The WTO's SCM Agreement and R&D Subsidies: A Ricardian Analysis and Evidence from Korea*

Yumi Koh† Gea M. Lee‡

November 30, 2017

Abstract

The WTO's SCM Agreement contained a safe harbor for R&D subsidies from 1995 to 1999, but reclassified R&D subsidies as actionable since 2000. We theoretically analyze the basis for regulating R&D subsidies and empirically assess whether the SCM Agreement has had any impact on government's support for R&D subsidies. We modify and develop a Ricardian trade model in which R&D subsidies can be designed as a strategic policy instrument to bring mutual benefits or beggar-thy-neighbor effects. We find that R&D subsidies targeting a specific and narrow range of goods entail beggar-thy-neighbor effects. Empirical evidence from Korea shows that the government/public sector tends to allocate R&D funds strategically and responds sharply to the new regulation environment imposed by the SCM Agreement.

Keywords: SCM Agreement, R&D subsidies, Welfare, Beggar-thy-neighbor policy.
JEL Classification Numbers: F13, H25, O32.

*This is a preliminary draft. Please do not cite or distribute without permission of the authors. This draft was done while Lee was visiting Stanford Economics Department.

†School of Economics, Singapore Management University, 90 Stamford Road, Singapore 178903 (e-mail: ymkoh@smu.edu.sg).

‡School of Economics, Singapore Management University, 90 Stamford Road, Singapore 178903 (e-mail: gmlee@smu.edu.sg).

1 Introduction

Government support for R&D activities is often considered as a desirable policy instrument to remedy under-production inefficiency. When there is no market or market price that reflects the external value of new knowledge or technology produced by R&D activities, government's support can help fill this under-production gap. A theoretical basis of R&D support, however, entails limitations if it hinges on the externality concept, because the nature of R&D ranges broadly from very basic to practical activities. Indeed, many R&D activities are highly applied and have a specific and practical purpose, which may not necessarily have much externalities but are perhaps crucial in promoting national welfare. Therefore, it is not surprising that governments have often used R&D subsidies as a strategic policy instrument to promote certain technologies and industries, which affects not only domestic markets but also international markets. On the other hand, since R&D activities bring some fundamental benefits such as productivity improvement, it appears difficult to support the argument that the use of R&D subsidies needs to be regulated by certain rules because of the potential welfare loss it could cause to other countries.

In 1995, the Agreement on Subsidies and Countervailing Measures (the SCM Agreement), which is the subsidy rules of the World Trade Organization (WTO), became effective. Originating from the Uruguay Round of the General Agreement on Tariffs and Trade (GATT) negotiations (1986-94), the SCM Agreement set guidelines for regulating subsidies. According to the SCM Agreement, a subsidy is deemed to exist if (i) a "financial contribution" by a government or any public body within the territory of a Member (or any form of income or price support in the sense of Article XVI of GATT) is made; and (ii) a "benefit" is thereby conferred. One peculiar feature of the SCM Agreement that has been commonly overlooked in the analytical literature is the change in regulations for some forms of subsidies, among which includes R&D subsidies. For the first five years of the WTO (1995–99), the SCM Agreement contained a safe harbor available to all the WTO members in the use of R&D subsidies. These were often called "green light" subsidies and treated as non-actionable. In 2000, the exemption expired and they were reclassified under the category of "yellow light" or actionable subsidies.[1]

In this paper, we theoretically analyze the basis for regulating R&D subsidies interna-

[1] A subsidy is actionable if it is subject to challenge either through multilateral dispute settlement or through countervailing action.

tionally and empirically assess whether the SCM Agreement has had any real impact on government support by exploiting regulation changes. A recent trade-agreement literature pays much attention to the SCM agreement and emphasizes the significance of its strict legal provisions. To the best of our knowledge, however, whether the SCM Agreement really constitutes an important regulatory environment for R&D activities in particular has not been addressed. Is there a theoretical justification for the WTO to strengthen regulations for R&D subsidies by placing them under the actionable category? Moreover, is there an empirical evidence that governments took the regulatory environment by the SCM Agreement to be significant enough to change their R&D policies in response to it?

To answer these questions, we first develop a trade model in which R&D subsidies can be designed as a strategic policy instrument to bring mutual benefits or beggar-thy-neighbor effects. For this purpose, we modify the Ricardian model of Dornbusch, Fischer and Samuelson (1977) in which there are a continuum of goods on an interval and two trading countries, Home and Foreign, whose markets are perfectly competitive. We establish two main findings to provide a theoretical justification for the WTO to put R&D subsidies under the actionable category with no further extension of the green light provision. First, we show that R&D subsidies offered generally for all Home produced goods are harmless to Foreign: under some conditions, such subsidies are mutually beneficial, and even when those conditions fail, Home does not use such subsidies to damage the Foreign welfare. Second, we show that R&D subsidies targeting a specific and narrow range of goods entail beggar-thy-neighbor effects. We report this finding in two steps: (i) if such subsidies extend the export boundary (which results in some import goods becoming export goods), then they increase the Home welfare at the expense of the Foreign welfare; and (ii) if Home uses such subsidies, then it opts to extend the export boundary.

In the empirical analysis, we focus on the case of South Korea (Korea) which is a typical example of an open economy that invests heavily in R&D and has a history of government-led economic development. Using data called the "Report on the Survey of Research and Development," we track direct funding of R&D activities by the government/public sector to firms given the institutional changes with respect to R&D subsidies. First, we find that the average government/public expenditure on firms' R&D activities sharply responds to the SCM Agreement, by reaching a peak during the green light period. This hump-shaped trend that coincides with the green light period is only found for government/public R&D support for firms, but not for private funding of firms or funding of research institutes.

Second, data suggests that the Korean government/public sector allocates R&D funds strategically to improve economic performance. Average government/public R&D fund increases with development research share or import share. Third, development research, to which firms devote their R&D resources most and government/public sector is most sensitive, tends to expand the variety of goods that Korea exports.

This paper is related to a few strands of the literature.[2] The SCM Agreement appears to have evolved on the premise that subsidization causes distortions in the world trading system, but the trade-agreement literature holds differing views on the regulation development. The terms-of-trade theory asserts that the SCM Agreement has gone too far. It provides an efficiency rationale for trade agreements to adopt a shallow integration, showing that international efficiency can be achieved by tariff negotiations alone under the GATT-type rules.[3] In contrast, a growing literature provides a rationale for trade agreements to take a deep-integration approach, showing that trade agreements can generate additional benefits of international cooperation by including negotiations on behind-the-border measures. For example, a deep-integration feature increases the value of international cooperation when governments have private information in Bajona and Ederington (2012) and Lee (2016), and it expands the self-enforceable set of policies when a country's current policies can affect its future production possibilities in Sauré (2014). A deep-integration approach corrects domestic distortions arising from the presence of offshoring in Antràs and Staiger (2012a, 2012b), and it eliminates investment distortions resulting from inefficient subsidies present at the time of tariff commitments in Brou and Ruta (2013). In Horn, Maggi and Staiger (2010), subsidies are included in the clauses of trade agreements when trade volume becomes large, whereas governments would otherwise leave subsidies out of contractual considerations to save contracting costs.

This paper is also related to the trade-agreement literature that offers a rationale for restrictions on export subsidies. A recent literature, using imperfect competition models, examines whether and how restrictions on export subsidies can prevent unilateral policy choices from causing the cross-border effects on consumer or producer surplus.[4] In our

[2]For a more comprehensive survey of a recent trade-agreement literature on the SCM Agreement, see Lee (2016).

[3]The general themes of the terms-of-trade theory are broadly found in Bagwell and Staiger (1999, 2001, 2002, 2006, 2016) among many others.

[4]The regulation on export subsidies is puzzling from the terms-of-trade perspective, because given its trade-promoting nature, a country's export subsidy creates a positive terms-of-trade externality on its trading partners. The literature thus adopts the imperfect competition models that contain other

theoretical analysis, we use the Ricardian perfect competition setting, and for the analysis of R&D subsidies targeting a specific range of goods, we refer to the work of Itoh and Kiyono (1987) which focuses primarily on the effects of ad valorem export subsidies on the home country's welfare. Despite a widespread recognition of restrictions on subsidies, none of the existing papers listed here have called attention to the questions we address in this paper.

The remainder of this paper is organized as follows. The next section describes the institutional background of the SCM Agreement, especially with a focus on change of rules for R&D subsidies. Section 3 discusses the theoretical model. Section 4 contains the description of the data set. Section 5 discusses the empirical analysis and Section 6 concludes. Remaining proofs are found in the Appendices.

2 Background on the SCM Agreement

In this section, we briefly summarize the SCM Agreement and some regulatory backgrounds on R&D subsidies.[5] The SCM Agreement has established the definition of the term "subsidy" as mentioned earlier. It also classifies subsidies into two categories, prohibited and actionable subsidies: (i) export subsidies and local-content subsidies (which are offered for the use of domestic over imported goods) are prohibited, except as provided in the Agreement on Agriculture; and (ii) subsidies are "actionable" if they are "specific" and cause "adverse effects" to the interests of another Member. Notice that specificity is an important criteria in regulating subsidies. A subsidy is deemed to be specific if it is limited to certain enterprise or industry or group of enterprises or industries. As for adverse effects, there are three types: (i) "injury" to a domestic industry is caused by subsidized imports in the territory of the complaining member, and it is the basis for a countervailing duty; (ii) "serious prejudice" arises when a subsidy offered by a Member causes a loss of exports by another Member in the subsidizing-country market or in a third-country market; and (iii) "nullification or impairment" of the benefits expected by another Member occurs when subsidization undercuts the market access reasonably

types of cross-border externalities such as firm-delocation and profit-shifting externalities. The related literature includes Bagwell and Lee (2015), Bagwell and Staiger (2012a, 2012b, 2015), DeRemer (2013), Mrazova (2011), Ossa (2011) and Venables (1985, 1987).

[5]Coppens (2014) and Jackson (2000) offer a historical and legal background of the GATT/WTO subsidy rules in greater detail.

expected from a bound tariff reduction.[6]

In Article 8, the SCM Agreement identified the following forms of subsidies as green light (non-actionable): (i) R&D subsidies for research activities conducted by firms or by higher education or research establishments on a contract basis with firms; (ii) regional support for disadvantaged regions within the territory of a WTO member; and (iii) environmental subsidies for easing firms' compliance with new environmental requirements in their existing facilities. However, Article 31 stipulated that Article 8 would be a provisional application for the first five years, and that the Committee would review before the end of the period for a possible extension or modification. Article 8.3 of the SCM Agreement required that any subsidy program that a WTO member believed was non-actionable should be notified in advance of its implementation to the SCM Committee. The WTO Secretariat was then to review the notification, and the SCM Committee would determine whether the notified program qualified for green light status. Interestingly, during the five years in which the category of green light subsidies was in effect, none of the WTO members notified the SCM Committee of a non-actionable subsidy pursuant to Article 8.3. The SCM Committee did attempt to address issues of Article 8 such as notification and arbitration procedures, but there was no notification during the five-year period.

As the SCM Committee did not choose to extend the green light status, Article 8 finally expired on January 1st, 2000. Since then, these three forms of subsidies including R&D subsidies have been placed under the category of yellow light (actionable) subsidies. Despite the institutional changes, it may seem at a glance that there has been not much actions in response to these changes. There were no procedural actions such as notification or arbitration during the green light period, or official attempts at the Committee level to extend the green light status. However, whether it had any real impact on the government/public R&D funds in the economy is a different issue, which requires an empirical investigation. Also, note that a seeming underutilization of rules does not mean that they are unimportant. For example, Staiger and Sykes (2017) highlight that the paucity of GATT/WTO rulings on non-violation claims and their limited success do not undermine the importance of the rule. They show that the non-violation clause plays a

[6]Serious prejudice is a new ingredient that was not present in the GATT rules, while the other two adverse effects broadly correspond to the circumstances under which a countervailing duty and a non-violation complaint are used under the GATT rules.

minimal on-equilibrium-path role whereas it plays an important off-equilibrium-path role.

3 A Ricardian Analysis of R&D Subsidies

In this section, we offer some theoretical insights using the Ricardian trade model of Dornbusch, Fischer and Samuelson (1977). In the model, there are a continuum of goods indexed by $z \in [0,1]$ and two trading countries, Home and Foreign, in which markets are all perfectly competitive. Home and Foreign have one factor of production with wages, w and w^*, and endowments, L and L^*, respectively. Under the assumption of constant returns to scale, technologies of Home and Foreign are captured by the constant unit labor requirements for good z, $a(z)$ and $a^*(z)$. It is also assumed that goods may be ordered such that $\frac{a^*(z)}{a(z)}$ is continuous and strictly decreasing in z. Home (Foreign) has a comparative advantage in goods with lower (higher) z.

