R&D Subsidies and Trade: Rationale for WTO Rules and Empirical Evidence

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Introduction

- Trade agreements have evolved into a deep-integration form, which involves regulations of behind-the-border measures.
- A notable legal establishment that goes along with this trend is the Subsidies and Countervailing Measures (SCM) Agreement adopted by the WTO to strengthen the GATT subsidy rules.
- The legitimacy of strengthening existing subsidy disciplines has been extensively discussed in association with its potential benefit or harm.
- By contrast, the legitimacy of regulating R&D subsidies in the world trading system has rarely been assessed.
- In fact, a government's support for R&D activities has often been perceived as harmless to other countries due to externalities.

Introduction

- However, a government's R&D subsidization has another critical aspect that carries different implications in international trade.
- In reality, a large part of R&D activities are highly practical and intended for commercial success in specific products with no significant externalities.
- Therefore, governments with opportunistic motives may selectively subsidize practical research to promote certain firms/industries to affect not only domestic but international markets.

Questions

- We shed light on R&D subsidies from this practical perspective and address the two main questions to theoretically and empirically analyze the legitimacy of the WTO rules on R&D subsidies.

- 1) Are R&D subsidies harmless or beggar-thy-neighbor policies?

- 2) Is there an empirical evidence that R&D subsidies are used as a strategic policy tool with which to affect trade?

Context of Legal Environment

- We study these questions in the context of the actual legal environment imposed by the SCM Agreement, which has two ideal features.
- 1) It regulates R&D subsidies deemed to be specifically targeted and cause adverse effects to other countries.
  - We associate this specificity criterion with the R&D subsidies offered for a narrow and specific range of goods in our theoretical model.
  - We assess the theoretical foundations of the WTO's stance on regulating R&D subsidies.
- 2) The SCM Agreement gradually tightened regulations on R&D subsidies in two distinct phases.
  - From 1995 to 1999: non-actionable/"green light" subsidies
  - Since 2000: actionable/"yellow light" subsidies
  - We test whether a government exploits this opportunity to strategically subsidize R&D activities.

Theoretical Analysis

- We adopt the Ricardian trade model of Dornbusch, Fischer and Samuelson (1977), and analyze two contrasting policies:
  - R&D subsidies offered generally for all Home-produced goods.
  - R&D subsidies offered only for a specific range of goods.
- We find that R&D subsidies offered for all original Home-produced goods are harmless to Foreign.
- We report the conditions under which R&D subsidies are classified as beggar-thy-neighbor policies.
  - The subsidy interval is sufficiently narrow and the export boundary extends.
  - Home government using R&D subsidies manipulates double-factoral terms of trade by lifting the relative productivity on the subsidy level.

Empirical Analysis

- We focus on the case of South Korea, which is a typical example of an open economy that invests heavily in R&D activities.
- We track R&D subsidies given to firms in sixteen industries within the manufacturing sector from 1991 to 2010.
  - Data from Report on the Survey of Research and Development
- We find evidence of a strategic use of R&D subsidies by the Korean government in response to regulation changes.
  - There is a significant increase in R&D subsidies during the green light period.
  - R&D subsidization is sensitive to how intensively a firm conducts applied/development research.
  - The trade pattern is changed during the green light period and is sensitive to practical research spending.

Literature Review

- Terms-of-trade theory of trade agreements.
  - Bagwell and Staiger (2001, 2006)
- A recent literature on deep-integration approach.
  - Antràs and Staiger (2012a, 2012b); Brou and Ruta (2013); Bajona and Ederington (2012); Lee (2016b); Horn, Maggi and Staiger (2010)
- There has been no theoretical assessment of its specificity criterion in the SCM Agreement, which is the key regulation guideline.
- The insight of our theoretical analysis is closely related to the work of Itoh and Kiyono (1987).

Literature Review

- The existing empirical studies investigate whether subsidies affect export performance by using firm-level or plant-level data.
  - Testing the link between subsidies and trade performance at the micro level.
  - Girma et al. (2009) and Görg, Henry, and Storbl (2008).
- Although our study also uses micro-level data on R&D subsidies, it is distinct from these studies.
  - The question of interest is not merely whether subsidies improve export performance.
  - We highlight the WTO subsidy rules that ultimately affect trade patterns via shaping subsidy policies.

Institutional Background on the SCM Agreement

- The SCM Agreement regulates only "specific subsidies" and classifies subsidies into two basic categories:
  - i) **Prohibited (Red):** Export subsidies and local-content subsidies. (Except as provided in the Agreement on Agriculture)
  - ii) **Actionable (Yellow):** Subject to challenge in the WTO or to countervailing measures if they cause "adverse effects" to the interests of another member.
- There are three types of adverse effects:
  - i) "injury" to a domestic industry is caused by subsidized imports in the territory of the complaining member.
  - 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.
  - iii) "nullification or impairment" of the benefits expected by another member occurs when subsidization undercuts the market access reasonably expected from a bound tariff reduction.

Institutional Background on the SCM Agreement

- **Non-actionable (Green):** Apart from these two basic categories, Article 8 identifies another category of non-actionable subsidies:
  - i) R&D subsidies for research activities conducted by firms/higher education/research establishments on a contract basis with firms.
  - ii) Regional support for disadvantaged regions within the territory of a WTO member.
  - iii) Environmental subsidies for easing firms' compliance with new environmental requirements in their existing facilities.
- Article 31 stipulated that Article 8 would be a provisional application for the first five years.
- The Committee would review before the end of the period for a possible extension or modification.

