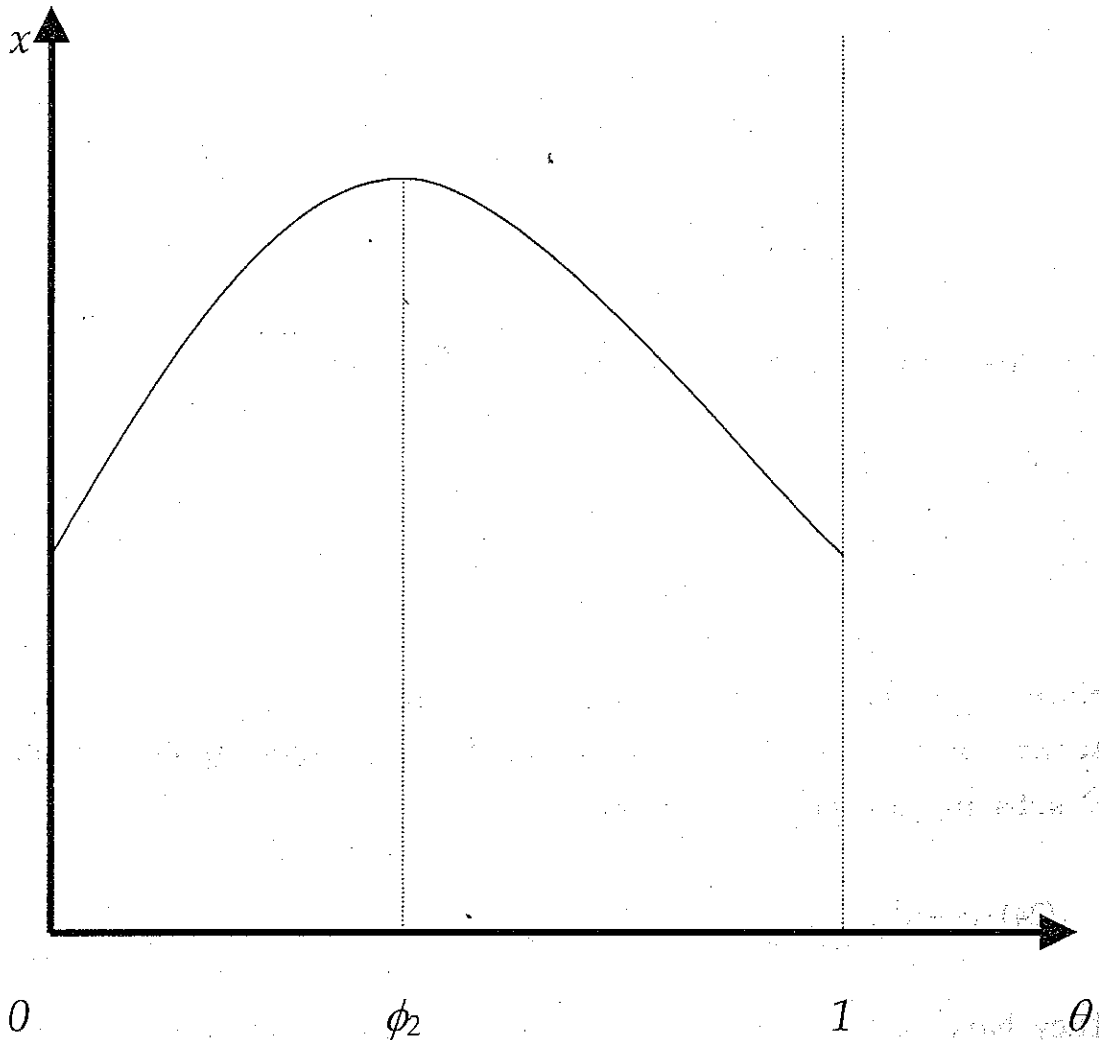
ϕ_2: The critical point of strategic relationship in the *home* country