3.1 Trade Equilibrium

We characterize trade equilibrium of the Ricardian model by looking at production and demand aspects under the assumption that tariffs are fixed at zero. We begin by characterizing the production side. In Home, the unit production cost of good z equals $wa(z)$. We introduce a unilateral R&D policy in the model: Home offers the R&D subsidy, $s(z)wa(z)$, for the Home production of good z, where subsidy rate $s(z) \in (0,1)$ is the government's policy instrument. This policy has the purpose of improving the productivity of good z. We thus include a parameter, $\gamma(z) > 0$, to take account of the productivity effect of the given policy $s(z)$: the R&D subsidy for good z reduces the unit production cost of good z by $s(z)\gamma(z)wa(z)$. If $\gamma(z)$ is close to zero, then the R&D subsidy is mostly wasted and does little to improve the productivity of good z, and if $\gamma(z)$ is larger, then the R&D subsidy is more effective to increase the productivity. We henceforth focus on $s(z)\gamma(z) < 1$ for all z, and assume that $\frac{1}{1-s(z)\gamma(z)}\frac{a^*(z)}{a(z)}$ is nonincreasing in z. This assumption ensures that the interval $[0,1]$ divides into two connected non-empty sets: there exists $(\widehat{z}, \frac{w}{w^*})$ such that marginal cost for $z \in [0,\widehat{z}]$ is smaller in Home and marginal cost for $z \in (\widehat{z},1]$ is strictly smaller in Foreign,

$$\frac{w}{w^*} \leq \frac{1}{1-s(z)\gamma(z)}\frac{a^*(z)}{a(z)} \text{ for } z \in [0,\widehat{z}] \text{ and } \frac{w}{w^*} > \frac{a^*(z)}{a(z)} \text{ for } z \in (\widehat{z},1]. \tag{1}$$

Thus, under the government's R&D support for Home produced goods $z \in [0, \widehat{z}]$, the production side of the model entails a jump at the Home export boundary $\widehat{z}$: the function $\frac{a^*(z)}{a(z)}$ is continuous and strictly decreasing for $z \in (\widehat{z}, 1]$ and shifts up to $\frac{1}{1-s(z)\gamma(z)}\frac{a^*(z)}{a(z)}$ for $z \in [0, \widehat{z}]$.

We next analyze the demand side to pin down the relative wage $\frac{w}{w^*}$ and the export boundary $\widehat{z}$. All consumers in Home and Foreign have identical Cobb-Douglas preferences. The Home and Foreign welfare functions may thus be represented by

$$\int_0^1 b(z) \ln c(z) dz \text{ and } \int_0^1 b^*(z) \ln c^*(z) dz.$$

We assume that $\int_0^1 b(z)dz = \int_0^1 b^*(z)dz = 1$, and use $b(z) \in (0,1)$ and $b^*(z) \in (0,1)$ to denote the shares of expenditure on good z in Home and Foreign, respectively. Using the Home consumer problem,

$$\max_{c(z)} \int_0^1 b(z) \ln c(z) dz \text{ subject to } \int_0^1 p(z)c(z)dz \leq y,$$

we can substitute the Home consumer's choice and the marginal-cost pricing,

$$c(z) = b(z)\frac{y}{p(z)} \text{ and } p(z) = \begin{cases} w[1 - s(z)\gamma(z)]a(z) & \text{for } z \leq \widehat{z} \\ w^* a^*(z) & \text{for } z > \widehat{z}, \end{cases}$$

and obtain the Home welfare function

$$v = B - \int_0^{\widehat{z}} b(z) \ln w[1 - s(z)\gamma(z)]a(z)dz - \int_{\widehat{z}}^1 b(z) \ln w^* a^*(z) dz + \ln y,$$

where $B \equiv \int_0^1 b(z) \ln b(z) dz$. We can analogously use the Foreign consumer's choice, $c^*(z) = b^*(z)\frac{y^*}{p^*(z)}$, and the marginal-cost pricing to derive the Foreign welfare function:

$$v^* = B^* - \int_0^{\widehat{z}} b^*(z) \ln w[1 - s(z)\gamma(z)]a(z)dz - \int_{\widehat{z}}^1 b^*(z) \ln w^* a^*(z) dz + \ln y^*,$$

where $B^* \equiv \int_0^1 b^*(z) \ln b^*(z) dz$. We now report two additional requirements that trade equilibrium must satisfy. First, the trade balance requires that Home imports and Home

exports should be the same:

$$\int_{\widehat{z}}^{1} b(z)dz \cdot (1-\rho)wL = \int_{0}^{\widehat{z}} b^*(z)dz \cdot w^*L^*, \tag{2}$$

where $(1-\rho)wL = y$ and $w^*L^* = y^*$. Second, the government budget balance requires that the Home subsidies should be financed by part of its labor income:

$$\int_{0}^{\widehat{z}} s(z)wa(z)dz = \rho wL, \text{ or equivalently } \rho = \frac{\int_{0}^{\widehat{z}} s(z)a(z)dz}{L}. \tag{3}$$

We may thus derive the demand-side equation that satisfies those two conditions:

$$\frac{w}{w^*} = \frac{L^*}{(1-\rho)L}\frac{\int_{0}^{\widehat{z}} b^*(z)dz}{\int_{\widehat{z}}^{1} b(z)dz} = \frac{L^*}{L - \int_{0}^{\widehat{z}} s(z)a(z)dz}\frac{\int_{0}^{\widehat{z}} b^*(z)dz}{\int_{\widehat{z}}^{1} b(z)dz}. \tag{4}$$

Therefore, the demand side of the model is represented by a strictly increasing function on the space of $(\widehat{z}, \frac{w}{w^*})$ since the RHS of (4) strictly increases when $\widehat{z}$ rises.

Finally, we define trade equilibrium as the combination of $(\widehat{z}, \frac{w}{w^*})$ that satisfies the production and demand requirements, (1) and (4), at the same time. Once the export boundary $\widehat{z}$ is determined, the relative income $\frac{y}{y^*}$ is given by

$$\frac{y}{y^*} = \frac{\int_{0}^{\widehat{z}} b^*(z)dz}{\int_{\widehat{z}}^{1} b(z)dz}. \tag{5}$$

The RHS of (5) is strictly increasing in $\widehat{z}$: an increase in the export boundary $\widehat{z}$ causes a trade surplus to Home, and this trade surplus is balanced when a higher $\frac{y}{y^*}$ allows Home consumers to purchase more Foreign produced goods. For welfare analysis, we write the Home welfare function under R&D subsidies in terms of endogenous variables and parameters:

$$\begin{aligned} v = B + \ln(\frac{y}{y^*}) + \ln L^* - \ln(\frac{w}{w^*}) \int_{0}^{\widehat{z}} b(z)dz \\ - \int_{0}^{\widehat{z}} b(z)\ln[1 - s(z)\gamma(z)]a(z)dz - \int_{\widehat{z}}^{1} b(z)\ln a^*(z)dz. \end{aligned} \tag{6}$$

Similarly, we may write the Foreign welfare function under R&D subsidies:[7]

$$v^* = B^* + \ln L^* - \ln(\frac{w}{w^*}) \int_0^{\widehat{z}} b^*(z)dz \tag{7}$$
$$- \int_0^{\widehat{z}} b^*(z) \ln[1 - s(z)\gamma(z)]a(z)dz - \int_{\widehat{z}}^1 b^*(z) \ln a^*(z)dz.$$

3.2 Mutually Beneficial Subsidies

We now proceed to analyze the welfare effect of R&D subsidies. For this purpose, we characterize the original free-trade equilibrium that would exist under no subsidies, $s(z) = 0$ for all z. The original $\widehat{z}_0$ and $(\frac{w}{w^*})_0$ are determined by the intersection of the strictly decreasing function in (1) and the strictly increasing function in (4),

$$(\frac{w}{w^*})_0 = \frac{a^*(\widehat{z}_0)}{a(\widehat{z}_0)} = \frac{L^*}{L} \frac{\int_0^{\widehat{z}_0} b^*(z)dz}{\int_{\widehat{z}_0}^1 b(z)dz}.$$

By setting $\widehat{z} = \widehat{z}_0$ in (5), we also obtain

$$(\frac{y}{y^*})_0 = \frac{\int_0^{\widehat{z}_0} b^*(z)dz}{\int_{\widehat{z}_0}^1 b(z)dz}. \tag{8}$$

In this and next subsection, we consider two contrasting policies: (i) R&D subsidies offered for all Home produced goods; and (ii) R&D subsidies offered only for a specific range of Home produced goods. To analyze the policy option (i), suppose that Home offers R&D subsidies for all Home produced goods, $s(z) > 0$ for all $z \in [0, \widehat{z}_0]$. The production-side curve then has a jump at the original export boundary $\widehat{z}_0$ since the RHS of (1) shifts up only on the interval $[0, \widehat{z}_0]$, while the demand-side curve shifts up on the entire interval $[0, 1]$. We assume further that the subsidy at the export boundary, $s(\widehat{z}_0)$,

[7] We express v^* in the form of (7) since it simplifies our welfare analyses presented below. In fact, the Foreign welfare may be rewritten to include the term $\ln(\frac{y}{y^*})$ since the first three terms on the RHS of (7) equal

$$B^* - \ln(\frac{y}{y^*}) + \ln(1-\rho) + \ln L + \ln(\frac{w}{w^*}) \int_{\widehat{z}}^1 b^*(z)dz,$$

and in this case, the Foreign welfare function includes the negative term $\ln(1-\rho)$ to reflect the effects of R&D costs born by Home on the Foreign welfare.

satisfies

$$\frac{1}{1-s(\widehat{z}_0)\gamma(\widehat{z}_0)}\frac{a^*(\widehat{z}_0)}{a(\widehat{z}_0)} \geq \frac{L^*}{(1-\rho)L}\frac{\int_0^{\widehat{z}_0} b^*(z)dz}{\int_{\widehat{z}_0}^1 b(z)dz}, \tag{9}$$

where $\rho = \frac{1}{L}\int_0^{\widehat{z}_0} s(z)a(z)dz$. The inequality (9) implies that the production-side curve shifts more than the demand-side curve at $\widehat{z}_0$, and thus the original export boundary $\widehat{z}_0$ is kept intact. Given $s(z) > 0$ for all $z \in [0, \widehat{z}_0]$, the inequality (9) always holds if $\gamma(\widehat{z}_0)$ is sufficiently large, or L is sufficiently large. The subsidies result in a new equilibrium with $\widehat{z}$, $\frac{y}{y^*}$ and $\frac{w}{w^*}$. In comparison with the original equilibrium, $\widehat{z} = \widehat{z}_0$ and $\frac{y}{y^*} = (\frac{y}{y^*})_0$, while the new relative wage equals the RHS of (9),

$$\frac{w}{w^*} = \frac{L^*}{(1-\rho)L}\frac{\int_0^{\widehat{z}_0} b^*(z)dz}{\int_{\widehat{z}_0}^1 b(z)dz},$$

and thus $\frac{w}{w^*} > (\frac{w}{w^*})_0$.[8] Fig. 1 illustrates an example of R&D subsidies that corresponds to this scenario.

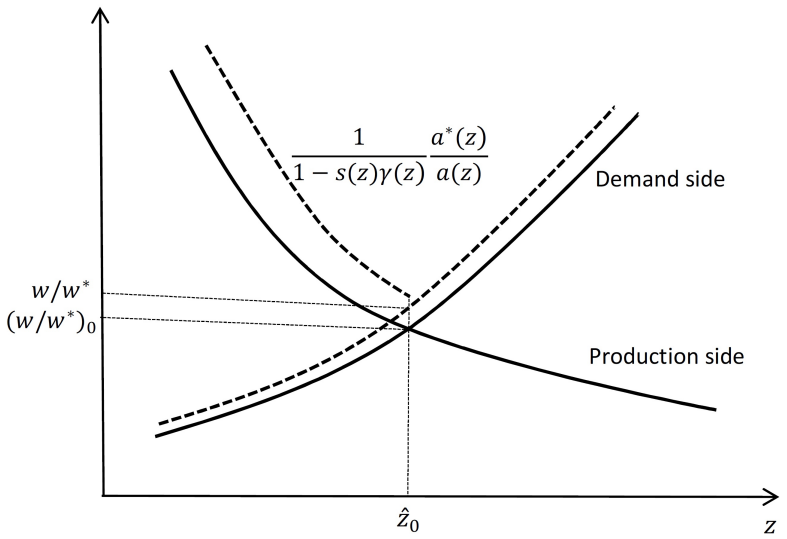


Figure 1: An Example of Mutually Beneficial Subsidies.

[8]We can show that the relative wage $\frac{w}{w^*}$ must be the RHS of (9) in the new equilibrium. If $\frac{w}{w^*}$ is above the RHS of (9), then the trade balance condition is satisfied at a point $\widehat{z}' > \widehat{z}_0$ and at this point, the production condition in (1) is satisfied at $(\frac{w}{w^*})' < \frac{w}{w^*}$. If $\frac{w}{w^*}$ is below the RHS of (9), then the trade balance condition is satisfied at a point $\widehat{z}' < \widehat{z}_0$ and at this point, the production condition in (1) is satisfied at $(\frac{w}{w^*})' > \frac{w}{w^*}$.