Institutional Background on the SCM Agreement

- A meeting was held on December 20, 1999 to discuss the possibility of extending the application of Article 31.
  - As no clear consensus could be reached, Article 8 finally expired on January 1, 2000.
- Since then, the three types of non-actionable subsidies including R&D subsidies are now actionable.
- Despite these institutional changes, procedural or legal actions in responses have been lacking.
  - Four cases on civil aircraft (DS70, DS316, DS317, and DS353).
  - Seeming under-utilization of the rules does not mean that they are unimportant.
  - Procedural or legal outcomes are different from changes in R&D subsidies funded by governments.

A Ricardian Analysis of R&D Subsidies
Basic Model

- The Ricardian model is adopted in the context of the actual legal environment imposed by the SCM Agreement.
- A standard Dornbusch, Fischer and Samuelson (1977) model
  - A continuum of goods indexed by $z \in [0, 1]$.
  - Two trading countries, Home and Foreign, whose markets are perfectly competitive.
  - One factor of production with wages, w and w^*, and endowments, L and L^*.
  - CRS: Constant unit labor requirements for good z, $a(z)$ and $a^*(z)$.
  - Goods are ordered on $[0, 1]$: $\frac{a^*(z)}{a(z)}$ is continuous and strictly decreasing. Home (Foreign) has a comparative advantage in goods with lower (higher) z.
  - Tariffs are fixed at zero.

Production Side

- The unit production cost of good $z \in [0, 1]$ equals $wa(z)$.
- The Home government unilaterally offers the R&D subsidy $s(z)wa(z)$ for good $z \in [z_1, z_2]$.
  - We consider R&D subsidies offered for a range of goods.
  - $s(z) > 0$ is the policy instrument and $[z_1, z_2]$ is the interval of subsidized goods.
  - The policy reduces the production cost by $s(z)\gamma(z)wa(z)$ for good z.
  - Parameter $\gamma(z) > 0$ takes account of the productivity effect of $s(z)$.
  - If $\gamma(z)$ is close to zero, the R&D subsidy is mostly wasted and does little to improve the productivity.
  - We focus on $s(z)\gamma(z) < 1$.

Production Side

- We define the production-side requirement based on the combinations of the export boundary and relative wage, $(\widehat{z}, \frac{w}{w^*})$, that satisfy

$$\frac{w}{w^*} \leq \alpha(z) \text{ for } z \in [0, \widehat{z}] \text{ and } \frac{w}{w^*} > \alpha(z) \text{ for } z \in (\widehat{z}, 1], \qquad (1)$$

  where $\alpha(z)$ is the relative productivity for Home and shifts on the subsidy interval,

$$\alpha(z) \equiv \begin{cases} \frac{1}{1-s(z)\gamma(z)} \frac{a^*(z)}{a(z)} & \text{for } z \in [z_1, z_2] \\ \frac{a^*(z)}{a(z)} & \text{for } z \notin [z_1, z_2]. \end{cases}$$

- This requirement (1) indicates that $(\widehat{z}, \frac{w}{w^*})$ divides the interval $[0, 1]$ into two non-empty sets.
  - Home has lower marginal costs for $z \in [0, \widehat{z}]$
  - Foreign has strictly lower marginal costs for $z \in [\widehat{z}, 1]$

Demand Side

- Home and foreign welfare are represented by consumers' utility functions since profits are zero in perfectly competitive markets.
- Consumers have identical Cobb-Douglas preferences in Home and Foreign, respectively :

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

  - $b(z)$ and $b^*(z)$denote the consumer's share of expenditure on good z in Home and Foreign, respectively.

$$\int_0^1 b(z) dz = \int_0^1 b^*(z) dz = 1$$

Demand Side

- To describe the Home welfare, we use the consumer problem:

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

- The consumer's choice in Home becomes $c(z) = b(z)\frac{y}{p(z)}$, where $p(z)$ is the marginal-cost pricing under perfect competition:

$$p(z) = \begin{cases} w[1 - s(z)\gamma(z)]a(z) & \text{for } z \leq \widehat{z} \text{ and } z \in [z_1, z_2] \\ wa(z) & \text{for } z \leq \widehat{z} \text{ and } z \notin [z_1, z_2] \\ w^* a^*(z) & \text{for } z > \widehat{z}. \end{cases}$$

Demand Side

- We impose two requirements on the demand side:
  - **Budget Balance:** Home R&D expenditure should be financed by labor income,

$$\int_{z_1}^{z_2} s(z)wa(z)dz = \rho wL, \text{ or equivalently } \rho = \frac{\int_{z_1}^{z_2} s(z)a(z)dz}{L}.$$

  - **Trade Balance:** Home imports and Home exports should be the same,

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

    where $(1-\rho)wL = y$ and $w^*L^* = y^*$.

- The demand-side requirement is defined by $(\widehat{z}, \frac{w}{w^*})$ that satisfies both,

$$\frac{w}{w^*} = \beta(\widehat{z}), \tag{2}$$

where $\beta(\widehat{z}) \equiv \frac{L^*}{(1-\rho)L} \frac{\int_0^{\widehat{z}} b^*(z)dz}{\int_{\widehat{z}}^1 b(z)dz} = \frac{L^*}{L-\int_{z_1}^{z_2} s(z)a(z)dz} \frac{\int_0^{\widehat{z}} b^*(z)dz}{\int_{\widehat{z}}^1 b(z)dz}$.