C. 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 the domestic welfare that is the domestic firm's profits less R&D subsidy costs. The each country's optimization problem will be

given as follows:

(P3)

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: $\max_{s^*}$ $W^*(s, s^*; \theta, \theta^*)$
$\equiv G^*\big(z(s, s^*; \theta, \theta^*), z^*(s, s^*; \theta, \theta^*), s^*; \theta, \theta^*\big) - s^* z^*(s, s^*; \theta, \theta^*)$

The first-order conditions are given as follows:

(22) $G_z z_s + G_{z^*} z_s^* + G_s - z - s z_s = 0$;

(23) $G_z^* z_{s^*} + G_{z^*}^* z_{s^*}^* + G_{s^*}^* - z^* - s^* z_{s^*}^* = 0$.

Since $G_z = 0(G_{z^*}^* = 0)$, $G_s = z(G_{s^*}^* = z^*)$, and $z_s^*/z_s = dx^*/dx(z_{s^*}/z_{s^*}^* = dx/dx^*)$ from (17), (22) and (23), one can show that the optimal R&D subsidies are given as follows:

(24) $s = G_{z^*} \dfrac{dx^*}{dx}$; $s^* = G_z^* \dfrac{dx}{dx^*}$.

They have the same formula as Spencer and Brander (1983), but the logic is totally different. The sign of the 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). From (17), 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 are good (bad) for the domestic firm's profits implying positive (negative) externalities. Using Proposition 2 we have shown

that each country's IPR policy determine the strategic relationship between home and foreign R&D investment levels. In addition, IPR policy over countries determines strategic externalities in this R&D game.

Proposition 5 (Externalities)

There is a positive externality in the R&D game when both countries are loosely enforcing patent protection.

Proof.   By differentiating the domestic firm's profit function with respect the foreign R&D level, one can show the following: $G_{x*} = R_{q*}q^*_{x*} - q\theta c_{x*}$. Plugging (11) into this equation, we can rewrite $G_{x*} = \frac{c_{x*}}{A} [(R_{qq} - \theta R^*_{q*q})R_{q*} - \theta qA]$. Thus we can show that the sign of G_{x*} is positive if $\theta > \dfrac{R_{qq}R_{q*}}{R^*_{q*q}R_{q*} + qA}$.   ∎

Under a weak enforcement regime, the rival firm's R&D outcome is good for a firm's profit implying that the R&D game exhibits positive externalities. What is the difference between strategic relationships and externalities, then? The difference between positive externalities and strategic complementarity is simple: The former refers to interactions between firms at the level of profits, while the latter refers to interactions at the level of strategies. Positive externalities arise if an increase in the foreign R&D raises the domestic firm's profits, while strategic complementarity implies that an increase in the foreign firm's R&D investment increases the marginal profit to the domestic firm's R&D investment. Hence the domestic R&D will be an increasing function of foreign R&D activities. However, it turns out that the critical levels of these two terms are different. Analyzing these critical levels, we find the following relationship:

Proposition 6 (Positive Externalities and Strategic Complementarity)
When the demand for the final good is convex, positive externalities guarantee strategic complementarity.

Proof.   See Appendix B. ∎

It is hard to get intuition on this result because the relationship depends on the demand feature. Assuming the convexity of demand for the final good, we conclude that there is a positive externality in the R&D game so that home and foreign R&D investment levels are strategic complements. However, in case of the linear demand those critical levels are the same at ½, implying positive externalities and strategic complementarity are necessary and sufficient to each other.