We next compare the Home welfare (6) to the original welfare v_0, and find that

$$v - v_0 = \left[\ln(\frac{w}{w^*})_0 - \ln(\frac{w}{w^*})\right] \int_0^{\widehat{z}_0} b(z)dz - \int_0^{\widehat{z}_0} b(z) \ln[1 - s(z)\gamma(z)]dz. \tag{10}$$

Home continues to produces goods $z \in [0, \widehat{z}_0]$, but with a higher relative wage, $\frac{w}{w^*} > (\frac{w}{w^*})_0$, which causes welfare loss to Home as the first term in (10) shows. The second term in (10) is strictly positive and captures the welfare improvement that accompanies the productivity effects on goods $z \in [0, \widehat{z}_0]$,

$$-\int_0^{\widehat{z}_0} b(z) \ln[1 - s(z)\gamma(z)]dz = \int_0^{\widehat{z}_0} b(z) \left[\ln \frac{a^*(z)}{[1 - s(z)\gamma(z)]a(z)} - \ln \frac{a^*(z)}{a(z)}\right] dz > 0.$$

Thus, given $s(z) > 0$ for all $z \in [0, \widehat{z}_0]$, if $\gamma(z)$ is sufficiently large for $z \in [0, \widehat{z}_0]$, or L is sufficiently large, then the second term in (10) dominates and thus the Home welfare strictly increases, $v > v_0$. For the condition on L, observe that if L is sufficiently large, then the first term in (10) approaches zero since the term,

$$\ln(\frac{w}{w^*})_0 - \ln(\frac{w}{w^*}) = \ln(1 - \rho) = \ln(1 - \frac{\int_0^{\widehat{z}} s(z)a(z)dz}{L}),$$

approaches zero. Similarly, given the same Home subsidies, we can compare the Foreign welfare (7) to the original welfare v_0^*, and find that

$$\begin{aligned} v^* - v_0^* = &\left[\ln(\frac{w}{w^*})_0 - \ln(\frac{w}{w^*})\right] \int_0^{\widehat{z}_0} b^*(z)dz \\ &+ \int_0^{\widehat{z}_0} b^*(z) \left[\ln \frac{a^*(z)}{[1 - s(z)\gamma(z)]a(z)} - \ln \frac{a^*(z)}{a(z)}\right] dz. \end{aligned} \tag{11}$$

Thus, given $s(z)$ for all $z \in [0, \widehat{z}_0]$, if $\gamma(z)$ is sufficiently large for $z \in [0, \widehat{z}]$, or L is sufficiently large, then the Foreign welfare strictly increases as well, $v^* > v_0^*$.

Proposition 1. *Suppose that Home offers R&D subsidies for all Home produced goods, $s(z) > 0$ for all $z \in [0, \widehat{z}_0]$. If $\gamma(z)$ is sufficiently large for $z \in [0, \widehat{z}_0]$, or L is sufficiently large, then welfare strictly increases in Home and Foreign.*

Proposition 1 shows that R&D subsidies offered generally for all Home produced goods are "good subsidies" under some conditions: such subsidies are mutually beneficial if their

productivity effects are sufficiently large, or R&D costs of Home relative to its labor income are sufficiently small.

3.3 Beggar-Thy-Neighbor Subsidies

Our next question is whether R&D subsidies offered generally for all Home produced goods can be used as beggar-thy-neighbor policies. To answer this question simply, we assume that Home and Foreign consumers have the same preferences, $b(z) = b^*(z)$, for all Home produced goods $z \in [0, z_0]$.

We may consider two possible scenarios. Suppose first that the inequality (9) continues to hold and thus the original export boundary $\widehat{z}_0$ remains intact. We can then use previous analyses immediately and establish that Home and Foreign experience the same welfare effects, $v - v_0 = v^* - v_0^*$, regardless of the sign of $v - v_0$. Suppose next that the inequality (9) is violated, and the export boundary cannot stay at the original level. In comparison with the original equilibrium, the new equilibrium then satisfies $\widehat{z} < \widehat{z}_0$, $\frac{y}{y^*} < (\frac{y}{y^*})_0$ and $\frac{w}{w^*} > (\frac{w}{w^*})_0$. We can compare the Home welfare (6) to v_0 and find that

$$\begin{aligned} v - v_0 = &\left[\ln(\frac{y}{y^*}) - \ln(\frac{y}{y^*})_0\right] + \int_{\widehat{z}}^{\widehat{z}_0} b(z) \left[\ln(\frac{w}{w^*})_0 - \ln \frac{a^*(z)}{a(z)}\right] dz \\ &+ \left[\ln(\frac{w}{w^*})_0 - \ln(\frac{w}{w^*})\right] \int_0^{\widehat{z}} b(z)dz - \int_0^{\widehat{z}} b(z) \ln[1 - s(z)\gamma(z)]dz. \end{aligned} \tag{12}$$

Note that the sign of $v - v_0$ is not clear. The first term on the RHS of (12) is negative since Home has a lower $\frac{y}{y^*}$. The second term represents the welfare loss that Home experiences when production of $z \in [\widehat{z}, \widehat{z}_0]$ is taken over by Foreign even when Home productivity relative to Foreign productivity is above the original level, $\frac{a^*(z)}{a(z)} > (\frac{w}{w^*})_0 = \frac{a^*(\widehat{z}_0)}{a(\widehat{z}_0)}$, for those goods $z \in [\widehat{z}, \widehat{z}_0]$. The remaining terms are similarly shown in (10). We can also compare the Foreign welfare (7) to v_0^* and find that

$$\begin{aligned} v^* - v_0^* = &\int_{\widehat{z}}^{\widehat{z}_0} b^*(z) \left[\ln(\frac{w}{w^*})_0 - \ln \frac{a^*(z)}{a(z)}\right] dz + \left[\ln(\frac{w}{w^*})_0 - \ln(\frac{w}{w^*})\right] \int_0^{\widehat{z}} b^*(z)dz \\ &+ \int_0^{\widehat{z}} b^*(z) \ln[1 - s(z)\gamma(z)]dz. \end{aligned} \tag{13}$$

Note again that the sign of $v^* - v_0^*$ is not clear. The comparison between (12) and (13) shows that the Home welfare contains the additional welfare-loss term when the export

boundary falls, $\widehat{z} < \widehat{z}_0$. Thus, if $b(z) = b^*(z)$ for all $z \in [0, z_0]$, then $v - v_0 < v^* - v_0^*$.

To summarize, regardless of whether the inequality (9) is satisfied or violated, we can report the following result.

Proposition 2. *Suppose that Home offers R&D subsidies for all Home produced goods,* $s(z) > 0$ *for all* $z \in [0, \widehat{z}_0]$. *If* $b(z) = b^*(z)$ *for all* $z \in [0, z_0]$, *then* $v - v_0 \leq v^* - v_0^*$.

Proposition 2 implies that it is unlikely that R&D subsidies offered generally for all Home produced goods can be classified as "bad subsidies" even when the conditions in Proposition 1 fail. In other words, it appears unreasonable to expect that Home develops such subsidies to damage the Foreign welfare: if Foreign suffers welfare loss, $v^* - v_0^* < 0$, then Home suffers more, and if Home achieves welfare gain, $v - v_0 > 0$, then Foreign achieves more.

We next consider the other policy option: (ii) R&D subsidies offered only for a specific range of Home produced goods. Itoh and Kiyono (1987) use ad valorem export subsidies and show that the Home can increase its own welfare if its export subsidies are offered for a specific range of export goods to expand the export boundary. In line of their work, we examine whether R&D subsidies offered for a specific range of goods can become beggar-thy-neighbor policies. Formally, we define the government's subsidy policy as

$$s(z) = \begin{cases} \dfrac{w/w^* - a^*(z)/a(z)}{[w/w^*]\gamma(z)} & \text{for } z \in [\widehat{z}_1, \widehat{z}] \\ 0 & \text{for } z \notin [\widehat{z}_1, \widehat{z}]. \end{cases} \tag{14}$$

Under the subsidy policy (14), the marginal-cost pricing in Home becomes

$$p(z) = \begin{cases} wa(z) & \text{for } z < \widehat{z}_1 \\ w[1 - s(z)\gamma(z)]a(z) & \text{for } z \in [\widehat{z}_1, \widehat{z}] \\ w^* a^*(z) & \text{for } z > \widehat{z}. \end{cases} \tag{15}$$

The subsidy policy (14) is designed such that the endpoint $\widehat{z}_1$ and the relative wage $\frac{w}{w^*}$ in (14) are selected from a point on the production-side curve under no subsidies,

$$\frac{w}{w^*} = \frac{a^*(\widehat{z}_1)}{a(\widehat{z}_1)}, \tag{16}$$

and this relative wage $\frac{w}{w^*}$ in (16) is kept constant on the subsidy interval $[\widehat{z}_1, \widehat{z}]$. The

consequent horizontal line segment then becomes the new production-side curve on $[\widehat{z}_1, \widehat{z}]$, and the endpoint $\widehat{z}$ is the new equilibrium boundary: plugging (14) into the demand-side equation, we can have

$$\frac{w}{w^*} = \frac{L^*}{L - \int_{\widehat{z}_1}^{\widehat{z}} \left(\frac{w/w^* - a^*(z)/a(z)}{[w/w^*]\gamma(z)} \right) a(z)dz} \frac{\int_0^{\widehat{z}} b^*(z)dz}{\int_{\widehat{z}}^1 b(z)dz}, \tag{17}$$

and identify the equilibrium boundary $\widehat{z}$.[9] Fig. 2 depicts the subsidy policy (14).

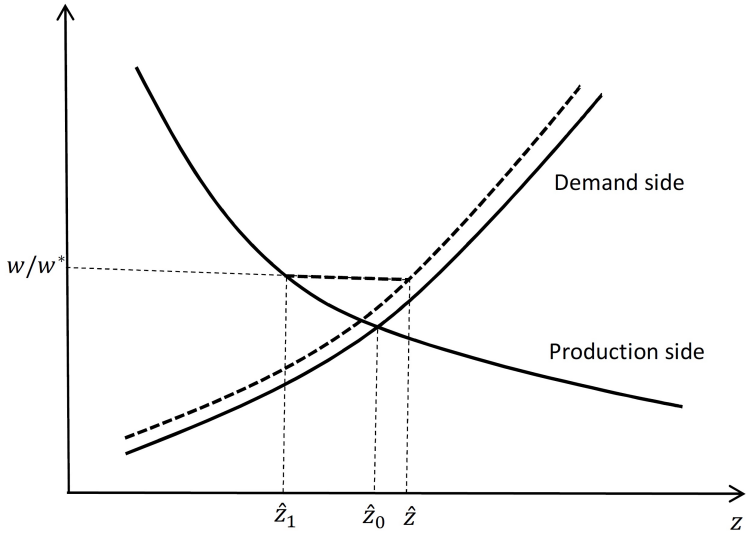


Figure 2: An Illustration of the Subsidy Policy in (14).

We now report that R&D subsidies offered for a specific range of goods can become beggar-thy-neighbor policies: Home can use such subsidies to increase its welfare at the expense of the Foreign welfare.

Proposition 3. *Suppose that Home offers R&D subsidies in (14), where the new export boundary $\widehat{z}$ is above $\widehat{z}_0$. If the subsidy interval $[\widehat{z}_1, \widehat{z}]$ is sufficiently small, the Home welfare*

[9]Under the subsidy policy (14), the endpoint $\widehat{z}_1$ must be below $\widehat{z}_0$, $\widehat{z}_1 < \widehat{z}_0$, for the new equilibrium boundary $\widehat{z}$ to be above the original level $\widehat{z}_0$; if $\widehat{z}_1 \geq \widehat{z}_0$, then the original equilibrium with $\widehat{z}_0$ and $(\frac{w}{w^*})_0$ remains unaffected. Thus, if $\widehat{z} > \widehat{z}_0$, then $\widehat{z}_1 < \widehat{z}_0$ must follow. A challenge is that the inequality $\widehat{z} > \widehat{z}_0$ cannot be arbitrarily assumed since the demand-side curve shifts up with the subsidy policy. In the Appendix, the proof of Proposition 3 shows that the subsidy policy (14) contains the relationship between the level of $\frac{w}{w^*}$ and the interval $[\widehat{z}_1, \widehat{z}]$: if the interval $[\widehat{z}_1, \widehat{z}]$ is sufficiently small, then a small increase in $\widehat{z}$ above $\widehat{z}_0$ decreases $\widehat{z}_1$ from $\widehat{z}_0$ and increases $\frac{w}{w^*}$ from $(\frac{w}{w^*})_0$. Thus, it is always possible to develop the subsidy interval $[\widehat{z}_1, \widehat{z}]$ such that $\widehat{z}_1 < \widehat{z}_0 < \widehat{z}$ if the interval is sufficiently small.

strictly increases. Moreover, for any subsidy interval $[\widehat{z}_1, \widehat{z}]$ *and for any* $\gamma(z)$*, the Foreign welfare strictly decreases.*

We first consider the second result and show that R&D subsidies in (14) decrease the Foreign welfare. To gain some insights, we rewrite the marginal-cost pricing for subsidized goods $z \in [\widehat{z}_1, \widehat{z}]$ as

$$w[1 - s(z)\gamma(z)]a(z) = w\left[1 - \left(\frac{w/w^* - a^*(z)/a(z)}{[w/w^*]\gamma(z)}\right)\gamma(z)\right]a(z) = w^* a^*(z). \tag{18}$$

Thus, under the subsidy policy (14), Home sells subsidized goods $z \in [\widehat{z}_1, \widehat{z}]$ at the prices $w^* a^*(z)$ that Foreign would charge if it produced those goods. In the equilibrium with $\widehat{z}$ and $\frac{w}{w^*}$, the Foreign welfare can be written in terms of $\widehat{z}_1$,

$$v^* = B^* + \ln L^* - \ln(\frac{w}{w^*}) \int_0^{\widehat{z}_1} b^*(z)dz - \int_0^{\widehat{z}_1} b^*(z) \ln a(z)dz - \int_{\widehat{z}_1}^1 b^*(z) \ln a^*(z)dz.$$

In comparison with the original welfare v_0^*, we find that the subsidy policy (14) causes welfare loss to Foreign,

$$v^* - v_0^* = \left[\ln(\frac{w}{w^*})_0 - \ln(\frac{w}{w^*})\right] \int_0^{\widehat{z}_1} b^*(z)dz + \int_{\widehat{z}_1}^{\widehat{z}_0} b^*(z) \left[\ln(\frac{w}{w^*})_0 - \ln \frac{a^*(z)}{a(z)}\right] dz < 0, \tag{19}$$

for any interval $[\widehat{z}_1, \widehat{z}]$ and for any $\gamma(z)$ for $z \in [\widehat{z}_1, \widehat{z}]$. Home continues to produce non-subsidized goods $z \in [0, \widehat{z}_1]$, but with a higher relative wage, $\frac{w}{w^*} > (\frac{w}{w^*})_0$, which causes welfare loss to Foreign as the first term in (19) shows. We also know from (18) that Home sells subsidized goods $z \in [\widehat{z}_1, \widehat{z}]$ at the Foreign marginal costs $w^* a^*(z)$. For goods $z \in [\widehat{z}_0, \widehat{z}]$, the subsidies cause no welfare loss to Foreign since Foreign already produced those goods under no subsidies, but for goods $z \in [\widehat{z}_1, \widehat{z}_0]$, the subsidies cause welfare loss to Foreign that amounts to the last term in (19).