Trade Equilibrium

- Trade equilibrium is $(\widehat{z}, \frac{w}{w^*})$ that satisfies (1) and (2). Once the export boundary $\widehat{z}$ is determined, the relative income $\frac{y}{y^*}$ is given by the trade balance requirement:

$$\frac{y}{y^*} = \frac{\int_0^{\widehat{z}} b^*(z)dz}{\int_{\widehat{z}}^1 b(z)dz}. \tag{3}$$

- Equilibrium $(\widehat{z}, \frac{w}{w^*})$ has welfare functions:

$$\begin{aligned} v &= B + \ln(\tfrac{y}{y^*}) + \ln L^* - \ln(\tfrac{w}{w^*}) \int_0^{\widehat{z}} b(z)dz - \int_0^{\widehat{z}} b(z) \ln a(z)dz \\ &\quad - \int_{\widehat{z}}^1 b(z) \ln a^*(z)dz - \int_{z\in P} b(z) \ln[1 - s(z)\gamma(z)]dz; \\ v^* &= B^* - \ln(\tfrac{y}{y^*}) + \ln(1-\rho)L + \ln(\tfrac{w}{w^*}) \int_{\widehat{z}}^1 b^*(z)dz - \int_0^{\widehat{z}} b^*(z)a(z)dz \\ &\quad - \int_{\widehat{z}}^1 b^*(z) \ln a^*(z)dz - \int_{z\in P} b^*(z) \ln[1 - s(z)\gamma(z)]dz, \end{aligned}$$

where

$$P \equiv \{z : z_1 \le z \le z_2\} \cap \{z : 0 \le z \le \widehat{z}\}$$

Original Equilibrium under No Subsidies

- Under no subsidies, $s(z) = 0$ for all z.
- The original equilibrium $(\widehat{z}_0, (\frac{w}{w^*})_0)$ satisfies $(\frac{w}{w^*})_0 = \alpha(\widehat{z}_0) = \beta(\widehat{z}_0)$,

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

  From (3), we also obtain

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

- The original equilibrium $(\widehat{z}_0, (\frac{w}{w^*})_0)$ has welfare functions, v_0 and v_0^*.

SCM Agreement and Two Policy Options

- We associate the specificity criterion with R&D subsidies offered for a specific range of goods and analyze two contrasting policies:
  - Policy I: R&D subsidies offered generally for all Home-produced goods;
  - Policy II: R&D subsidies offered only for a specific range of goods.
- R&D subsidies generate two forces in conflict:
  - The production-side function $\alpha(z)$ captures the productivity effects of R&D subsidies.
  - The demand-side function $\beta(z)$ reflects the government R&D expenditure borne by labor. $\beta(z)$ shifts as if there is a decrease in labor endowment from L to $(1-\rho)L$, causing an increase in $\frac{w}{w^*}$.
  - When $\gamma(z)$ becomes larger, the productivity effects become more dominant.

Policy I: Mutually Beneficial Subsidies

Proposition

Proposition 1. Suppose that Home offers R&D subsidies for all $z \in [0, \hat{z}_0]$. *(i) If* $\gamma(z)$ *is sufficiently large for* $z \in [0, \hat{z}_0]$, *or*
(ii) for any given $\frac{L^*}{L}$, *if* L *is sufficiently large*
and $\frac{1}{1-s(z)\gamma(z)} \frac{a^*(z)}{a(z)} \geq \beta(\hat{z}_0)$ *for* $z \in [0, \hat{z}_0]$, *then* $v > v_0$ *and* $v^* > v_0^*$ *in equilibrium.*

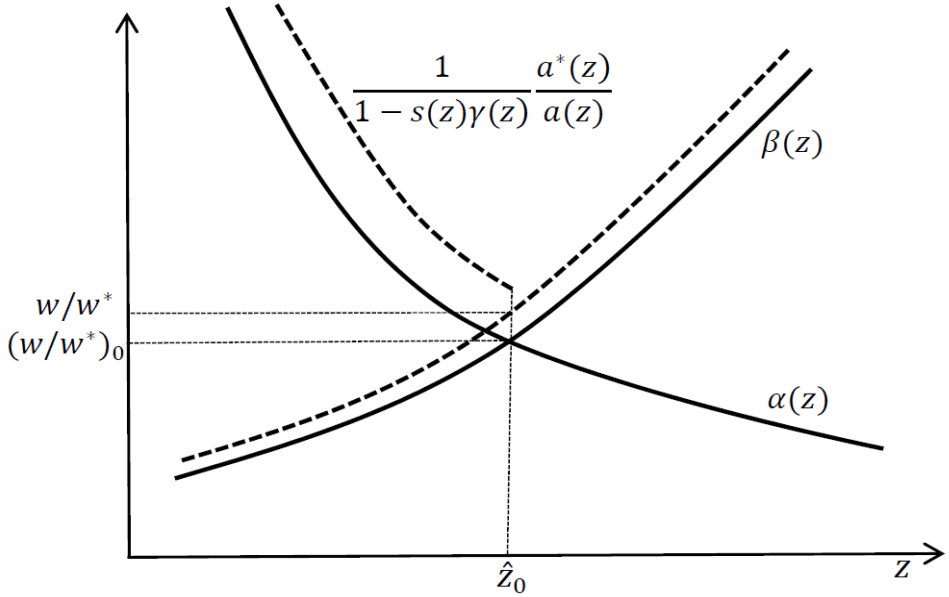


Figure:

Policy I: Mutually Beneficial Subsidies

$$v - v_0 = \underbrace{[\ln(\tfrac{w}{w^*})_0 - \ln(\tfrac{w}{w^*})]\int_0^{\widehat{z}_0} b(z)dz}_{(-)} \underbrace{- \int_0^{\widehat{z}_0} b(z)\ln[1 - s(z)\gamma(z)]dz}_{(+)}$$

$$v^* - v_0^* = \underbrace{[\ln(\tfrac{w}{w^*})_0 - \ln(\tfrac{w}{w^*})]\int_0^{\widehat{z}_0} b^*(z)dz}_{(-)} \underbrace{- \int_0^{\widehat{z}_0} b^*(z)\ln[1 - s(z)\gamma(z)]dz}_{(+)}$$

- Welfare loss: Home produces goods $z \in [0, \widehat{z}_0]$ at a higher relative wage, $\frac{w}{w^*} = \beta(\widehat{z}_0) > (\frac{w}{w^*})_0$.
- Welfare gain: Increased productivity on Home-produced goods $z \in [0, \widehat{z}_0]$ are induced by R&D subsidies.
- Under (i) or (ii), productivity effects relative to the increase in $\frac{w}{w^*}$ are dominant in Home.