D. The Optimal R&D Subsidies

Now let us go back to the optimal R&D subsidy issue. Spencer and Brander (1983) 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 are different. From (24), 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 is dependent 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

⟨Figure III-2⟩ The Optimal R&D Subsidy
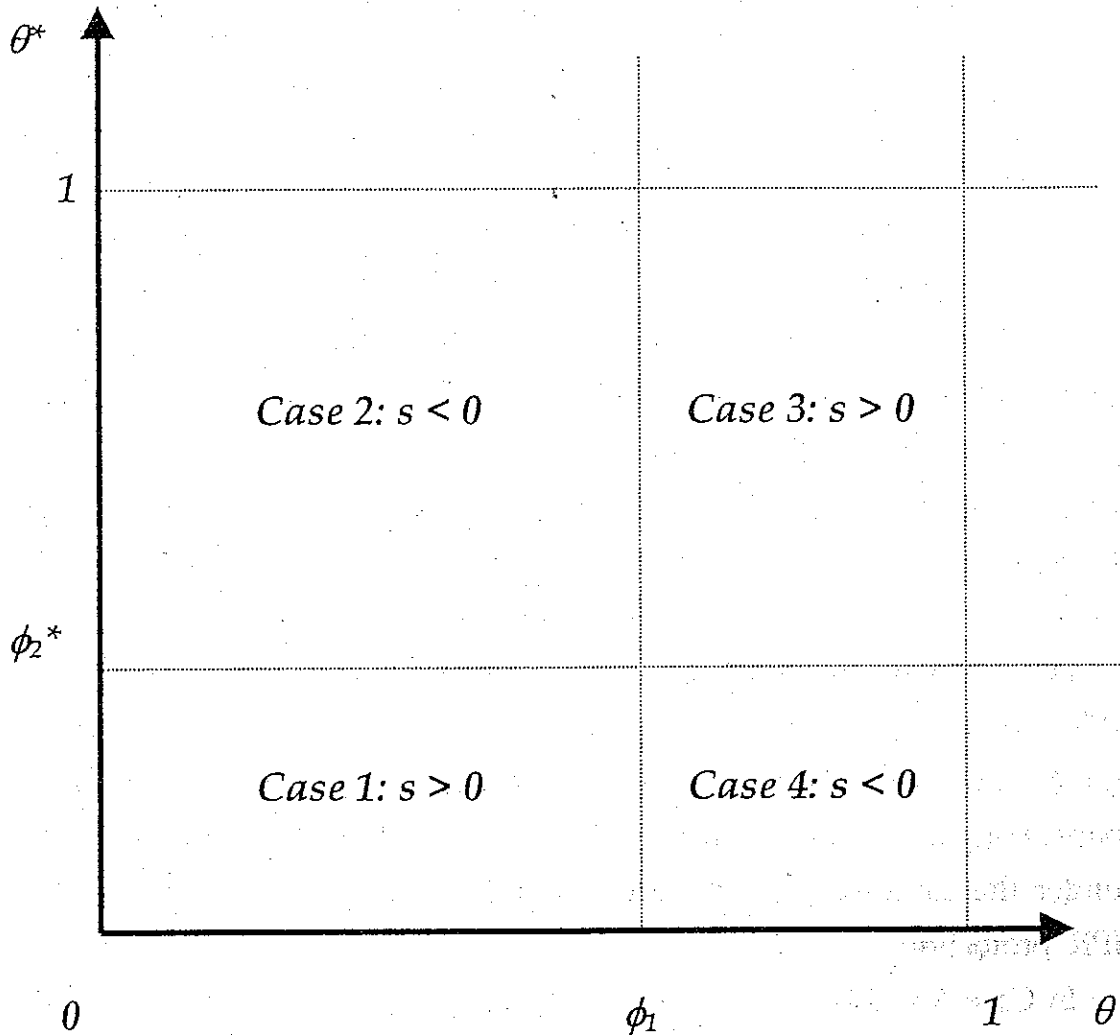
ϕ_1: The critical point of externality in the *home* country
ϕ_2^*: The critical point of strategic relationship in the *foreign* country

the foreign R&D reaction curve. ⟨Figure III-2⟩ shows the signs of the optimal R&D subsidy over both countries' IPRs protection regime.