We next analyze the Home welfare. In the equilibrium with $\frac{w}{w^*}$ and $\widehat{z}$, the Home welfare can be rewritten in terms of $\widehat{z}_1$,

$$v = B + \ln(\frac{y}{y^*}) + \ln L^* - \ln(\frac{w}{w^*}) \int_0^{\widehat{z}_1} b(z)dz - \int_0^{\widehat{z}_1} b(z) \ln a(z)dz - \int_{\widehat{z}_1}^1 b(z) \ln a^*(z)dz, \tag{20}$$

which leads to the welfare differential:

$$v - v_0 = \left[\ln(\frac{y}{y^*}) - \ln(\frac{y}{y^*})_0\right] + \left[\ln(\frac{w}{w^*})_0 - \ln(\frac{w}{w^*})\right] \int_0^{\widehat{z}_1} b(z)dz \tag{21}$$
$$+ \int_{\widehat{z}_1}^{\widehat{z}_0} b(z) \left[\ln(\frac{w}{w^*})_0 - \ln \frac{a^*(z)}{a(z)}\right] dz.$$

In comparison with $v^* - v_0^*$ in (19), $v - v_0$ in (21) includes a positive term, $[\ln(\frac{y}{y^*}) - \ln(\frac{y}{y^*})_0] > 0$. The sign of $v - v_0$ is not clear due to other negative terms. As our formal proof shows in the Appendix A.1, however, we can identify the welfare effects at the margin where the subsidy interval $[\widehat{z}_1, \widehat{z}]$ is sufficiently small near $\widehat{z}_0$ and the export boundary $\widehat{z}$ increases slightly above $\widehat{z}_0$. At the margin, we find that the positive effect dominates, as the Foreign marginal costs on the subsidy interval approximate the original level at $\widehat{z}_0$ where both countries have the same marginal costs, $(\frac{w}{w^*})_0 = \frac{a^*(\widehat{z}_0)}{a(\widehat{z}_0)}$.

The remaining question is whether the subsidy policy (14) can cause beggar-thy-neighbor effects if it does not increase the export boundary. Our analysis is based on an alternative subsidy policy,

$$s(z) = \begin{cases} \dfrac{w/w^* - a^*(z)/a(z)}{[w/w^*]\gamma(z)} & \text{for } z \in [\widehat{z}_1, \widehat{z}_2] \\ 0 & \text{for } z \notin [\widehat{z}_1, \widehat{z}_2], \end{cases} \tag{22}$$

where $\frac{w}{w^*}$ equals $\frac{a^*(\widehat{z}_1)}{a(\widehat{z}_1)}$ and the subsidy interval $[\widehat{z}_1, \widehat{z}_2]$ stays within the original export boundary, $\widehat{z}_2 \leq \widehat{z}_0$. Under the subsidy policy (22), the endpoint $\widehat{z}_2$ is not necessarily the new equilibrium boundary, while the new equilibrium satisfies $\widehat{z} \leq \widehat{z}_0$, $\frac{y}{y^*} \leq (\frac{y}{y^*})_0$ and $\frac{w}{w^*} > (\frac{w}{w^*})_0$ since the demand-side curve shifts up given the R&D costs born by Home. We now report that the Home welfare strictly decreases under the subsidy policy (22).

Proposition 4. *If Home offers R&D subsidies in (22) and $\widehat{z}_2 \leq \widehat{z}_0$, then the Home welfare strictly decreases.*

Proposition 4 implies that Home has no incentive to use the subsidy policy (22). Based on our analysis of two subsidy options, (14) and (22), we can conclude that R&D subsidies targeting a specific range of goods entail beggar-thy-neighbor effects: Proposition 3 shows that if such subsidies extend the export boundary, then they increase the Home welfare but decrease the Foreign welfare, and Proposition 4 implies that Home uses such subsidies

only if its subsidies extend the export boundary.

In this section, using the Ricardian trade model of Dornbusch, Fischer and Samuelson (1977), we show that Home has incentive to use R&D subsidies in a wide range of circumstances. We find that some subsidies are mutually beneficial while others are detrimental to the Foreign welfare. We now conclude this section by summarizing our findings on two contrasting aspects of R&D subsidies. First, R&D subsidies offered generally for all Home produced goods are harmless to Foreign: under some conditions, such subsidies are mutually beneficial, and even when those conditions fail, Home does not use such subsidies to damage the Foreign welfare. Second, R&D subsidies targeting a specific range of goods entail beggar-thy-neighbor effects: if such subsidies extend the export boundary, then they increase the Home welfare at the expense of the Foreign welfare, and Home uses such subsidies only if its subsidies extend the export boundary.

4 Data

Although one can look at various countries for an empirical analysis, we focus on the case of Korea for several reasons. First, Korea is one of the top countries that invests heavily in R&D. According to the OECD Main Science and Technology Indicators Database, Korea had the second highest R&D intensity in 2015, which is the expenditure on R&D as a percentage of GDP, followed by Israel. Korea's R&D intensity was 4.23%, compared to 4.25% for Israel, 2.78% for the U.S., 2.38% for the OECD average, and 1.95% for the EU average.[10] Not only the private sector, but also the government and public sector actively invest in R&D in Korea. In 2014, Korea was ranked third among the OECD countries in terms of the total volume of public support for business R&D, which is the mix of direct funding and tax relief, as a percentage of GDP. Korea spent 0.36% of its GDP for supporting business R&D from the public sector, compared to 0.37% in France which was ranked first and 0.25% in the U.S. Among Korea's public support for R&D activities, 52.7% was in the form of tax incentives and the remaining 47.2% was through direct funding.[11] Although indirect government support through tax relief is also an important way of subsidizing R&D activities, in this paper we focus on direct funding given available information in our data.

[10] http://www.oecd.org/sti/msti.htm

[11] http://www.oecd.org/sti/rd-tax-incentive-indicators.htm

Second, Korea is a typical example of an open economy where trade has long been a source of its economic development. According to the World Bank Database, the sum of exports and imports of goods and services measured as a share of GDP is around 78% in Korea in 2016, which grew from 15% in 1960.[12] At the same time, government led policies and interventions have often played an important role in promoting national welfare. For these reasons, Korea is a particularly interesting case to analyze impact of the SCM Agreement on a country that heavily relies on R&D support and trade.

4.1 Data Source

The dataset used in this paper is called the "Report on the Survey of Research and Development," published annually by the Ministry of Educational Science and Technology and the Korea Institute of Science & Technology Evaluation and Planning.[13] The survey began in 1963 to collect information on R&D activities in Korea for policy-making purposes. The archive of the survey reports is publicly available on the Ministry of Science, ICT and Future Planning Library website in a book format.[14] The survey is conducted by mailing method in which questionnaires are directly mailed to representative samples, accompanied by additional telephone survey in some cases. The survey covers four types of organizations in Korea nationwide: 1) public research institute, 2) college/university, 3) medical institute, and 4) firm. The average number of samples for each organization category along with retrieval rates are summarized in Table 1. Firms account for the largest sampled group in the data. The survey covers venture businesses and firms which are either affiliated with research institutes or own R&D divisions.

The survey items include information on organizations' characteristics (e.g. size of employees, amount of capital, number of researchers, location) along with data on R&D expenditure and workforce involved in R&D activities. The data gives detailed information on R&D expenditure, as it classifies spending by research types (basic, applied, or development), type of costs (labor, machinery, land, or computer software), source (government/public, private, or foreign), type of usage (new product, existing product, new

[12] `https://data.worldbank.org/indicator/NE.TRD.GNFS.ZS?year_high_desc=false`

[13] The survey was originally called the "Status Survey of Research Institutes" and was renamed as the "Report on the Survey of Research and Development in Science and Technology" in 1967. The survey was finally renamed as "Report on the Survey of Research and Development" in 2007 after including additional fields on humanities and social science.

[14] `http://lib.msip.go.kr/`

Table 1: Sample Summary Statistics

	Average sample size	Average retrieval rate
Research institute	394	94%
College/university	358	97%
Medical institute	483	96%
Firm	14,750	81%

Notes: The statistics are based on years from 1993 to 2014. Average sample size is the number of organizations to which surveys were sent. Average retrieval rate is the share among the sample that have sent back their replies to survey reports.

process, or existing process), and research fields (natural science, engineering, agriculture, medical, etc.). The information is aggregated and reported at a group level within an industry. For instance, firms are classified into different industries and then further classified into four different groups within an industry by the size of employees. Although the information is not reported at the individual firm level, the data give detailed information for each specific subcategory within an industry.

In the empirical analysis, we mainly focus on firms' R&D expenditures from 1987 to 2013. As we are interested in analyzing effects of the SCM Agreement, we include sufficiently many years before and after the 1995-1999 period. We track the following seven 2-digit industries in the manufacturing sectors according to the ISIC Rev. 2 classification: 1) manufacture of food, beverages, and tobacco; 2) textile, wearing apparel and leather industries; 3) manufacture of wood and wood products & manufacture of paper and paper products, printing and publishing; 4) manufacture of chemicals and chemical, petroleum, coal, rubber and plastic products; 5) manufacture of non-metallic mineral products, except products of petroleum and coal; 6) basic metal industries; and 7) manufacture of fabricated metal products, machinery and equipment. Although the survey data also has information at the 3 or 4-digit industry level, we focus on the 2-digit industries for the following reasons. First, industry classification changed throughout the sample period in the data, so some industry classifications are inconsistent. However, 2-digit industries are invariant to these changes. Second, average R&D amounts are more reliable at the 2-digit industries as they are based on a larger number of firms. At the 3 or 4-digit industry level, the number of surveyed firms can become quite few which may make average R&D expenditures for that category to be unreliable.

In addition to the survey reports. we also append information from the following sources. For information on exports and imports, we refer to the United Nations Commodity Trade Statistics Database (UN Comtrade). We use the HS-ISIC concordance table from the Forum for Research in Empirical International Trade (F.R.E.I.T) to match the HS codes at the 6-digit level to 2-digit ISIC codes. For other macroeconomic variables, we refer to the Korea's national statistical database called the Korean Statistical Information Service (KOSIS).

4.2 Summary Statistics

Table 2: Average R&D Funds By Organizations

	Research Institute	College/University	Firm
Average amount (million KRW)	16,608.73	7,293.29	3003.24
<Source of Funds>			
Gov/Public sector	82.20%	59.83%	4.35%
Private sector	17.55%	64.21%	95.41%
Foreign sector	0.24%	0.29%	0.22%
<Research Type>			
Basic research	22.09%	47.97%	9.43%
Applied research	34.51%	28.08%	19.52%
Development research	43.38%	23.90%	71.04%

Notes: Average amounts are in real million Korean won, deflated by the CPI (base year 2010). The sum of amounts by source of funds equals the sum of amounts by research type.

We now summarize various statistics from the survey reports. In Table 2, we show the average R&D expenditure of research institutes, colleges/universities, and firms. The amounts are in real Korean million won and are averaged from 1985 to 2013. The average amount is calculated based on information from all surveyed research institutes, colleges/universities, and firms across various fields and industries. Compared to research institutes and colleges/universities, the share of funds financed by the government/public sector for firms is relatively low, which is around 4.35%. In the last set of rows, Table 2 summarizes average R&D amount spent on each research type. The survey report defines three research types as the following:

- Basic research: "Any experimental or theoretical study, undertaken primarily to acquire new knowledge of the underlying foundations of phenomena and observable

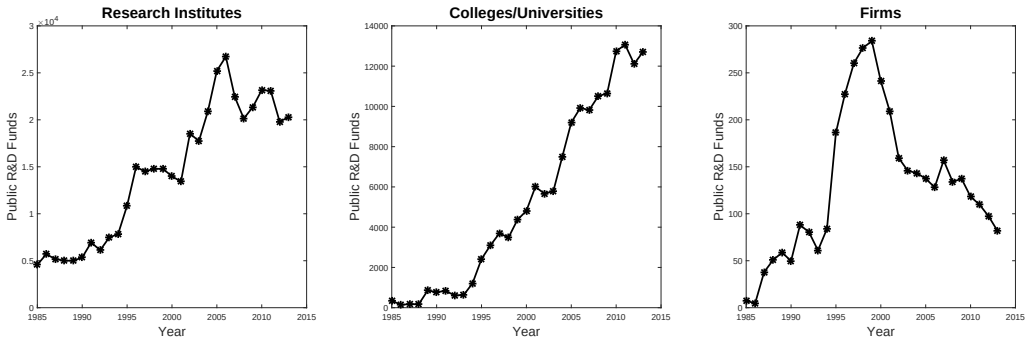
facts, without any particular application or specific use."