Policy I: Harmless Subsidies

- When conditions in Proposition 1 fail, can Policy I still be used for beggar-thy-neighbor purpose?
  - Proposition 2 shows that this is unlikely.

Proposition

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

- The use of such subsidies cannot increase Home welfare and decrease Foreign welfare.
  - If the original boundary $\widehat{z}_0$ remains intact (as in Proposition 1), then $v - v_0 = v^* - v_0^*$.
  - If the new equilibrium satisfies $\widehat{z} < \widehat{z}_0$, then $v - v_0 - (v^* - v_0^*) < 0$.

Policy I: Difficult to Damage Foreign

- What if Home offers R&D subsidies for all Home-produced goods while extending the set of Home-produced goods, $\widehat{z} > \widehat{z}_0$, which results in some import goods becoming export goods?

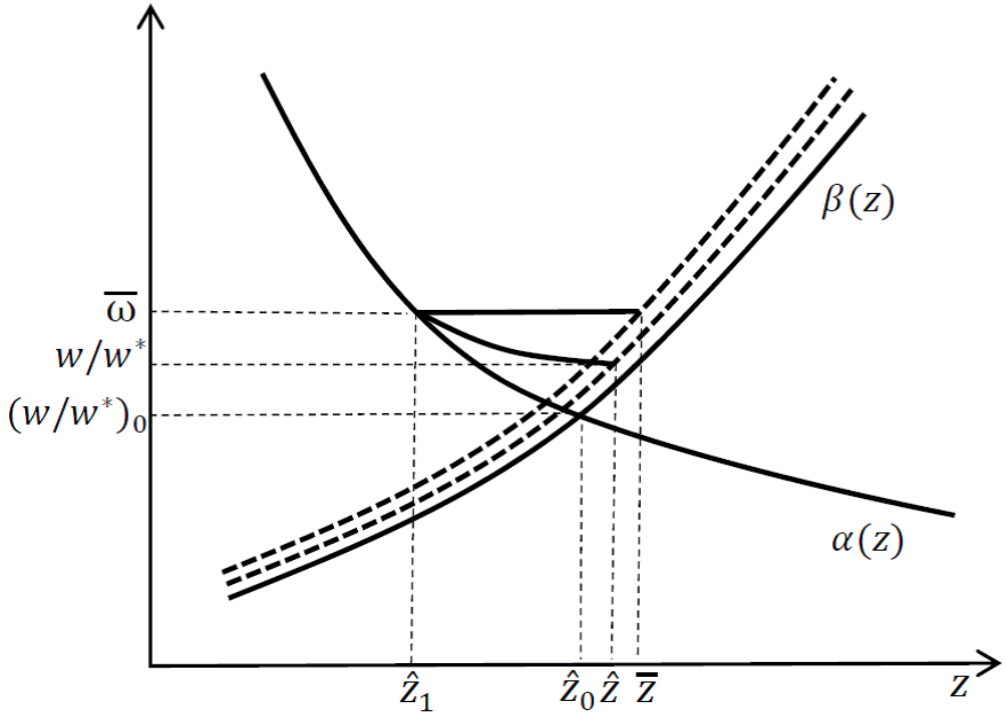
- Policy I is still difficult to be used for beggar-thy-neighbor purpose.
  - This policy is only available when it entails sufficiently large productivity effects on the original Home-produced goods.
  - Thus, Foreign also benefits from the same productivity effects.

Policy II: Beggar-Thy-Neighbor Policies

- We now analyze Policy II in which R&D subsidies are offered only for a specific range of goods.
- The main question is whether this policy option can be used for beggar-thy-neighbor purpose.
- Itoh and Kiyono (1987) consider ad valorem export subsidies and show that Home can increase its own welfare if subsidies are offered for a specific range of goods to extend the export boundary.
- We show that Home can devise beggar-thy-neighbor R&D policies essentially by restricting the productivity effects that potentially benefit Foreign to a sufficiently narrow interval.

Policy II: Beggar-Thy-Neighbor Policies

- Suppose that Home offers R&D subsidies for a specific range of goods $z \in [\hat{z}_1, \hat{z}]$ such that the relative productivity on the subsidy interval $[\hat{z}_1, \hat{z}]$ is any continuous and nonincreasing function with $s(\hat{z}_1) = 0$.



Policy II: Beggar-Thy-Neighbor Policies

Proposition

Proposition 3. Suppose that Home offers R&D subsidies for a specific range of goods $z \in [\widehat{z}_1, \widehat{z}]$ such that $\alpha(z)$ is any continuous and non-increasing function on $[\widehat{z}_1, \widehat{z}]$ with the endpoint condition $s(\widehat{z}_1) = 0$. If the subsidy interval $[\widehat{z}_1, \widehat{z}]$ is sufficiently small and the export boundary is extended, $\widehat{z} > \widehat{z}_0$, then $v > v_0$ and $v^* < v_0^*$ in the equilibrium.

- The conditions have two main ingredients:
  - The subsidy interval is sufficiently small: Home restricts the productivity effects that bring welfare gains to Foreign.
  - The export boundary extends: Home lifts the relative productivity intensively on a narrow interval near $\widehat{z}_0$, Home can always extend the export boundary while raising the relative wage.

