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Abstract

We explore the effects of domestic environmental standards when a domestic firm and a foreign rival compete in the domestic market. We focus on a situation where the introduction of environmental standards forces the foreign product out of the domestic market because it does not meet the standards. Such prohibitive standards may induce the foreign firm to produce an environmentally friendly good through R&D or licensing obtained from the domestic firm. However, this does not guarantee that the product, which now complies with the environmental standards, will improve the environment. In the case of licensing, governments may intervene to shift the rent from the domestic firm. In certain circumstances, the shifted rent could exceed the amount paid by the foreign firm for licensing.

Key words: environmental standards, international oligopoly, R&D, licensing, rent-shifting

JEL classification numbers: F13, F18

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1 Introduction

Concern for environmental destruction has been growing in the world. To protect environment, various environmental policies are adopted all over the world. However, attitudes towards environmental destruction are different across countries. Thus, some countries adopt more stringent policies than others. Examples include environmental standards. For instance, exhaust emission and fuel consumption regulations are more stringent in developed countries than in developing countries and hence automobiles in developed countries are environmentally more friendly.

It is often observed that governments prohibit firms from selling those products that do not meet certain environmental standards. Such stringent standards (i.e., prohibitive standards) may work as trade barriers and protect domestic producers. For example, the United States banned imports of yellowfin tuna and their related processed products from Mexico based on the Marine Mammal Protection Act.[1] The EU prohibited the use of chrysotile asbestos products and banned their imports from Canada in 1998.[2] In 2002, China introduced the China Compulsory Certification, under which foreign firms cannot export to China without implementing certain standards including environmental ones. When domestic standards are prohibitive for foreign firms, however, they may have an incentive to circumvent them. For example, foreign producers may develop new products which meet the domestic standards. It is also widely observed that foreign firms obtain licenses to produce environmentally friendly products or key intermediate inputs to clear standards from their domestic rivals.[3]

The purpose of this paper is to explore the effects of environmental standards in the framework of international oligopoly. We ask whether prohibitive standards actually protect environment and whether prohibitive standards actually benefit domestic firms. In particular, we analyze a situation under which prohibitive standards lead foreign firms

[1] The United States also restricted imports of shrimp and shrimp products from India, Malaysia, Pakistan, Thailand and the Philippines under Section 609 of Public Law 101-162 of 1989.

[2] Moreover, in the EU, electronic and electrical equipment that does not comply with the RoHS (Restriction of Hazardous Substances) directive restricting the use of six hazardous materials in the manufacture cannot be imported. The EU also introduced a regulation called Registration, Evaluation, Authorization and restriction of Chemicals (REACH) in 2006 to protect human health and environment. Supply of chemical substances to the EU which have not been pre-registered or registered is illegal.

[3] For example, Mitsubishi Motors Corporation (MMC) and PSA Peugeot Citroën have announced that MMC will provide PSA an MMC-made electric vehicle for Europe. The vehicle will be sold under Peugeot brand, in parallel to Mitsubishi's own vehicle. Nissan Motor Co. is developing lithium-ion batteries for hybrid and electric vehicles. They are planning to provide it to other auto makers.

to engage in R&D or get licenses from domestic rivals to produce goods that meet the standards. In this situation, we compare with and without standards from the viewpoint of environmental quality and domestic profits. We also compare between R&D and licensing. Furthermore, the presence of R&D and licensing leads to strategic interactions between domestic and foreign firms and generates rent. We specifically examine the opportunities of rent-shifting across countries in the presence of R&D and licensing.

To this end, we build a simple model in which a domestic firm and a foreign rival produce slightly differentiated products and compete in the domestic market. Both domestic and foreign products generate negative externalities during either production or consumption. However, the foreign product damages environment more than the domestic product. For example, foreign cars (say, gasoline cars) emit more carbon dioxide than domestic cars (say, hybrid cars). The domestic government introduces a standard which the domestic product satisfies but the foreign product does not. To serve the domestic market, therefore, the foreign firm has to produce a product meeting the domestic standard through either R&D or licensing. In this circumstance, we obtain counter-intuitive results that prohibitive standards may deteriorate environment and/or hurt the domestic firm. Although the foreign firm may be led to produce an environmentally friendly good, prohibitive standards do not guarantee an improvement in environment.

In our model, the domestic firm strategically licenses their technologies or supplies a key intermediate input to the foreign rival when the foreign firm is willing to engage in R&D to produce a good meeting the standard. That is, the domestic firm intends to deter the foreign firm from engaging in R&D. Such a strategy mitigates the loss of the domestic firm caused by the reentry of the foreign firm to the domestic market. When the domestic firm sets the license fee or the input price, it tries to extract rent from the foreign firm as much as possible. However, the foreign government may intervene to manipulate rent-shifting through taxes and subsidies.[4] We point out that the foreign government can shift the rent from the domestic firm to the foreign government either directly or indirectly. However, such a rent-shifting opportunity may be deterred by the domestic government through taxes. Interestingly, the shifted rent could exceed the payment from the foreign firm to the domestic firm. Moreover, the presence of rent-shifting could make the license fee negative.