In Case 1, the result is identical to that of the original Spencer and Brander (1983), and exhibits its well-known features. A firm's profits rise when its rival undertakes smaller amounts of R&D, and so governments seek to reduce the R&D levels of rival firms with their

R&D policies. As a foreign firm's best response to an increase in R&D by a domestic firm is to reduce its own R&D (i.e., R&D reaction curves slope down: $dx^*/dx < 0$), the domestic government will wish to subsidize R&D 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 the *lower* R&D investment of the foreign rival increases the profits of the domestic firm ($G_{z^*} < 0$).

In Case 2 where home country is relatively strongly enforcing IPR protection but foreign country is loosely enforcing, the optimal subsidy is negative, that is, the optimal intervention is to impose a tax. 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 the foreign R&D is still harmful to the domestic firm's profits because the home government is relatively strongly enforcing IPR protection ($G_{z^*} < 0$). By imposing a tax on R&D activities the home government can help its national firm because an R&D subsidy to encourage the 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 from Spencer and Brander (1983). 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. For both patent protection cooperation (Case 1) and R&D investment cooperation (Case 3), the home government has an incentive to subsidize the domestic R&D activities. However, both cases have different reasons. Positive

externalities are a key reason in Case 3, while rivalry matters in Case 1. In Case 1, since R&D reaction curves are negatively sloped, the domestic government will wish to subsidize R&D 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 the *lower* R&D investment of the foreign rival *increases* the profits of the domestic firm. However, in the presence of imperfect IPR protection, 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. However, it is for precisely the opposite reason found in the original SB logic: the domestic government will wish to subsidize its firm's R&D in the presence of weak IPR protection, because 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 the *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 7 (The Optimal R&D Subsidies)
The optimal domestic R&D subsidy is positive (i) if both countries strongly enforce, or (ii) loosely enforce patent protection.

E. The Unique Patent Protection Enforcement

So far, this paper has presented a general model in which both firms are facing two relevant enforcement levels. However, *unique* patent protection enforcement is also possible over countries, including a case in which both countries enforce patent protection by the same level ($\theta = \theta^*$). This paper provides several circumstances in which only one patent protection enforcement level matters in this game:

(i) *Case 3 in Section III–A:* $\theta^I \leq \theta \leq \theta^*$;

(ii) *The symmetric setup;*

(iii) *International agreement for patent protection enforcement (e.g. TRIPS Agreement);*

(iv) *Multinational enterprises with R&D facilities in the same country.*

First, as we have mentioned before, if the third importing country's enforcement level is the strongest, the home and foreign levels are irrelevant. This is because both firms take out a patent only in the third importing country in order to exclude the rival from using their own invention.

Second, both countries choose the unique level of patent protection enforcement if both countries have the symmetric setup: the same revenue and cost functions and the same unit R&D cost. They do choose the unique level because there is no reason for both governments to choose an asymmetric level.

Third, the unique level is also possible if both countries agree to choose the *unique* patent protection enforcement through reciprocal trade agreements such as the TRIPS Agreement. Actually this point is related to one of the leading issues in the trade policy – the debate

over the appropriate method and standard for protection of trade–related intellectual property, or more specifically trade–related patents. The primary forum for this discussion has been the GATT, which is committed to a uniform or non–discriminatory standard for patent protection.[14] A uniform standard is based on the fact that part of the Uruguay Round involved an agreement to improve patent protection