Policy II: Beggar-Thy-Neighbor Policies

- If $\widehat{z}_1$ is sufficiently close to $\widehat{z}_0$, then

$$\begin{aligned}
\frac{d(v-v_0)}{d\widehat{z}} &\approx \frac{d\ln\beta(\widehat{z}_0;s=0)}{d\widehat{z}}\int_{\widehat{z}_0}^{1} b(z)dz > 0; \\
\frac{d(v^*-v_0^*)}{d\widehat{z}} &\approx -\frac{d\ln\beta(\widehat{z}_0;s=0)}{d\widehat{z}}\int_{0}^{\widehat{z}_0} b^*(z)dz < 0.
\end{aligned}$$

- Home government using R&D subsidies manipulates the double-factoral terms of trade, $\frac{w}{w^*}$, by lifting the relative productivity on the subsidy interval.

- The conditions in Proposition 3 ensure that such terms-of-trade manipulation causes the beggar-thy-neighbor externalities.
  - When $(\widehat{z}, \frac{w}{w^*})$ moves away from $(\widehat{z}_0, (\frac{w}{w^*})_0)$, Foreign produced goods $z \in [\widehat{z}_0, 1]$ become more affordable for Home consumers while Home produced goods $z \in [0, \widehat{z}_0]$ become less affordable for Foreign consumers.

Policy II: Beggar-Thy-Neighbor Policies

- Lastly, we show that the beggar-thy-neighbor policies in Proposition 3 may decrease the global welfare, $(v - v_0) + (v^* - v_0^*) < 0$

Corollary

Suppose that Home offers the same R&D subsidies as in Proposition 3 on a sufficiently small interval $z \in [\widehat{z}_1, \widehat{z}]$ and extends the export boundary $\widehat{z} > \widehat{z}$. If $\int_0^{\widehat{z}_0} b^*(z)dz > \int_{\widehat{z}_0}^1 b(z)dz$, then $v > v_0, v^* < v_0^*$, and $(v - v_0) + (v^* - v_0^*) < 0$ in the equilibrium.

- This additional condition ensures that Foreign welfare losses on the original Home-produced goods $z \in [0, \widehat{z}_0]$ are greater than Home welfare gains on the original Foreign-produced goods $z \in [\widehat{z}_0, 1]$.

Data

- In the empirical analysis, we analyze the case of Korea.
  - Korea has the second highest R&D intensity of 4.34% (OECD, 2015).
  - The sum of exported and imported goods and services as a share of GDP in Korea grew from 15% in 1960 to 78% in 2016 (World Bank).
- We focus on the government's R&D subsidies to firms using data from " Report on the Survey of Research and Development."
  - Survey data published annually to collect information on R&D activities for policymaking purposes.
  - Track firms in sixteen industries in the manufacturing sector at the 3-digit level according to the ISIC Rev.2 from 1991 to 2010.
- The survey items include information such as the following:
  - R&D expenditure by research types, source, field, and etc.

Summary of Statistics

Table: Sample Summary Statistics.

	Average sample size	Average retrieval rate
Research institute	320.40	93.85%
College/university	333.30	96.98%
Medical institute	449.63	93.85%
Firm	8,317.80	81.65%

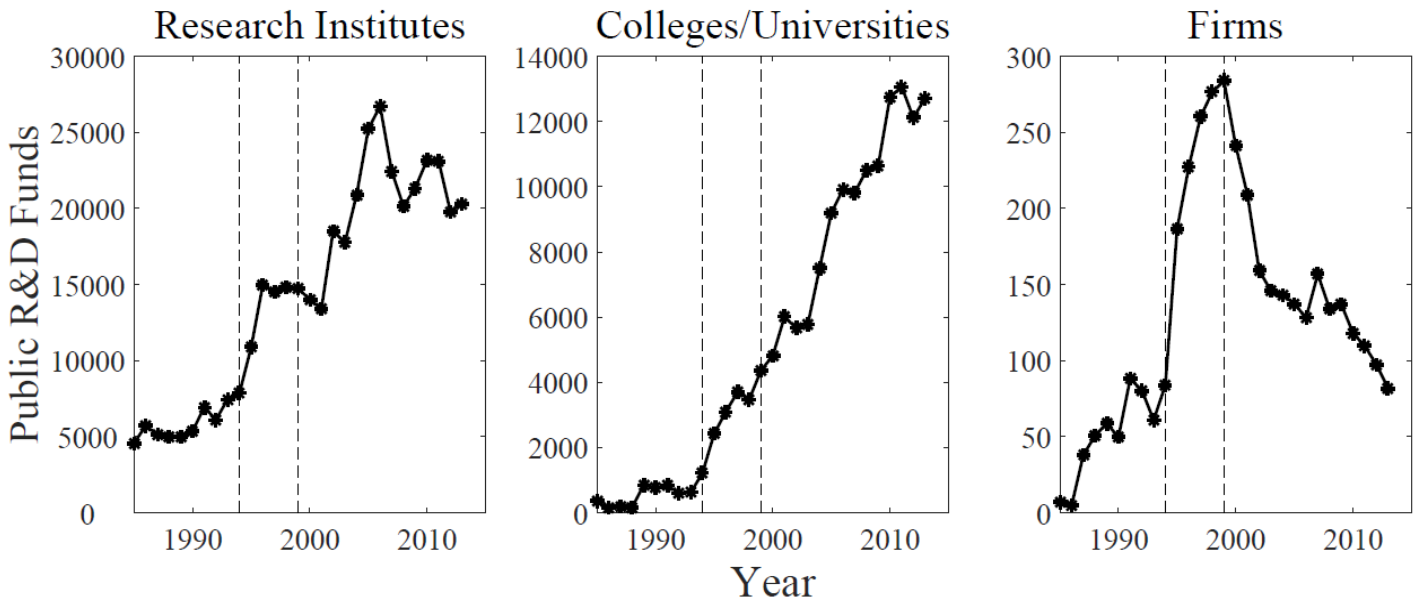
Summary of Statistics

Table: Average R&D Funds By Organizations.