- Applied research: "Any original investigation, undertaken in order to acquire new knowledge primarily towards a specific practical purpose or objective."

- Experimental/Development research: "Any systematic work, applying existing knowledge gained from basic and applied research, or practical experience to produce new materials, products and devices, to install new processes, systems and services, and substantially improve those already produced or installed."

Whereas research institutes and colleges/universities allocate somewhat similar proportion of funds to each research type, firms spend 71.04% of R&D funds on average for development research. In contrast, colleges/universities spend the largest share of R&D funds on basic research. In line with our intuition, profit maximizing firms concentrate more on R&D activities that serve practical purposes and yield quick returns.

Figure 3: Trends of Public R&D Funds Across Different Organizations



Next, we analyze average R&D expenditure trends across time for the three types of organizations in Figure 3. Each plot shows the average R&D expenditure per institution funded by the government/public sector from 1985 to 2013 for research institutes, colleges/universities, and firms. The average amounts are in real Korean million won. The SCM Agreement regulates funds from government/public sector to firms under stipulated conditions. Therefore we use research institutes and colleges/universities as a benchmark to see if the trend for firms is different and responds to the SCM Agreement adoption. Whereas the average R&D amount for research institutes and colleges/universities is increasing throughout time, the trend for firms is hump-shaped with a peak in year 2000. The sharply increasing slope from 1995 to 1999 coincides with the green light period

when R&D subsidies were non-actionable and the peak coincides with the beginning of the yellow light period. Such a response is not found for research institutes and colleges/universities, which are not subject to the SCM Agreement.

Table 3: Firms' Average R&D Expenditures Across Industries

	Avg R&D Amount	Share of Public Funds	Export to Import Ratio
Food, beverages, tobacco	1251.71	3.52%	0.31
Textile, wearing apparel, leather	1232.26	6.62%	2.84
Wood/paper products, printing, publishing	1044.67	2.77%	0.50
Chemicals, petroleum, coal, rubber, plastic	1989.88	5.87%	1.10
Non-metallic mineral products	1366.01	5.59%	0.55
Basic metals	2600.38	6.18%	0.80
Fabricated metal products, machinery	1846.63	9.13%	1.80

Notes: Average amounts are in real million Korean won, deflated by the CPI (base year 2010). Export to import ratio is export value divided by import value in current US dollars and averages across years.

Table 4: Firms' R&D Expenditures By Research Types Across Industries

	Share of Basic R&D	Share of Applied R&D	Share of Dev R&D
Food, beverages, tobacco	13.58%	23.15%	63.25%
Textile, wearing apparel, leather	11.18%	20.25%	68.55%
Wood/paper products, printing, publishing	8.51%	18.92 %	72.55%
Chemicals, petroleum, coal, rubber, plastic	9.87%	25.88%	64.24%
Non-metallic mineral products	10.33%	23.81%	65.85%
Basic metals	7.86%	22.71%	69.45%
Fabricated metal products, machinery	8.40%	18.67%	72.91%

In Table 3 and 4, we look at various statistics on R&D activities by firms across different industries. These are averages between 1988 and 2013.[15] The total R&D amount is in real Korean million won. The average R&D amount is heterogeneous across industries, as the basic metals industry on average invested almost 2.5 times as much as the wood/paper products, printing, and publishing industry. The textile, wearing apparel, and leather industry and the fabricated metal products, machinery, and equipment industry are the top two industries with the largest share of public funds and the highest

[15]The export and import data on Korea from Comtrade is only available from 1988.

export to import ratio. The export to import ratio in the last column is calculated as the following: the export value is divided by the import value for each industry in a year, and then these ratios averaged across years. Lastly, Table 4 shows that all seven industries allocate a great majority of their R&D spendings on development research.

5 Empirical Analysis

The empirical analysis contains four parts. In the first section, we investigate whether government/public R&D funds in Korea have responded to adoption of the SCM Agreement. We use structural breaks marked by different R&D regulation periods to study their effects on government/public R&D expenditure trends. In the second section, we study whether there is a tendency of government/public funds to be allocated strategically. In the third section, we look for the link between R&D forms and export boundary. We wrap up with a discussion in the last section.

5.1 Response to the SCM Agreement

R&D subsidies were classified as green light subsidies from 1995 to 1999 and then reclassified as yellow light subsidies from 2000 onwards. This change gives us an exogenous institutional break in the data that we can use to identify whether government/public funding behaved differently during these periods. As we focus on the government/public funding for firms' R&D activities, we similarly analyze three other cases for a comparison. We also look at private funding of research institutes' R&D activities, government/public funding of research institutes' R&D activities, and private funding of firms' R&D activities. As these three cases are not subject to the SCM Agreement, theoretically they should not respond to the institutional breaks.

Before we present the results, we first discuss expectations and exogeneity of the institutional changes on R&D subsidies. At the time of the SCM Agreement adoption in 1995, R&D subsidies were classified as non-actionable by Article 8. However, Article 31 stipulated that this would be a provisional application for a period of five years and would be subject to a possible extension afterwards.[16] Therefore, all countries could rationally

[16] Article 31 in the SCM Agreement states "... the provisions of Article 8 and Article 9 shall apply for a period of five years, beginning with the date of entry into force of the WTO Agreement. Not later than 180 days before the end of this period, the Committee shall review the operation of those provisions, with

Table 5: Response of Private R&D Funds to the SCM Agreement for Research Institutes

log(Avg private R&D amount$_t$+1)	(1)	(2)	(3)	(4)
log(Avg private R&D amount$_{t-1}$+1)	0.4383***	0.4399***	0.4485***	0.4622***
	(0.0304)	(0.0325)	(0.0434)	(0.0317)
t	0.0053		-0.0182	
	(0.0317)		(0.0195)	
I(Green light period)	-0.3427	-0.0163	0.2480	0.2065
	(0.3217)	(0.2554)	(0.1910)	(0.3032)
I(Yellow light period)	-0.6911	-0.3640	-0.2059	-0.3370
	(0.7358)	(0.6119)	(0.5050)	(0.5669)
I(Asian Financial Crisis)			-0.6919*	-0.6135
			(0.3095)	(0.4420)
<Field FE>				
I(Engineering)	1.9068***	1.9012***	1.8711***	1.8238***
	(0.1061)	(0.1132)	(0.1512)	(0.1104)
I(Medical sciences)	0.6897***	0.6884***	0.6813***	0.6702***
	(0.0250)	(0.0267)	(0.0356)	(0.0260)
I(Natural sciences)	1.2316***	1.2279***	1.2079***	1.1763***
	(0.0706)	(0.0754)	(0.1007)	(0.0735)
I(Others)	0.2596***	0.2629***	0.2715***	0.2628***
	(0.0195)	(0.0173)	(0.0205)	(0.0156)
Constant term	Yes	Yes	Yes	Yes
Political regime FE	No	Yes	No	Yes
Number of observations	133	133	133	133
R-squared	0.7748	0.7887	0.7927	0.7958

Notes: Robust standard errors are clustered at the field level. The amounts are in real million Korean won, deflated by the CPI (base year 2010).

expect that although an extension is possible, it was not guaranteed and possibilities of modifications or termination also existed. The changes in these institutional regulations can be treated as exogenously given from each individual country's perspective as they are determined by a consensus within the WTO, in which a country is one of many members.

In Table 5 and Table 6, we present the results for research institutes' average R&D expenditures funded by private and government/public sector respectively. The unit of observation is field average in a year from 1987 to 2013 for five fields: 1) agriculture;

a view to determining whether to extend their application, either as presently drafted or in a modified form, for a further period."

Table 6: Response of Public R&D Funds to the SCM Agreement for Research Institutes

log(Avg public R&D amount$_t$+1)	(1)	(2)	(3)	(4)
log(Avg public R&D amount$_{t-1}$+1)	0.5834***	0.5718***	0.6247***	0.6179***
	(0.0364)	(0.0461)	(0.0271)	(0.0505)
t	0.0151		0.0019	
	(0.0146)		(0.0110)	
I(Green light period)	0.2564	0.3096	0.5326**	0.4022
	(0.1793)	(0.2459)	(0.1906)	(0.2465)
I(Yellow light period)	0.1445	0.1022	0.3647	0.0857
	(0.3286)	(0.3333)	(0.2454)	(0.3271)
I(Asian Financial Crisis)			-0.3382	-0.3319
			(0.1966)	(0.1569)
<Field FE>				
I(Engineering)	0.5698***	0.5858***	0.5130***	0.5223***
	(0.0503)	(0.0636)	(0.0373)	(0.0696)
I(Medical sciences)	-0.4463***	-0.4581***	-0.4046***	-0.4114***
	(0.0369)	(0.0467)	(0.0274)	(0.0511)
I(Natural sciences)	0.4770***	0.4900***	0.4311***	0.4386***
	(0.0406)	(0.0514)	(0.0302)	(0.0562)
I(Others)	-0.3021***	-0.3078***	-0.2649***	-0.2697***
	(0.0251)	(0.0363)	(0.0260)	(0.0431)
Constant term	Yes	Yes	Yes	Yes
Political regime FE	No	Yes	No	Yes
Number of observations	133	133	133	133
R-squared	0.9019	0.9091	0.9099	0.9129

Notes: Robust standard errors are clustered at the field level. The amounts are in real million Korean won, deflated by the CPI (base year 2010).

2) engineering; 3) medical sciences; 4) natural sciences; and 5) others. That is, each observation is average amount received by research institutes within a field in a year. I(Green light period) is a dummy indicator capturing years 1995 to 1999. I(Yellow light period) similarly captures years from 2000. The coefficients of these two variables are of our interest to see whether the trend of private or public funding for research institutes changes with respect to the SCM Agreement. There are other several control variables that we include. We control for the five field fixed effects. During our data period, there was the Asian Financial Crisis which began in 1997. Korea had to receive a $58 billion dollar rescue package from the IMF and the loans were fully repaid in 2001. To control

for any effects coming from the Asian Financial Crisis, we also include a dummy variable for years 1997 to 2001. Lastly, different political regimes may have different investment initiatives or policies that can affect R&D expenditure trends. We also include political regime fixed effects in columns (2) and (4) for each president. The term length for a president is 5 years and 7 presidents served during the time period in our data.

In all empirical results, we use asterisks */**/*** to denote significance at 1%, 5%, and 10% respectively. Table 5 shows that none of coefficients for the green light period indicator is statistically significant at standard levels. Similarly, the yellow light period indicator is not significant. The results are similar in Table 6 for government/public funding of research institutes, except the green light indicator in column (3) is statistically significant at 5%. However, this is not robust to other specifications as shown in the remaining columns. Overall, Table 5 and Table 6 show that the average R&D expenditure of research institutes does not respond to the SCM Agreement. Also, none of political regime indicators were statistically significant at standard levels.

Next, we analyze firms' average R&D expenditure funded by private and government/public sectors in Table 7 and Table 8. As before, the data period covers 1987 to 2013. The dependent variable is an average R&D expenditure from private or public sector for firms within a specific employee size range in an industry. There are 7 types of 2-digit industries in manufacturing as explained in the data section. Within each industry, the data further classifies firms into 4 groups depending on the size of employees: 1) with less than 100 employees; 2) from 100 to 299 employees; 3) from 300 to 999 employees; and 4) more than 1000 employees. For instance, one example of an observation is average R&D expenditure from the private sector for firms with less than 100 employees in the textiles industry in 2000.[17]

As before, the focus of interest is the effect of structural breaks captured by the I(Green light period) and I(Yellow light period) indicators on the average R&D expenditures. The specifications are analogous to those in Tables 5 and 6. Results in (2) and (4) of Table 7 show that the coefficients of green and yellow light indicators are marginally significant at 10% with negative signs for private funding of firms. The rest are not statistically significant at standard levels. In contrast, the results for government/public

[17]The number of observations is much larger for firms in Tables 7 and 8, as sub-categories based on employee size are reported in the data. Such information is not available for research institutes, so observations for research institutes are field averages in a year.