⟨Figure III–3⟩ Non–Monotonic Relationship between the Optimal R&D Subsidy and Unique Patent Protection Level
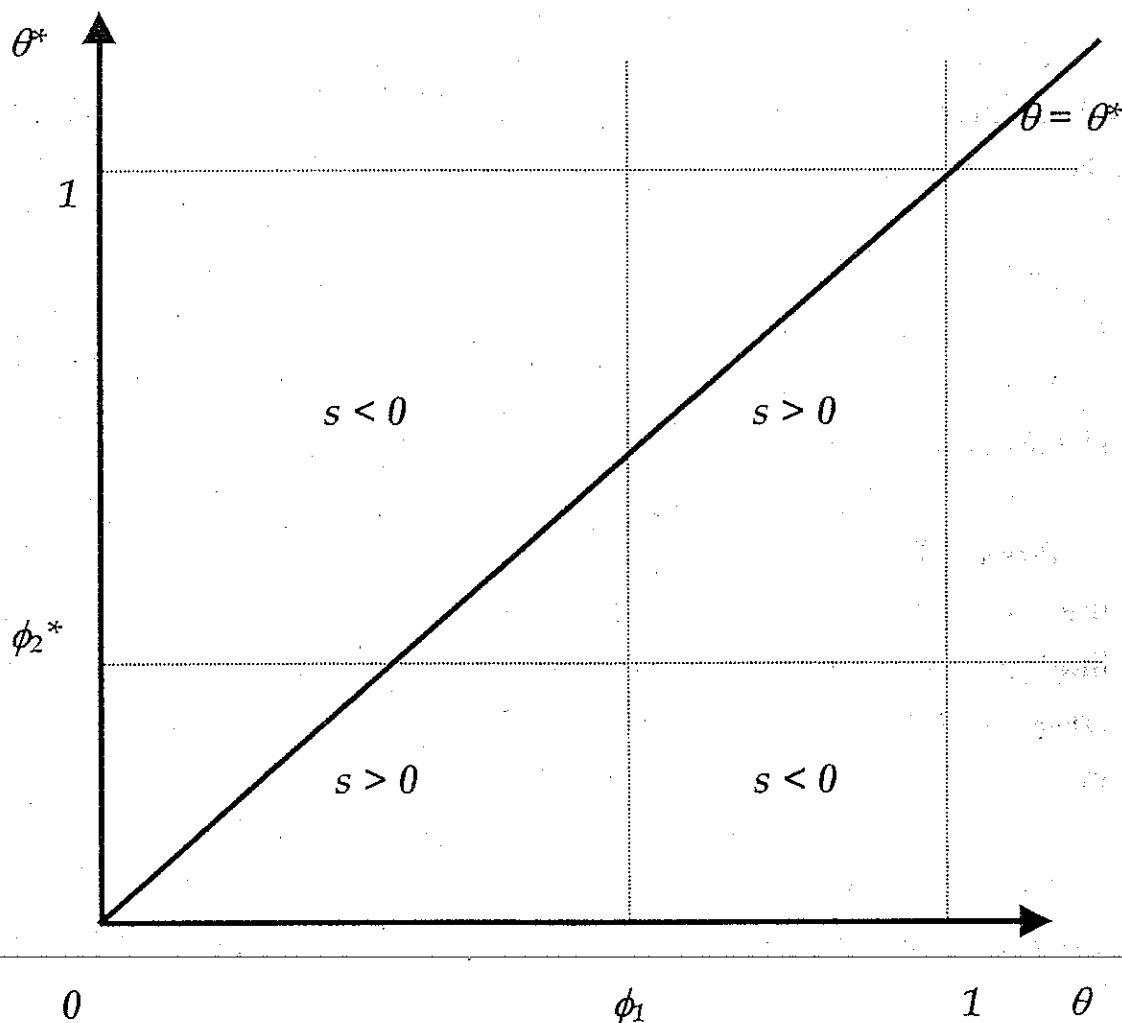
ϕ_1: The critical point of externality in the *home* country
ϕ_2^*: The critical point of strategic relationship in the *foreign* country

in all countries to ensure minimum uniform standards. On the other hand, discriminatory protection is based on Section 337 in U.S. trade law, which provides domestic intellectual property owners additional protection against an infringing product of foreign origin.

Forth, suppose that the domestic and foreign firms are multinational enterprises who have R&D facilities in the third country. For example, Siemens and Toshiba have R&D institutes in Silicon Valley, California. Then the U.S. government provides patent protection. In this case, both firms are facing the unique patent protection enforcement level.

Based on these stories, consider the *unique* patent protection enforcement. Drawing a 45 line on ⟨Figure III-2⟩ as ⟨Figure III-3⟩ shows, one can find the following result:

Proposition 8 (Non-Monotonic Relationship of Unique Enforcement)

There is a non-monotonic relationship between the optimal domestic R&D subsidy and the unique patent protection level.