	Research Institute	College/University	Firm
Average amount (million KRW)	18,476.67	7,871.85	3325.40
<Source of Funds>			
Government/Public sector	84.53%	62.83%	5.08%
Private sector	15.31%	36.87%	94.64%
Foreign sector	0.15%	0.28%	0.26%
<Research Type>			
Basic research	21.08%	42.69%	9.50%
Applied research	35.95%	29.37%	19.97%
Development research	42.95%	27.93%	70.52%

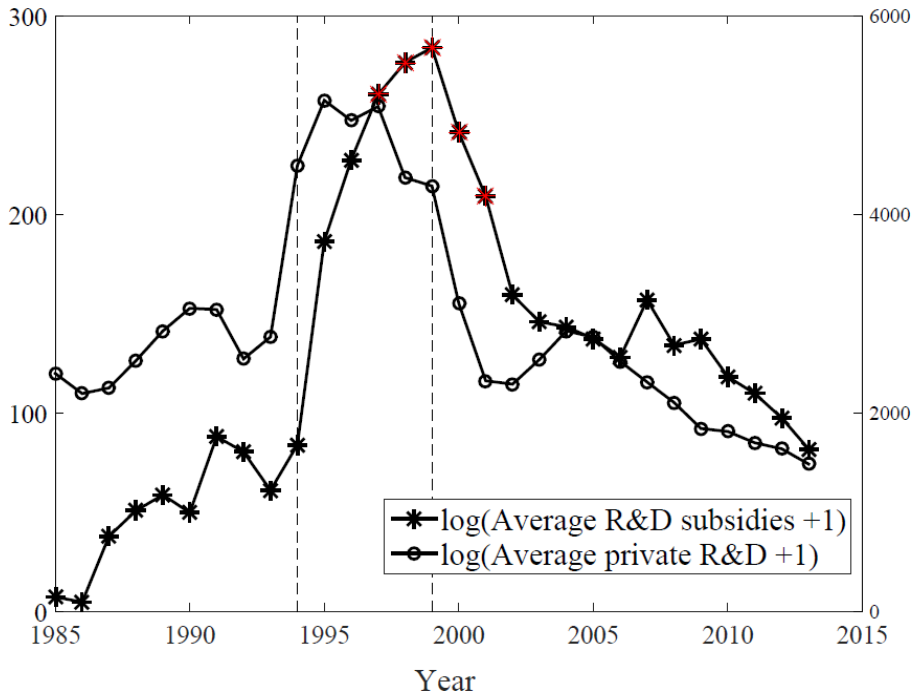
Summary of Statistics

- Average R&D subsidies financed by the government/public sector across organizations shows different trends.
- In particular, the trend for firms is hump-shaped where it increases sharply from 1995 and reaches the peak in 2000.
- This coincides with the green light period.



Summary of Statistics

- There is a possibility that an increase R&D subsidies during the green light period was driven by the replacement of falling private R&D funds during the Asian Financial Crisis.
  - If this were the case, then the increasing trend of R&D subsidies would persist even after 1999 as private R&D funds continued to fall.
- Moreover, most of the increase in R&D subsidies occurred in the earlier years of the green light period.



Summary of Statistics

Table: Heterogeneous R&D Expenditure Across Industries.

	Avg R&D Amount	Share of Public Funds	Share of Dev Research
Food products and beverages	1,271.70	3.23%	64.18%
Textiles	1,242.94	10.78%	65.12%
Wearing apparel and fur	1,092.40	1.78%	71.39%
Leather products and footwear	1,253.81	3.38%	83.65%
Pulp, paper, and paper products	925.31	3.66%	68.66%
Printing and reproduction of recorded media	1,460.28	3.00%	78.59%
Coke, refined petroleum, and nuclear fuel	9,136.08	6.44%	64.37%
Chemicals and chemical products	1,995.88	6.66%	60.69%
Rubber and plastic products	1,664.24	3.92%	79.38%
Non-metallic mineral products	1,453.41	5.90%	66.15%
Basic metals	2,892.94	6.64%	70.16%
Fabricated metal products	779.69	10.91%	74.10%
Electrical equipment	3250.80	8.91%	73.95%
Other machinery and equipment	1,457.90	13.69%	77.76%
Motor vehicles, trailers, and semitrailers	10,545.95	1.92%	73.56%
Other transport equipment	10,376.96	18.12%	76.24%

Response to Different Regulation Phases

- We first investigate whether R&D subsidies change in response to regulation changes given by the SCM Agreement.

$$
\begin{aligned}
& log(\text{Average R\&D subsidies} + 1)_{k,m,t} \\
= \; & \alpha_0 + \alpha_1 log(\text{Average R\&D subsidies} + 1)_{k,m,t-1} \\
+ \; & \alpha_2 log(\text{Average private R\&D amount} + 1)_{k,m,t-1} + \alpha_3 t^{0.5} \\
+ \; & \alpha_4 I(\text{Green light period})_t + \alpha_5 I(\text{Yellow light period})_t + \mu_{k,m} + \epsilon_{k,m,t}
\end{aligned}
$$

- The subscripts k, m, and t denote the industry, firm's size group, and year, respectively.
- The panel data consists of 64 groups (16 industries * 4 size groups) of observations across 20 years.