Table 7: Response of Private R&D Funds to the SCM Agreement for Firms

log(Avg private R&D amount$_t$+1)	(1)	(2)	(3)	(4)
log(Avg private R&D amount$_{t-1}$+1)	0.7286***	0.7287***	0.7289***	0.7287***
	(0.0908)	(0.0922)	(0.0907)	(0.0926)
t	0.0092**		0.0096***	
	(0.0028)		(0.0020)	
I(Green light)	-0.0503	-0.1439*	-0.0602	-0.1429*
	(0.0714)	(0.0670)	(0.0676)	(0.0709)
I(Yellow light)	-0.0477	-0.1073*	-0.0559	-0.1073*
	(0.0780)	(0.0501)	(0.0692)	(0.0503)
I(Asian Financial Crisis)			0.0121	-0.0028
			(0.0337)	(0.0544)
<Industry FE>				
I(Textiles)	-0.0013	-0.0013	-0.0013	-0.0013
	(0.0029)	(0.0030)	(0.0029)	(0.0030)
I(Wood, paper, printing & publishing)	0.0056***	0.0056***	0.0056***	0.0056***
	(0.0001)	(0.0001)	(0.0001)	(0.0001)
I(Chemicals, rubber & plastic products)	0.2576**	0.2575**	0.2573**	0.2575**
	(0.0794)	(0.0807)	(0.0793)	(0.0810)
I(Non-metallic mineral products)	0.0830***	0.0830***	0.0829***	0.0830***
	(0.0219)	(0.0222)	(0.0219)	(0.0223)
I(Basic metal products)	0.1202**	0.1201**	0.1200**	0.1201**
	(0.0386)	(0.0393)	(0.0386)	(0.0394)
I(Fabricated metal products)	0.2190**	0.2198**	0.2187**	0.2198**
	(0.0760)	(0.0777)	(0.0760)	(0.0781)
<Firm Size FE>				
I(Employees $\in [100, 299]$)	0.2537***	0.2537***	0.2535***	0.2537***
	(0.0625)	(0.0635)	(0.0625)	(0.0638)
I(Employees $\in [300, 999]$)	0.5389***	0.5388**	0.5384***	0.5388**
	(0.1464)	(0.1487)	(0.1464)	(0.1493)
I(Employees > 1000)	1.0382**	1.0385**	1.0372**	1.0386**
	(0.3240)	(0.3299)	(0.3245)	(0.3312)
Constant term	Yes	Yes	Yes	Yes
Political regime FE	No	Yes	No	Yes
Number of observations	720	720	720	720
R-squared	0.9369	0.9378	0.9369	0.9378

Notes: Robust standard errors are clustered at the industry level. The amounts are in real million Korean won, deflated by the CPI (base year 2010). Firm size fixed effect brackets for number of employees are as reported in the survey data.

Table 8: Response of Public R&D Funds to the SCM Agreement for Firms

log(Avg public R&D amount$_t$+1)	(1)	(2)	(3)	(4)
log(Avg public R&D amount$_{t-1}$+1)	0.4239***	0.4302***	0.4249***	0.4310***
	(0.0493)	(0.0536)	(0.0531)	(0.0541)
t	0.4447***		0.0435***	
	(0.0106)		(0.0102)	
I(Green light period)	0.6687***	0.7363**	0.6868***	0.7494**
	(0.1443)	(0.2561)	(0.1248)	(0.2516)
I(Yellow light period)	0.2913	0.5687**	0.3066**	0.5682**
	(0.1605)	(0.1910)	(0.1011)	(0.1915)
I(Asian Financial Crisis)			-0.0242	-0.0422
			(0.1666)	(0.0586)
<Industry FE>				
I(Textiles)	0.4210***	0.4161***	0.4202***	0.4154***
	(0.0388)	(0.0422)	(0.0419)	(0.0426)
I(Wood, paper, printing & publishing)	-0.2203***	-0.2182***	-0.2199***	-0.2179***
	(0.0168)	(0.0183)	(0.0181)	(0.0185)
I(Chemicals, rubber & plastic products)	1.1920***	1.1786***	1.1897***	1.1767***
	(0.1052)	(0.1143)	(0.1134)	(0.1154)
I(Non-metallic mineral products)	0.5412***	0.5355***	0.5403***	0.5347***
	(0.0451)	(0.0491)	(0.0487)	(0.0496)
I(Basic metal products)	1.0962***	1.0843***	1.0941***	1.0827***
	(0.0925)	(0.1006)	(0.0998)	(0.1015)
I(Fabricated metal products)	1.1679***	1.1526***	1.1655***	1.1507***
	(0.1052)	(0.1162)	(0.1142)	(0.1172)
<Firm Size FE>				
I(Employees $\in [100, 299]$)	0.0524	0.0523	0.0524	0.0521
	(0.0634)	(0.0630)	(0.0630)	(0.0625)
I(Employees $\in [300, 999]$)	0.1131	0.1129	0.1130	0.1125
	(0.1986)	(0.1984)	(0.1981)	(0.1964)
I(Employees > 1000)	0.8748***	0.8710***	0.8733***	0.8642***
	(0.1733)	(0.1778)	(0.1725)	(0.1705)
Constant term	Yes	Yes	Yes	Yes
Political regime FE	No	Yes	No	Yes
Number of observations	720	720	720	720
R-squared	0.6087	0.6088	0.6087	0.6088

Notes: Robust standard errors are clustered at the industry level. The amounts are in real million Korean won, deflated by the CPI (base year 2010). Firm size fixed effect brackets for number of employees are as reported in the survey data.

R&D expenditure of firms show significant and robust response to different regulation phases of the SCM Agreement. Compared to years before 1995, we find positive and statistically significant increase in public R&D expenditure for firms during the limited 5 year period when R&D subsidies were classified as non-actionable. This supports the hump-shaped trend graph for firms in Figure 3. We also find that the effects during the yellow light period are positive and statistically significant in specifications (2), (3), and (4). However, the magnitude of increase is smaller than that for the green light period. This is in line with our intuition since R&D subsidies became actionable since 2000. Overall, Tables 5, 6, 7, and 8 confirm our expectation that only government/public funding of firms responded to the SCM Agreement. Moreover, we find that the increase during the non-actionable green light period is larger than that in the actionable yellow light period.

5.2 Specificity and Strategic Use of R&D Funds

The key discipline of the SCM Agreement is regulating a "specific" subsidy which can potentially cause adverse effects to others. However, it is difficult to track specifically targeted R&D subsidies offered by the government/public sector, as it would require individual level data on firms or industries. Information on targeted beneficiaries as well as the remaining group which did not receive such benefits would be necessary. For instance, information on a few individual firms with government/public funding would not be sufficient to conclude whether they were indeed the specifically targeted few or among many others who received similar benefits. The data used in this study also has this limitation as information is not sufficient to identify specific subsidies which would be subject to the SCM Agreement. Instead, we investigate other available information in the data to infer whether there is an evidence that the Korean government/public sector strategically allocates its R&D resources.

The first dimension that we study is the government/public sector's allocation of R&D funds depending on the type of research. Among basic, applied, and development R&D, the latter two types are primarily used to achieve a specific practical goal. The specificity of purpose does not imply specificity of beneficiaries' scope or vice versa. For instance, development R&D subsidies may be given broadly across firms, or R&D subsidies specifically given to certain firms may be used for basic research. Therefore, this is not to

claim that subsidies spent on applied or development R&D satisfy the specificity condition of the SCM Agreement. At the same time, spending on applied or development R&D can serve as an attractive intervention tool for the government/public sector as it is tightly linked to improving firms' performance in the short run.

In Table 9, we study whether research types affect the average R&D funds received from the government/public sector and whether the SCM Agreement had any impact on this relationship. There are many plausible reasons to believe why the government/public sector may care about type of research conducted by firms. For instance, if the government/public sector seeks to help firms improve their performance in the short run, it may contribute to those doing more applied or development research. On the other hand, if the government aims to contribute to making fundamental innovations which often tend to be under-invested in the private market but can potentially have great spillover effects in the long run, it may place a greater value on basic research. As before, the unit of observation is a group of firms with a similar employment size in an industry from 1987 to 2013. The data reports R&D expenditure by source and by research type separately, but not how R&D funds from the government/public sector were spent on basic, applied, and development R&D respectively. Therefore, we use basic, applied, and development R&D shares given the aggregated fund sources as control variables. Fungibility of money implies that a dollar spent on basic research financed by the private sector is essentially the same as a dollar financed by the public/government sector. As a result, what may be more relevant is the aggregate share of funds spent on a particular type of research.

Table 9 shows that the coefficient for development R&D share is positive, which contrasts with the negative coefficients for basic and applied R&D shares, but all three variables are not statistically significant at standard levels. We also investigate whether the government/public R&D funds' responsiveness to research types change during the green or yellow light period. This is done by including control variables which interact these period indicators with research type shares. We find that during the green light period, the average government/public R&D amount increases additionally compared to years before 1995 when the lagged development share is higher. As for basic research share, the effect was opposite so that the government/public support decreases during the green light period as the lagged basic R&D share increases.

The second dimension that we analyze is whether there is a tendency for the government/public R&D funds to be allocated based on export or import performance. For

Table 9: Public R&D Expenditures and R&D Types

log(Avg public R&D amount$_t$+1)	(1)	(2)	(3)
log(Avg public R&D amount$_{t-1}$+1)	0.4450***	0.4539***	0.4535***
	(0.0546)	(0.0584)	(0.0576)
I(Green light period)	1.3647***	1.3653***	-0.4871
	(0.2105)	(0.2035)	(0.7090)
I(Yellow light period)	0.7973**	0.9946***	1.2282**
	(0.2540)	(0.2275)	(0.4113)
I(Asian Financial Crisis)	-0.2082	-0.1701	-0.1971
	(0.1596)	(0.1550)	(0.1524)
Basic share$_{t-1}$	-1.2516		
	(1.1089)		
Basic share$_{t-1}\times$ I(Green light period)	-3.1740*		
	(1.3335)		
Basic share$_{t-1}\times$ I(Yellow light period)	1.9218		
	(1.7367)		
Applied share$_{t-1}$		-0.4831	
		(0.7223)	
Applied share$_{t-1}\times$ I(Green light period)		-1.8901	
		(1.3199)	
Applied share$_{t-1}\times$ I(Yellow light period)		-0.1199	
		(0.8124)	
Dev share$_{t-1}$			0.5803
			(0.5755)
Dev share$_{t-1}\times$ I(Green light period)			2.1450**
			(0.8283)
Dev share$_{t-1}\times$ I(Yellow light period)			-0.3480
			(0.6417)
Constant term	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes
Firm size FE	Yes	Yes	Yes
Number of observations	720	720	720
R-squared	0.6091	0.6066	0.6095

Notes: Robust standard errors are clustered at the industry level. The amounts are in real million Korean won, deflated by the consumer price index (CPI; base year 2010). The denominator for basic, applied, and development research share variables is R&D amount aggregated from private, government/public, and foreign sources.

instance, the government may provide R&D subsidies to increase export or to substitute away imports. We study whether export or import performance of an industry affects its government/public R&D expenditure in Table 10. The unit of observation is an industry in a year, with the same seven industries from 1988 to 2013. As the export and import data are only available at the industry level, we do not use data on subcategories within industries based on employee size as before. The key variables of interest are export share and import share in the lagged year. Export share is defined as the export value in a 2-digit industry in a year divided by the aggregate export value of the entire manufacturing sector in the same year in U.S. constant dollars. R&D expenditures are in Korean won, whereas export and import values are in U.S. dollars. As export and import values cannot be deflated by a price index in local currency, we use the ratio. We find that the

Table 10: Public R&D Expenditures and Trade Shares

log(Avg public R&D amount$_t$+1)	(1)	(2)	(3)	(4)
log(Avg public R&D amount$_{t-1}$+1)	0.2057*	0.1951*	0.2102*	0.1969*
	(0.1060)	(0.1005)	(0.0920)	(0.0846)
t	-0.0076	-0.0073		
	(0.0098)	(0.0107)		
I(Green light period)	1.1122***	1.1237***		
	(0.2802)	(0.2802)		
I(Yellow light period)	1.0117**	1.0250**		
	(0.3225)	(0.3281)		
I(Asian Financial Crisis)	0.0934	0.0973		
	(0.1127)	(0.1161)		
Export share$_{t-1}$	0.2541		0.2477	
	(1.3096)		(1.4994)	
Import share$_{t-1}$		2.3665**		2.4601***
		(0.7833)		(0.6409)
Constant term	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes
Year FE	No	No	Yes	Yes
Number of observations	175	175	175	175
R-squared	0.7554	0.7568	0.7923	0.7939

Notes: Robust standard errors are clustered at the industry level. The amounts are in real million Korean won, deflated by the CPI (base year 2010). Export share is defined as export value of an industry in current U.S. dollars in a year divided by the export value of the entire manufacturing sector in current U.S. dollars in the same year. Import share is analogously defined.

government/public sector's funds respond to the import share, where the effect is positive and statistically significant at 5% as in column (2). That is, the government/public sector allocated greater R&D amount on average to industries which had a higher share of import values in the manufacturing sector, all other things being equal. As for export share, the estimated coefficient was insignificant. We also checked whether responsiveness to export or import share changes during the green or yellow light period as in the previous analyses. The additional effects during these periods were not statistically significant. Nevertheless, columns (3) and (4) show that the results are still robust as in (1) and (2), after including year fixed effects.

5.3 Extension of the Export Boundary

Proposition 3 shows that R&D subsidies which target a specific range of goods and extend the export boundary entail beggar-thy-neighbor effects. Moreover, Proposition 4 shows that there is no reason for Home to provide R&D subsidies for a specific range of goods unless they extend the export boundary, which implies having beggar-thy-neighbor effects. In this section, we investigate the use of particular types of R&D funds to expand the export boundary in our data. As before, we focus on the types of R&D funds given information availability. Our analyses in the previous section show that the R&D funds from the Korean government/public sector tend to be allocated more to industries with a higher development research share during the green light period and a higher import share among the manufacturing sector throughout years. Then is there an evidence that development research spending, for which the government/public sector responds most to, affects the export boundary? We study this in Table 11 and 12.