Proof.   From Proposition 6, the critical point of positive externalities is greater than that of strategic complementarity. Drawing a 45 line on ⟨Figure III-2⟩, one can show that this line passes through 3 areas as ⟨Figure III-3⟩ shows. Thus the optimal subsidy is positive in Cases 1 and 3, but negative in Case 2.   ■

At low or high values of θ, the home government will subsidize the domestic R&D activities. At low values of θ, negative externalities

---

14) See Maskus (1990) and Aoki and Prusa (1993) for an in-depth discussion of GATT negotiations concerning intellectual property protection.

arise and the R&D reaction curves are negatively sloped. Thus the exporting country has an incentive to subsidize its domestic R&D activities because higher domestic R&D reduces foreign R&D which in turn increases domestic profits: $(dx^*/dx < 0)$ and $(G_{z^*} < 0)$. Allowing patent protection to be loosely enforced at mid values of θ, we still have negative externalities, but now home and foreign R&D activities are strategic complements, which implies that R&D reaction curves become positively sloped. Then the home government has an incentive to impose a tax on domestic R&D because higher domestic R&D increases foreign R&D which in turn reduces domestic profits: $(dx^*/dx > 0)$ and $(G_{z^*} < 0)$. At high values of θ, positive externalities arise and R&D reaction curves are upward sloping. Then the optimal intervention goes back to a subsidy mode because higher domestic R&D increases foreign R&D but still increases domestic profits: $(dx^*/dx > 0)$ and $(G_{z^*} > 0)$. In the positive c_{xx^*} case, there is still a non-monotonic relationship between the optimal domestic R&D subsidy and the unique patent protection level. However, the critical point of strategic relationship is greater than that of spillovers: $\phi_2^* > \phi_1$.

F. The Optimal Intervention of Both Countries

Now we consider both countries' intervention in this R&D game, deciding whether to impose a tax or to subsidize their own R&D activities. Both countries simultaneously determine their optimal intervention considering the rival's policy given. From (24), we can identify the signs of the optimal R&D policy given both countries' IPRs protection regime. As ⟨Figure 1-4⟩ shows, the optimal intervention of both countries depends on patent protection levels over both countries, in turn, the signs of substitutability and externalities in both

countries.