Table: Response to the SCM Agreement and R&D Subsidies to Firms.

Dependent variable:	log(Average R&D subsidies+1)$_{k,m,t}$		
log(Average R&D subsidies+1)$_{k,m,t-1}$	0.2572***	0.2623***	0.2552***
	(0.0711)	(0.0685)	(0.0717)
log(Average private R&D+1)$_{k,m,t-1}$	0.1406	0.1283	0.1381
	(0.2452)	(0.2303)	(0.2440)
I(Green light period)$_t$	0.6237***	0.7551***	0.6027**
	(0.2278)	(0.1824)	(0.2351)
I(Yellow light period)$_t$	0.1516**	0.4632*	0.1707
	(0.3274)	(0.2627)	(0.3255)
$t^{0.5}$	8.8626***	5.7714***	8.6335***
	(2.9305)	(1.5536)	(2.8863)
I(Asian Financial Crisis)$_t$		0.1218	0.1003
		(0.1119)	(0.1287)
Political regime fixed effects	Yes		Yes
Constant term	Yes	Yes	Yes
Estimation Method	GMM	GMM	GMM
Number of observations	1,128	1,128	1,128
P-value for AR(2)	0.709	0.788	0.732
P-value for the Hansen test	0.280	0.742	0.280
Degree of freedom for the Hansen test	4	4	4
Significance level of testing: I(GL)$_t$ = I(YL)$_t$	0.0114	0.0707	0.0184

Table: Response to the SCM Agreement and Private R&D Funds to Firms.

Dependent variable:	log(Average private R&D+1)$_{k,m,t}$		
log(Average R&D subsidies+1)$_{k,m,t-1}$	-0.0302	-0.0254	-0.0302
	(0.0190)	(0.0198)	(0.0188)
log(Average private R&D+1)$_{k,m,t-1}$	0.3412***	0.3072***	0.3413***
	(0.0692)	(0.0676)	(0.0694)
I(Green light period)$_t$	-0.2423	0.0518	-0.2415
	(0.1687)	(0.0789)	(0.1683)
I(Yellow light period)$_t$	-0.4839	0.0047	-0.4829*
	(0.2882)	(0.1079)	(0.2875)
$t^{0.5}$	9.2242*	1.8521**	9.1956**
	(4.7107)	(0.7881)	(4.6858)
I(Asian Financial Crisis)$_t$		-0.0067	-0.0013
		(0.0465)	(0.0585)
Political regime fixed effects	Yes		Yes
Constant term	Yes	Yes	Yes
Estimation Method	GMM	GMM	GMM
Number of observations	1,128	1,128	1,128
P-value for AR(2)	0.903	0.894	0.903
P-value for the Hansen test	0.849	0.611	0.849
Degree of freedom for the Hansen test	4	4	4
Significance level of testing: I(GL)$_t$ = I(YL)$_t$	0.0774	0.4839	0.0877

R&D Subsidies for Practical Research

- We analyze whether the Korean government allocates more R&D subsidies to firms actively conducting a particular type of research.

- The WTO acknowledges that subsidies for applied or development research may be granted strategically to affect final sales in its dispute cases.

  ... the closer a subsidy brings a product to sale on the export market, the greater the possibility that the facts may demonstrate that the subsidy would not have been granted but for anticipated exportation or export earnings. . . . In this light, subsidies for pure research, or for general purposes such as improving efficiency or adopting new technology, would be less likely to satisfy the "but for" test than subsidies that directly assist companies in bringing specific products to the (export) market. (Source: The WTO's dispute settlement (DS) 70)

R&D Subsidies for Practical Research

- To analyze whether such tendency exists, we estimate the following:

$$
\begin{aligned}
& log(\text{Average R\&D subsidies} + 1)_{k,m,t} \\
= \;& \alpha_0 + \alpha_1 log(\text{Average R\&D subsidies} + 1)_{k,m,t-1} \\
+ \;& \alpha_2 log(\text{Average private R\&D} + 1)_{k,m,t-1} + \alpha_3(\text{Applied \& dev. share})_{k,m,t-1} \\
+ \;& \alpha_4(\text{Applied \& dev. share})_{k,m,t-1} \cdot I(\text{Green light period})_t \\
+ \;& \alpha_5(\text{Applied \& dev. share})_{k,m,t-1} \cdot I(\text{Yellow light period})_t \\
+ \;& \alpha_6 t^{0.5} + \alpha_7 \text{I}(\text{Asian Financial Crisis})_t + \alpha_8(\text{Political regime FE})_t + \mu_{k,m} + \epsilon_{k,m,t}
\end{aligned}
$$

Dependent variable:	log(Average R&D subsidies+1)$_{k,m,t}$		
log(Average R&D subsidies+1)$_{k,m,t-1}$	0.2979***	0.2990***	0.2903***
	(0.0706)	(0.0705)	(0.0633)
log(Average private R&D+1)$_{k,m,t-1}$	-0.0191	-0.0440	
	(0.2382)	(0.2419)	
I(Green light period)$_t$	0.6382**		
	(0.2542)		
I(Yellow light period)$_t$	0.1400		
	(0.3604)		
Applied & dev. share$_{k,t-1}$	2.7297**	2.1915*	1.8658*
	(1.1369)	(1.1063)	(1.0091)
I(Green light)$_t \times$ Applied & dev. share$_{k,t-1}$		0.8883***	0.9287***
		(0.2788)	(0.2406)
I(Yellow light)$_t \times$ Applied & dev. share$_{k,t-1}$		0.5211	0.5775*
		(0.3993)	(0.3428)
$t^{0.5}$	11.6515***	8.6170**	8.3306***
	(3.4288)	(3.3290)	(3.1262)
I(Asian Financial Crisis)$_t$	0.0043	-0.0037	-0.0137
	(0.1376)	(0.1353)	(0.1315)
Political regime fixed effects	Yes	Yes	Yes
Constant term	Yes	Yes	Yes
Number of observations	1,128	1,128	1,128
P-value for AR(2)	0.816	0.871	0.860
P-value for the Hansen test	0.195	0.236	0.264
Degree of freedom for the Hansen test	6	6	3
Testing the equality of GL and YL coefficients	0.0116	0.0773	0.0712