The unit of observation is an industry in a year, with the same seven industries from 1988 to 2013. We construct the following index measure as a dependent variable. For an industry in a year, we count the total number of all 6-digit HS commodities traded by Korea with rest of the world. The transaction takes one of these three forms: 1) Korea exporting and importing the good; or 2) Korea exporting but not importing the good; or 3) Korea importing but not exporting the good. As long as there was any non-zero export or import value of a 6-digit HS commodity good, that variety is included in the count. This aggregated sum of varieties is used as the denominator of the dependent variable in Table 11. For the numerator, we count all the 6-digit HS commodities in an industry in a

year for which Korea only imports from rest of the world but does not export at all. This is identified in the data when the import amount from the world is positive but there is no record of Korea exporting that good. The ratio gives us the share of traded goods in an industry in a year for which Korea does not export but only imports. Intuitively, this can be thought of as a proxy capturing the measure of $[\hat{z}, 1]$. For each industry in a year, the aggregate number of traded goods is sufficiently large as we look at 2-digit industries within manufacturing. The number ranges from 130 to 1314 during our time period. Note that the number of goods may change across years within an industry, as new goods may be introduced or transaction patterns may change. The ratio used as the dependent variable is also quite heterogeneous across industries and years, as it ranges from 0.011 to 0.337. The fabricated metal industry has the lowest share on average, which is around 0.032. The food, beverages, and tobacco industry has the highest average on share, which is around 0.276.

Table 11: R&D Types and Share of Goods With No Exports

Share of goods with no exports$_t$	(1)	(2)	(3)	(4)
Share of goods with no exports$_{t-1}$	0.6943***	0.7051***	0.6909***	0.7013***
	(0.0763)	(0.0827)	(0.0801)	(0.0755)
Avg basic R&D amount$_{t-1}$	0.0143	-0.0123		
	(0.0231)	(0.0134)		
Avg applied R&D amount$_{t-1}$	-0.0116		-0.0146***	
	(0.0089)		(0.0025)	
Avg development R&D amount$_{t-1}$	-0.0037*			-0.0043**
	(0.0017)			(0.0016)
Constant term	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Number of observations	175	175	175	175
R-squared	0.9780	0.9773	0.9777	0.9778

Notes: Robust standard errors are clustered at the industry level. The amounts are in real billion Korean won, deflated by the CPI (base year 2010). Dependent variable is the number of goods that Korea only imports but does not export in an industry divided by the number of all traded goods in that industry between Korea and rest of the world.

We analyze whether the range of commodities for which Korea only imports but does not export shrinks as a certain type of R&D spending increases. Table 11 shows that as average applied or development R&D expenditure in the lagged year increases, the

Table 12: R&D Types and Number of Goods With No Exports

Number of goods with no exports$_t$	(1)	(2)	(3)	(4)
Number of goods with no exports$_{t-1}$	0.8551***	0.8547***	0.8520***	0.8518***
	(0.0376)	(0.0419)	(0.0400)	(0.0383)
Avg basic R&D amount$_{t-1}$	9.1904	-2.4787		
	(8.0317)	(4.1208)		
Avg applied R&D amount$_{t-1}$	-2.6347		-4.3633**	
	(4.1105)		(1.6531)	
Avg development R&D amount$_{t-1}$	-2.3129***			-1.8854**
	(0.5534)			(0.6687)
Constant term	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Number of observations	175	175	175	175
R-squared	0.9775	0.9770	0.9772	0.9774

Notes: Robust standard errors are clustered at the industry level. The amounts are in real billion Korean won, deflated by the CPI (base year 2010). Dependent variable is the number of goods that Korea only imports but does not export in an industry.

share of traded goods that Korea does not export but only imports decreases. In other words, this implies that the share of goods for which Korea exports is expanding as applied or development R&D expenditure increases. Similar results still hold in Table 12 where we use only the numerator, the number of goods that Korea only imports but does not export, as a dependent variable. Unlike in Table 11, we do not deflate by the total number of commodities being traded. The results are robust in that applied and development subsidies have a statistically significant effect in diminishing the range of commodities that Korea only imports.

5.4 Discussion

Overall, results of the empirical section can be summarized as the following. First, the average government/public expenditure for firms' R&D activities responds to the regulation changes marked by the SCM Agreement, especially by reaching a peak during the green light period. This contrasts with private expenditure for firms or expenditure for research institutes, which are not responsive to the SCM Agreement. Second, results suggest that the Korean government/public sector allocates R&D funds strategically to

improve firms' performance. Average government/public R&D amount increases with development research share during the green light period. Also, import share in the lagged year has a positive and significant effect on current government/public R&D spending. Third, a higher average spending on applied and development R&D shrinks the share of traded goods that Korea only imports but does not export.

As we use data on Korea, numerical results may not be directly applicable to other countries. Nevertheless, empirical results of this paper serve as a good starting point to understand how the SCM Agreement may have affected a government's funding of R&D activities, which has not been acknowledged before. Although it may seem as if the SCM Agreement on R&D subsidies has not had real effects at a glance, the findings of this paper suggest otherwise. Given that the data was only based on direct funding of R&D activities, magnitude of response could potentially be bigger if indirect funding such as tax relief is taken into account. At the same time, the direction and magnitude of public R&D's response to the SCM Agreement can be heterogeneous across countries depending on their level of R&D activities and policy intentions. Lastly, government/public funds for R&D activities in Korea suggest strategic support to improve performance of economy and firms. Such incentives should not be specific to Korea, but are presumably common across countries. In line with theoretical implications of the model, R&D subsidies can potentially be used as intervention tools to improve national welfare at the expense of others. This provides a better understanding of the stance of the SCM Agreement in regulating R&D subsidies.

6 Conclusion

Despite much discussions on the adoption of SCM Agreement and its strict legal provisions, whether it constitutes a justifiable regulation environment with real impacts on governments has not been addressed. In this paper, we analyze this issue theoretically and empirically, with a focus on regulations on R&D subsidies which went through changes since 1995. In the theoretical model, we modify the Ricardian model of Dornbusch, Fischer and Samuelson (1977). The model analyzes two cases in which R&D subsidies can bring mutual benefits or beggar-thy-neighbor effects. In particular, propositions of the model suggest that specific subsidies that extend the export boundary will have beggar-thy-neighbor effects and that Home uses such subsidies only if it extends the export

boundary. This is in line with the WTO's stance in eventually placing R&D subsidies in the actionable subsidies category and thereby regulating R&D subsidies that are specific and cause adverse effects. In the empirical analysis, we find that the SCM Agreement in fact has had a significant impact on the trend of the government/public's support for firms' R&D activities in Korea. Moreover, we find supporting evidence of strategic R&D funding by the government/public sector as well as how some forms of R&D spending extend the export boundary. There are possible extensions for future research. First, it would be interesting to consider a multi-country model and analyze whether the SCM Agreement has differential welfare effects on countries with heterogeneous technology levels. This may offer some clue to the reason why some countries opposed the extension of the green light provision. Second, empirical analysis of data on other countries would make it possible to compare the magnitude of impact that the SCM Agreement has had on governments' R&D subsidies.

A Appendices

A.1 Proof of Proposition 3.

We prove that the Home welfare strictly increases if the subsidy interval $[\widehat{z}_1, \widehat{z}]$ is sufficiently small and $\widehat{z} > \widehat{z}_0$. For the verification of this finding, we begin by observing that the subsidy policy (14) contains the relationship between the level of $\frac{w}{w^*}$ and the interval $[\widehat{z}_1, \widehat{z}]$: if $\widehat{z}_1$ and $\widehat{z}$ are sufficiently close to the original boundary $\widehat{z}_0$, then

$$\frac{\partial(w/w^*)}{\partial \widehat{z}_1} < 0 \text{ and } \frac{\partial(w/w^*)}{\partial \widehat{z}} > 0. \tag{23}$$

The first inequality in (23) is given by (16) since $\frac{a^*(\widehat{z}_1)}{a(\widehat{z}_1)}$ is strictly decreasing in $\widehat{z}_1$. For the second inequality, we use (17) and define

$$\Phi \equiv \frac{w}{w^*} - \frac{L^*}{(1-\rho)L} \frac{\int_0^{\widehat{z}} b^*(z)dz}{\int_{\widehat{z}}^1 b(z)dz} = 0,$$

where

$$\rho = \frac{1}{L}\int_{\widehat{z}_1}^{\widehat{z}} s(z)a(z)dz = \frac{1}{L}\int_{\widehat{z}_1}^{\widehat{z}} \left(\frac{w/w^* - a^*(z)/a(z)}{[w/w^*]\gamma(z)} \right) a(z)dz.$$

We then derive

$$\frac{\partial(w/w^*)}{\partial\widehat{z}} = -\frac{\partial\Phi/\partial\widehat{z}}{\partial\Phi/\partial(w/w^*)}. \tag{24}$$

We first observe that the denominator of (24) becomes

$$\frac{\partial\Phi}{\partial(w/w^*)} = 1 - \frac{L^*\int_{\widehat{z}_1}^{\widehat{z}}\left(\frac{a^*(z)/a(z)}{[w/w^*]^2\gamma(z)}\right)a(z)dz - L^*s(\widehat{z}_1)a(\widehat{z}_1)\frac{d\widehat{z}_1}{d(w/w^*)}}{(1-\rho)^2L^2}\frac{\int_0^{\widehat{z}}b^*(z)dz}{\int_{\widehat{z}}^1 b(z)dz}, \tag{25}$$

where $s(\widehat{z}_1) = \frac{w/w^* - a^*(\widehat{z}_1)/a(\widehat{z}_1)}{[w/w^*]\gamma(\widehat{z}_1)}$ and the term $\frac{d\widehat{z}_1}{d(w/w^*)}$ follows from (16): by defining $\alpha(\widehat{z}_1) \equiv \frac{a^*(\widehat{z}_1)}{a(\widehat{z}_1)} = \frac{w}{w^*}$, we can define an inverse function $\widehat{z}_1 = \alpha^{-1}(\frac{w}{w^*})$ and so obtain

$$\frac{d\widehat{z}_1}{d(w/w^*)} = \frac{1}{\alpha'(\widehat{z}_1)} < 0. \tag{26}$$

We now report that if $\widehat{z}$ and $\widehat{z}_1$ are sufficiently close to $\widehat{z}_0$, then $\frac{\partial\Phi}{\partial(w/w^*)} > 0$ since the RHS of (25) approaches 1: the term $(\frac{a^*(z)/a(z)}{[w/w^*]^2\gamma(z)})a(z)$ is bounded on $[\widehat{z}_1, \widehat{z}]$, while $s(\widehat{z}_1)$ approach zero as $\frac{w}{w^*}$ approaches $\frac{a^*(\widehat{z}_0)}{a(\widehat{z}_0)}$. We next observe that the numerator of (24) is

$$\frac{\partial\Phi}{\partial\widehat{z}} = -\frac{L^*s(\widehat{z})a(\widehat{z})}{(1-\rho)^2L^2}\frac{\int_0^{\widehat{z}}b^*(z)dz}{\int_{\widehat{z}}^1 b(z)dz} - \frac{L^*}{(1-\rho)L}\frac{b^*(\widehat{z})\int_{\widehat{z}}^1 b(z)dz + b(\widehat{z})\int_0^{\widehat{z}}b^*(z)dz}{\left(\int_{\widehat{z}}^1 b(z)dz\right)^2} < 0. \tag{27}$$

Note that for the derivation of (27), $\frac{w}{w^*}$ is held constant, which keeps $\widehat{z}_1$ constant. Now, having the inequalities in (23) in hand, we can argue that it is possible to develop the subsidy interval $[\widehat{z}_1, \widehat{z}]$ such that $\widehat{z}_1 < \widehat{z}_0 < \widehat{z}$ if the interval is sufficiently small: if $\widehat{z}$ increases slightly from $\widehat{z}_0$, then $\frac{w}{w^*}$ increases above $(\frac{w}{w^*})_0 = \frac{a^*(\widehat{z}_0)}{a(\widehat{z}_0)}$ given the relationship (24), and $\widehat{z}_1$ decreases from $\widehat{z}_0$ given the inequality in (26).