〈Figure III-4〉 The Optimal Intervention of Both Countries
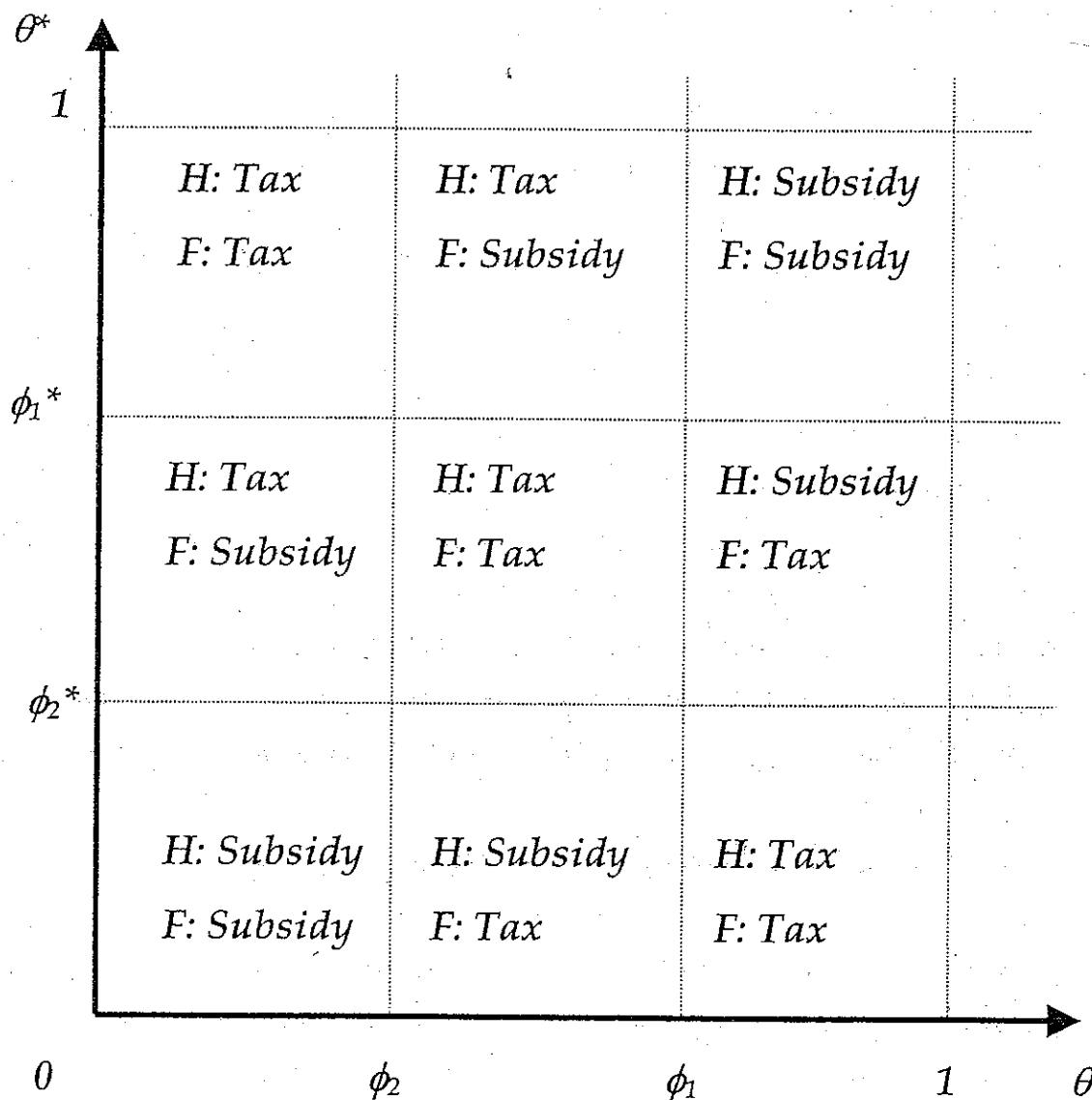
θ^*

1		
H: Tax	H: Tax	H: Subsidy
F: Tax	F: Subsidy	F: Subsidy
ϕ_1^*		
H: Tax	H: Tax	H: Subsidy
F: Subsidy	F: Tax	F: Tax
ϕ_2^*		
H: Subsidy	H: Subsidy	H: Tax
F: Subsidy	F: Tax	F: Tax

0   ϕ_2 ϕ_1 1 θ

ϕ_1: The critical point of externality in the *home* country
ϕ_2: The critical point of strategic relationship in the *home* country
ϕ_1^*: The critical point of externality in the *foreign* country
ϕ_2^*: The critical point of strategic relationship in the *foreign* country

IV. Conclusion

This paper has reconsidered the R&D policy issue, which has been a hot issue since Spencer and Brander (1983). By showing that IPRs protection is related to R&D policy, we have shown how each country's IPRs protection regime affects strategic relationship between R&D activities and the nature of externalities. We can interpret this externality as spillovers. 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 its domestic R&D activities. One is the case of Spencer and Brander (1983), but we have provided another possibility where both countries weakly enforcing 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 patent race process. To acquire a patent, a firm has to win the race, expecting to earn a monopolistic profit stream. However, this consideration is unlikely to provide any further implication on a strategic role of R&D policy. The reason is that a strategic role of R&D policy is determined by the interaction among firms rather than the dynamic process of an R&D patent race. Rather, a limit is on the fact that this study does not consider a worldwide welfare issue. Under the GATT, members can negotiate an optimal patent protection level that maximizes the worldwide welfare including the third consuming country. This level would imply the GATT-type unique patent protection enforcement. Comparing this level with discriminatory protection level based on Section 337 of the US trade

law, we will provide an important extension to this paper. To compare them, we should let governments to 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 cooperative R&D subsidy–tax policy. This extension would give some implications on trade policy instruments – patent protection enforcement, R&D subsidy, and R&D tax.