Extension of the Export Boundary

- Proposition 3 provides guidance that Home government has a policy option to strategically target a specific range of goods near the export boundary, which can have beggar-thy-neighbor effects.
- We investigate how the export boundary changes in response to R&D subsidies and regulation changes.
- To capture trade patterns, we count the number of goods that Korea exports to the number of goods that Korea imports at the HS six-digit level with a partner country.
    - We are interested in the variety of exports and imports, in line with the significance of changes in the export boundary in the theoretical model.

Extension of the Export Boundary

- The baseline specification for the estimation is the following:

$$
\begin{aligned}
& log\left(\frac{\text{Number of exports}+1}{\text{Number of imports}+1}\right)_{i,k,t} \\
= \; & \alpha_0 + \alpha_1 log\left(\frac{\text{Number of exports}+1}{\text{Number of imports}+1}\right)_{i,k,t-1} + \alpha_2 \text{Trade amount share}_{i,k,t-1} \\
+ \; & \alpha_3 log(\text{Average R\&D subsidies} + 1)_{k,t-1} + \alpha_4 log(\text{Average R\&D subsidies} + 1)_{k,t-2} \\
+ \; & \alpha_5 log(\text{Average private R\&D} + 1)_{k,t-1} + \alpha_6 log(\text{Average private R\&D} + 1)_{k,t-2} \\
+ \; & \alpha_7 I(\text{Green light period})_t + \alpha_8 I(\text{Yellow light period})_t \\
+ \; & \alpha_9 t^{0.5} + \alpha_{10} I(\text{Asian Financial Crisis})_t + \alpha_{11}(\text{Political regime FE})_t + \mu_{i,k} + \epsilon_{i,k,t}
\end{aligned}
$$

- The subscripts i, k, and t denote the partner country, industry, and year, respectively.
  - G7, Finland, Sweden, and Denmark.

Dependent variable:	log(Exports to imports)$_{i,k,t}$		
log(Exports to imports)$_{i,k,t-1}$	0.8472***	0.8601***	0.8974***
	(0.0365)	(0.0400)	(0.0488)
Trade amount share$_{i,k,t-1}$	0.0009	0.0011	0.0017
	(0.0019)	(0.0023)	(0.0017)
log(Average R&D subsidies+1)$_{k,t-1}$	-0.1065***	-0.0900***	-0.0666**
	(0.0376)	(0.0234)	(0.0269)
log(Average R&D subsidies+1)$_{k,t-2}$	0.0252*	0.0219*	0.0226*
	(0.0149)	(0.0113)	(0.0129)
log(Average private R&D+1)$_{k,t-1}$		-0.0583	0.0081
		(0.0454)	(0.0525)
log(Average private R&D+1)$_{k,t-2}$		-0.0209	-0.0770*
		(0.0253)	(0.0394)
I(Asian Financial Crisis)$_t$	0.0254	0.0141	0.0087
	(0.0160)	(0.0155)	(0.0161)
I(Green light period)$_t$	0.0866***	0.1268***	
	(0.0294)	(0.0387)	
I(Yellow light period)$_t$	-0.0469	-0.0126	
	(0.0306)	(0.0411)	
Applied & dev. share$_{k,t-1}$			0.8645***
			(0.2625)
I(Green light)$_t \times$ Applied & dev. share$_{k,t-1}$			0.0896***
			(0.0330)
I(Yellow light)$_t \times$ Applied & dev. share$_{k,t-1}$			-0.0597
			(0.0448)

Discussion

- The central message of our theoretical finding is that a government's R&D subsidization carries beggar-thy-neighbor effects when it extends the export boundary while restricting the productivity effects that bring welfare gains to Foreign.

- Our empirical findings offer a compelling evidence that the Korean government indeed strategically used R&D subsidies to affect its trade patterns during the green light period.

Discussion

- Our empirical analysis faces two main challenges and we address them in the following way:
- 1) The data do not disclose information on specifically targeted subsidies provided by the government at the individual firm level.
  - We alternatively address this issue by using the government's tendency to subsidize firms with a greater concentration in practical research.
- 2) Our empirical analysis does not directly test and quantify the beggar-thy-neighbor effects in the data.
  - One would need to model multilateral responses to derive actual welfare effects.
  - We instead assess the legitimacy of the WTO's discipline on R&D subsidies by establishing the link between the observable features in the data and the conditions under which R&D subsidies entail beggar-thy-neighbor effects in the theoretical model.

Conclusion

- We focus on the practical perspective of R&D subsidies and theoretically analyze the conditions under which R&D subsidies can serve as harmless or beggar-thy-neighbor policies.
- We find that R&D subsidies that target a sufficiently narrow range of goods and extend export boundary have beggar-thy-neighbor effects, which rationalizes the WTO's stance in tightening R&D regulations.
- We provide empirical evidence on a strategic use of R&D subsidies given to firms in the manufacturing sector by the Korean government.
- There are possible extensions for future research.
  - A multi-country model where the SCM Agreement has differential welfare effects on countries with heterogeneous technology levels.
  - Compare the magnitude of impact by the SCM Agreement across different countries.