We next write the Home welfare in terms of $\widehat{z}_1$, as we show in (20), and obtain the welfare effect of an increase in $\widehat{z}_1$:

$$\frac{\partial v}{\partial\widehat{z}_1} = \frac{\partial\ln(y/y^*)}{\partial\widehat{z}_1} - \frac{\partial\ln(w/w^*)}{\partial\widehat{z}_1}\int_0^{\widehat{z}_1}b(z)dz + b(\widehat{z}_1)\left[\ln\frac{a^*(\widehat{z}_1)}{a(\widehat{z}_1)} - \ln(\frac{w}{w^*})\right]. \tag{28}$$

The last term in (28) becomes zero given (16). Knowing that $\ln(\frac{w}{w^*}) = \ln\frac{L^*}{(1-\rho)L} + \ln(\frac{y}{y^*})$ and thus

$$\frac{\partial\ln(y/y^*)}{\partial\widehat{z}_1} = \frac{\partial\ln(w/w^*)}{\partial\widehat{z}_1} - \frac{\partial\ln L^*/(1-\rho)L}{\partial\widehat{z}_1},$$

we can rewrite (28) as

$$\frac{\partial v}{\partial \widehat{z}_1} = \frac{\partial (w/w^*)/\partial \widehat{z}_1}{w/w^*} \int_{\widehat{z}_1}^{1} b(z)dz - \frac{\partial \ln L^*/(1-\rho)L}{\partial \widehat{z}_1}. \tag{29}$$

For the last term in (29), we derive

$$\frac{\partial \rho}{\partial \widehat{z}_1} = \frac{1}{L}\frac{\partial}{\partial \widehat{z}_1}\int_{\widehat{z}_1}^{\widehat{z}} s(z)a(z)dz = \frac{1}{L}\left(s(\widehat{z})a(\widehat{z})\frac{d\widehat{z}}{d\widehat{z}_1} - s(\widehat{z}_1)a(\widehat{z}_1) + \int_{\widehat{z}_1}^{\widehat{z}} \frac{\partial s(z)}{\partial \widehat{z}_1}a(z)dz \right) \tag{30}$$

where $s(z) = \frac{w/w^* - a^*(z)/a(z)}{[w/w^*]\gamma(z)}$. Suppose that $\widehat{z}_1$ increases and approaches $\widehat{z}_0$ so that $\widehat{z}$ decreases and approaches $\widehat{z}_0$. Then $s(\widehat{z})$ and $s(\widehat{z}_1)$ approach zero since $\frac{w}{w^*}$ approaches $\frac{a^*(\widehat{z}_0)}{a(\widehat{z}_0)}$. Thus, $\frac{\partial \rho}{\partial \widehat{z}_1}$ approaches to zero: the first two terms in the round bracket in (30) approach zero, and given that $s(z)$ is bounded on $[\widehat{z}_1, \widehat{z}]$, the last term also approaches zero as the interval $[\widehat{z}_1, \widehat{z}]$ becomes shorter and approaches zero. Now, we know from (29) that if the interval $[\widehat{z}_1, \widehat{z}]$ is sufficiently small, then $\frac{\partial v}{\partial \widehat{z}_1} < 0$ since the last term approaches zero, while the first term remains strictly negative as we show in (24).

Finally, suppose that $\widehat{z}$ increases slightly from $\widehat{z}_0$. Then $\widehat{z}_1$ decreases from $\widehat{z}_0$, and the Home welfare strictly increases, $\frac{\partial v}{\partial \widehat{z}_1}\frac{d\widehat{z}_1}{d\widehat{z}} > 0$. Hence, under the subsidy policy (14), if the interval $[\widehat{z}_1, \widehat{z}]$ is sufficiently small, then the Home welfare strictly increases. ■

A.2 Proof of Proposition 4.

There are two possible cases in the subsidy interval $[\widehat{z}_1, \widehat{z}_2]$: (i) $\widehat{z}_2 < \widehat{z}_0$ and (ii) $\widehat{z}_2 = \widehat{z}_0$. For (i), the new equilibrium with $\widehat{z}$ and $\frac{w}{w^*}$ has the export boundary below $\widehat{z}_0$, $\widehat{z} < \widehat{z}_0$. We consider three possible cases of $\widehat{z}$. First, $\widehat{z}$ is above the interval $[\widehat{z}_1, \widehat{z}_2]$, $\widehat{z}_2 < \widehat{z} < \widehat{z}_0$. In this case, the new equilibrium has the Home welfare

$$\begin{aligned} v = B &- \int_0^{\widehat{z}_1} b(z)\ln wa(z)dz - \int_{\widehat{z}_1}^{\widehat{z}_2} b(z)\ln w^*a^*(z)dz \\ &- \int_{\widehat{z}_2}^{\widehat{z}} b(z)\ln wa(z)dz - \int_{\widehat{z}}^{1} b(z)\ln w^*a^*(z)dz + \ln y. \end{aligned} \tag{31}$$

Since the interval $[\widehat{z}_1, \widehat{z}_2]$ is below $\widehat{z}$, we have

$$\frac{a^*(z)}{a(z)} > \frac{a^*(\widehat{z})}{a(\widehat{z})} = \frac{w}{w^*} \text{ for } z \in [\widehat{z}_1, \widehat{z}_2],$$

which means that

$$\ln w^* a^*(z) > \ln wa(z) \text{ for } z \in [\widehat{z}_1, \widehat{z}_2].$$

Replacing $\ln w^* a^*(z)$ in the third term in (31) with $\ln wa(z)$, we define

$$\begin{aligned}\widetilde{v} = B &- \int_0^{\widehat{z}_1} b(z) \ln wa(z) dz - \int_{\widehat{z}_1}^{\widehat{z}_2} b(z) \ln wa(z) dz \\ &- \int_{\widehat{z}_2}^{\widehat{z}} b(z) \ln wa(z) dz - \int_{\widehat{z}}^{1} b(z) \ln w^* a^*(z) dz + \ln y.\end{aligned}$$

Hence, $v < \widetilde{v}$. Rearranging $\widetilde{v}$ as

$$\begin{aligned}\widetilde{v} = B &+ \ln(\frac{y}{y^*}) + \ln L^* - \ln(\frac{w}{w^*}) \int_0^{\widehat{z}} b(z) dz \\ &- \int_0^{\widehat{z}} b(z) \ln a(z) dz - \int_{\widehat{z}}^{1} b(z) \ln a^*(z) dz,\end{aligned}$$

and comparing it to v_0, we find that $\widetilde{v} < v_0$,

$$\begin{aligned}\widetilde{v} - v_0 = &\left[\ln(\frac{y}{y^*}) - \ln(\frac{y}{y^*})_0\right] + \left[\ln(\frac{w}{w^*})_0 - \ln(\frac{w}{w^*})\right] \int_0^{\widehat{z}} b(z) dz \\ &+ \int_{\widehat{z}}^{\widehat{z}_0} b(z) \left[\ln(\frac{w}{w^*})_0 - \ln \frac{a^*(z)}{a(z)}\right] dz < 0.\end{aligned} \tag{32}$$

Now, given $v < \widetilde{v}$ and $\widetilde{v} < v_0$, it follows that $v < v_0$. Second, $\widehat{z}$ is somewhere in the interval $[\widehat{z}_1, \widehat{z}_2]$, $\widehat{z}_1 < \widehat{z} \leq \widehat{z}_2 < \widehat{z}_0$, where the last inequality is given by (i) above. The new equilibrium has the Home welfare

$$v = B - \int_0^{\widehat{z}_1} b(z) \ln wa(z) dz - \int_{\widehat{z}_1}^{\widehat{z}} b(z) \ln w^* a^*(z) dz - \int_{\widehat{z}}^{1} b(z) \ln w^* a^*(z) dz + \ln y.$$

Rearranging, we have

$$\begin{aligned}v = B &+ \ln(\frac{y}{y^*}) + \ln L^* - \ln(\frac{w}{w^*}) \int_0^{\widehat{z}_1} b(z) dz \\ &- \int_0^{\widehat{z}_1} b(z) \ln a(z) dz - \int_{\widehat{z}_1}^{1} b(z) \ln a^*(z) dz.\end{aligned} \tag{33}$$

Observing that v in (33) looks similar to $\widetilde{v}$ if $\widehat{z}_1$ is replaced by $\widehat{z}$, we can calculate $v - v_0$ and show that $v < v_0$. Third, $\widehat{z}$ is below the interval $[\widehat{z}_1, \widehat{z}_2]$, $\widehat{z} \leq \widehat{z}_1$. In this case, the new

equilibrium has the Home welfare

$$v = B - \int_0^{\widehat{z}} b(z) \ln wa(z) dz - \int_{\widehat{z}}^1 b(z) \ln w^* a^*(z) dz + \ln y. \tag{34}$$

It is easy to show that v in (34) is similar to (33) if $\widehat{z}_1$ is replaced by $\widehat{z}$. Thus, $v < v_0$ immediately follows. Finally, we consider the case (ii) in which the subsidy interval $[\widehat{z}_1, \widehat{z}_2]$ becomes $[\widehat{z}_1, \widehat{z}_0]$. If the new equilibrium boundary $\widehat{z}$ is below $\widehat{z}_0$, $\widehat{z} < \widehat{z}_0$, then the proof analogously obtains from the proof in (i). We therefore focus on the case in which $\widehat{z} = \widehat{z}_0 = \widehat{z}_2$. The Home welfare then takes the form of (20), and the comparison with v_0 shows that

$$v - v_0 = \left[\ln(\frac{w}{w^*})_0 - \ln(\frac{w}{w^*})\right] \int_0^{\widehat{z}_1} b(z) dz + \int_{\widehat{z}_1}^{\widehat{z}_0} b(z) \left[\ln(\frac{w}{w^*})_0 - \ln \frac{a^*(z)}{a(z)}\right] dz < 0.$$

In summary, under the subsidy policy (22), the Home welfare strictly decreases. ■

References

Antràs, Pol and Robert W. Staiger. 2012a. "Offshoring and the Role of Trade Agreements." *American Economic Review* 102(7): 3140-3183.

Antràs, Pol and Robert W. Staiger. 2012b. "Trade Agreements and the Nature of Price Determination." *American Economic Review: Papers and Proceedings* 102(3): 470-476.

Bagwell, Kyle and Seung Hoon Lee. 2015. "Trade Policy under Monopolistic Competition with Firm Selection." Mimeogr., Stanford University.

Bagwell, Kyle and Robert W. Staiger. 1999. "An Economic Theory of GATT." *American Economic Review* 89(1): 215-248.

Bagwell, Kyle and Robert W. Staiger. 2001. "Domestic Policies, National Sovereignty, and International Economic Institutions." *Quarterly Journal of Economics* 116: 519-562.

Bagwell, Kyle and Robert W. Staiger. 2002. *The Economics of the World Trading System.* Cambridge, MA: MIT Press.

Bagwell, Kyle and Robert W. Staiger. 2006. "Will International Rules on Subsidies Disrupt the World Trading System?" *American Economic Review* 96(3): 877-895.

Bagwell, Kyle and Robert W. Staiger. 2012a. "The Economics of Trade Agreements in the Linear Cournot Delocation Model." *Journal of International Economics* 88(1): 32-46.

Bagwell, Kyle and Robert W. Staiger. 2012b. "Profit Shifting and Trade Agreements in Imperfectly Competitive Markets." *International Economic Review* 53(4): 1067-1104.

Bagwell, Kyle and Robert W. Staiger. 2015. "Delocation and Trade Agreements in Imperfectly Competitive Markets." *Research in Economics* 69(2): 132-156.

Bagwell, Kyle and Robert W. Staiger. 2016. "The Design of Trade Agreements" In *Handbook of Commercial Policy,* edited by Kyle Bagwell and Robert W. Staiger, Volume 1A: Elsevier.

Bajona, Claustre and Josh Ederington. 2012. "Domestic Policies, Hidden Protection and the GATT/WTO." Available at SSRN: http://ssrn.com/abstract=2140943.

Brou, Daniel and Michele Ruta. 2013. "A Commitment Theory of Subsidy Agreements." *The B.E. Journal of Economic Analysis & Policy* 14(1): 239-270.

Coppens, Dominic. 2014. *WTO Disciplines on Subsidies and Countervailing Measures: Balancing Policy Space and Legal Constraints*. Cambridge: Cambridge University Press.

DeRemer, David R. 2013. "The Evolution of International Subsidy Rules." ECARES Working Paper 2013-45.

Dornbusch, Rüdiger, Stanley Fischer and Paul Samuelson. 1977. "Comparative Advantage, Trade, and Payments in a Ricardian Model with a Continuum of Goods." *American Economic Review* 67(5): 823-839.

Horn, Henrik, Giovanni Maggi and Robert W. Staiger. 2010. "Trade Agreements as Endogenously Incomplete Contracts." *American Economic Review* 100(1): 394-419.

Itoh, Motoshige and Kazuharu Kiyono. 1987. "Welfare-Enhancing Export Subsidies." *Journal of Political Economy* 95(1): 115-137.

Jackson, John H. 2000. *The Jurisprudence of GATT and the WTO: Insights on Treaty Law and Economic Relations*. Cambridge: Cambridge University Press.

Lee, Gea M. 2016. "Optimal International Agreement and Restriction on Domestic Efficiency." *Journal of International Economics* 99: 138-155.

Lee, Gea M. 2016. "Subsidies and Countervailing Duties" In *Handbook of Commercial Policy,* edited by Kyle Bagwell and Robert W. Staiger, Volume 1B: Elsevier.

Mrazova, Monika. 2011. "Trade Agreements When Profits Matter." Mimeogr., London School of Economics.

OECD 2017. "R&D Tax Incentive Country Profiles 2016: Korea" Measuring R&D Tax Incentives, `http://oecd/rdtax`, Directorate for Science, Technology, and Innovation, March 2017.

Ossa, Ralph. 2011. "A 'New-Trade' Theory of GATT/WTO Negotiations." *Journal of Political Economy* 119(1): 122-152.

Sauré, Philip. 2014. "Domestic Policies in Self-Enforcing Trade Agreements." *European Economic Review* 68: 19-30.

Staiger, Robert W. and Alan O. Sykes. 2017. "How Important Can the Non-Violation Clause Be for the GATT/WTO? " *American Economic Journal: Microeconomics* 9(2): 149-187.

Venables, Anthony J. 1985. "Trade and Trade Policy with Imperfect Competition: The Case of Identical Products and Free Entry." *Journal of International Economics* 19(1-2): 1-19.

Venables, Anthony J. 1987. "Trade and Trade Policy with Differentiated Products: A Chamberlinian-Ricardian Model." *Economic Journal* 97(387): 700-717.