Additionally, motivated from Maggi (1997) one can consider an asymmetric information problem in which government has no idea of whether the R&D game exhibits *strategic substitutability* or *complementarity* but firms do. This consideration is another logical extension of this paper. However, we leave it for future research.

Appendix A: Proof of Proposition 2

From (14), one can show

$$(A1) \quad G_{xx^*} = \left(R_{q^*q} q_{x^*} + R_{q^*q^*} q^*_{x^*} \right) q^*_x - q_{x^*} c_x .$$

Assuming $R_{q^*q^*} = 0$ and using (10) and (11), we can rewrite (A1) as follows:

$$(A2) \quad G_{xx^*} = \frac{c_x c^*_{x^*}}{A^2} \left(\theta R^*_{q^*q^*} - R_{qq^*} \right) R_{qq^*} \left(\theta * R_{q^*q} - R^*_{q^*q^*} \right)$$

The equation (A2) is positive if $\theta > \dfrac{R_{qq^*}}{R^*_{q^*q^*}}$. Using the similar method,

we can show that $G^*_{x^*x}$ is positive if $\theta^* > \dfrac{R^*_{q^*q}}{R_{qq}}$.

Appendix B: Proof of Proposition 6

Comparing those critical levels of externalities and strategic relationship, we can prove Proposition 6.

$$\text{(B1)} \quad \frac{R_{qq^*}}{R_{qq}} - \frac{R_{qq}R_{q^*}}{R_{q^*q}R_{q^*} + qA} = \frac{-A\left(R_{q^*} - qR_{qq^*}\right)}{R_{qq}\left(R_{q^*}R_{qq^*} + qA\right)}.$$

By checking signs of partial derivatives, we can show:

$$\text{(B2)} \quad sign\left(\frac{R_{qq^*}}{R_{qq}} - \frac{R_{qq}R_{q^*}}{R_{q^*q}R_{q^*} + qA}\right) = sign\left(R_{q^*} - qR_{qq^*}\right) = sign\left(-y^2 \frac{\partial^2 P}{\partial y \partial y^*}\right).$$

When the demand for the final good is convex, the critical level of externalities is greater than that of strategic relationship.

$$\text{(B3)} \quad \frac{R_{qq^*}}{R_{qq}} \leq \frac{R_{qq}R_{q^*}}{R_{q^*q}R_{q^*} + qA}.$$

The equality holds when the demand is linear.

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國文要約

본 논문은 전략적 무역정책을 새로운 시각에서 다시 고찰하였다. R&D보조금에 대한 기존의 연구에서는 기업들이 완전한 지적 재산권을 영위하고 있다고 암묵적으로 가정하고 있다. 그러나, 실제 경제에서는 지적 재산권, 특히 R&D 투자결과에 대한 특허보호가 제대로 이루어지지 않는 실정이다. 일부 개발도상국의 지적 재산권 해적 행위에 의해 R&D 투자기업들이 기술개발에 따른 이익을 완벽하게 영위할 수 없을 뿐만 아니라 정부로부터 보조금을 받은 경우 이 보조금의 혜택이 외국 경쟁기업으로 유입될 가능성까지 존재한다. 본 논문에서는 지적 재산권의 불완전한 보호가 전략적 무역정책으로서의 R&D보조금 정책에 어떠한 영향을 미치는지 분석한다. 또한 각국의 지적 재산권 보호수준이 외생으로 주어졌을 때, 불완전한 지적 재산권 보호가 기업간 전력적 행태와 R&D 게임의 외부성에 어떻게 영향을 미치는지 분석하였다.

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