There exist many studies that investigate environmental policies in the presence of

[4] We examine simple intervention through taxes and subsidies. For strategic environmental policy, see Barret (1994), Kennedy (1994), Conrad (1996,2001), Ulph (1996), Tanguay (2001), and Kiyono and Ishikawa (2004), among others.

international trade.[5] However, relatively little attention has been paid to environmental standards in open economies.[6] In an international duopoly model, Fischer and Serra (2000) consider optimal minimum standards and examine whether they are protectionist. Haupt (2000) examines the relationship between environmental product standards and environmental R&D in a monopolistically competitive sector in a two-country model. On the basis of a model with environmentally differentiated products and heterogeneous consumers, Toshimitsu (2008) shows that a strict emission standard on an imported product may or may not increase social surplus. Ishikawa and Okubo (2010) also show that stringent environmental standards may actually worsen environment. However, they focus on firm relocation caused by product standards in the framework of new economic geography.

Although strategic use of licensing has been studied in the literature of industrial organization, those studies basically deal with a closed economy.[7] Thus, one cannot consider rent-shifting across countries. Only few studies analyze strategic use of licensing or input supply in the open economy framework. Chen et al. (2004) show that under international duopoly, trade liberalization leads to strategic outsourcing to the rival firm, which has a collusive effect. Horiuchi and Ishikawa (2009) explore the strategic relationship between tariffs and North–South technology transfer in an oligopoly model when technology is embodied in a key component that only North firms can produce.

The rest of the paper is organized as follows. In section 2, we present an international Cournot duopoly model with negative externalities. We consider a situation under which consumption generates emissions that deteriorate environment.[8] Then we examine emission standards in section 3. Specifically, we consider the foreign production of the domestic good through either R&D or licensing. In section 4, we explore the rent-shifting by governments in the presence of R&D and licensing. Section 5 concludes.

[5] See Rauscher (2005) for the literature survey.

[6] We deal with only compulsory standards in our analysis. Eco-laballing scheme is voluntary standards in the sense that products can be sold in the market even if they do not meet certain standards. For the analysis of eco-labelling scheme under international oligopoly, see Abe et al. (2001) and Tian (2003), among others.

[7] In the industrial organization literature, licensing is strategically used to (partially) deter entry. See Gallini (1984) and Yi (1999), for example.

[8] Regarding the case of production externalities, see section 5.

2 Base Model

We consider two goods X and Y, which are imperfect substitutes. Good X is produced by a foreign firm (firm f), that exports the good to the domestic country. In the domestic country, a domestic firm (firm d) produces good Y. The two firms engage in Cournot competition in the domestic market. We assume that emissions are generated through consumption of the products. By an appropriate choice of units, one unit of consumption of good X generates one unit of emissions and that of good Y results in $0 < k < 1$ units of emissions. The emissions cause negative externalities.

Demands are characterized by a representative consumer that consumes goods X and Y as well as a numéraire good. The numéraire good is competitively produced and freely traded between countries, and generates no externalities. We assume the following utility function:

$$U = \alpha x^f + \beta y^d - \frac{(x^f)^2 + (y^d)^2}{2} - \phi x^f y^d + m - V,$$

where x, y and m are, respectively, the consumption of goods X and Y and the numéraire good, $V(> 0)$ is externalities, α and β are parameters, and $0 < \phi < 1$ is a parameter indicating the degree of substitutability between goods X and Y. Following Fischer and Serra (2000) and Lai (2004), we assume that the representative consumer ignores the negative externalities when making the consumption decisions.[9]

Then the inverse demands for the imperfectly substitutable goods X and Y are, respectively, given by

$$p_x = \alpha - x^f - \phi y^d, \tag{1a}$$

$$p_y = \beta - y^d - \phi x^f, \tag{1b}$$

where p_x and p_y are the consumer prices of goods X and Y. Consumer surplus (CS) is given by

$$CS = \alpha x^f + \beta y^d - \frac{(x^f)^2 + (y^d)^2}{2} - \phi x^f y^d - (p_x x^f + p_y y^d) = \frac{(x^f)^2 + (y^d)^2}{2} + \phi x^f y^d$$

The profits of firms f and d can be written respectively as

$$\pi^f = (p_x - c_x^f)x^f,$$

$$\pi^d = (p_y - c_y^d)y^d,$$

[9] There is another modelling in which consumers care about environmental damage when making the consumption decisions. For example, in Moraga-Gonzalez and Padron-Fumero (2002), consumers differ in their willingness-to-pay for goods due to different environmental awareness.

where c_i^j $(i = x, y; j = f, d)$ is the constant marginal cost (MC) of firm j to produce good i. Then the first order conditions (FOCs) for profit maximization are:

$$\frac{d\pi^f}{dx^f} = -x^f + p_x - c_x^f = 0,$$
$$\frac{d\pi^d}{dy^d} = -y^d + p_y - c_y^d = 0.$$

In the laissez-faire equilibrium denoted by subscript 0, we have

$$x_0^f = \frac{2A - \phi B}{4 - \phi^2}, y_0^d = \frac{2B - \phi A}{4 - \phi^2},$$

where $A \equiv \alpha - c_x^f$ and $B \equiv \beta - c_y^d$. As the market size, $\alpha(\beta)$, becomes larger and the MC, c_x^f (c_y^d), becomes smaller, A (B) becomes larger. We call A (B) the effective market size for good X (Y). We assume that both firms serve the domestic markets in equilibrium, that is,

$$2B - \phi A > 0, 2A - \phi B > 0. \tag{2}$$

By using the FOCs, the profits of firms f and d are

$$\pi_0^f = (x_0^f)^2, \pi_0^d = (y_0^d)^2. \tag{3}$$

Thus, the following lemma is immediate:

Lemma 1 *The profits increase if and only if the output rises.*

3 Effects of Standards

In this section, we consider the effects of emission standards. The domestic government introduces an emission standard, λ, which sets a maximum amount of emissions per unit of product consumption. If a product does not satisfy the standard, its sale is prohibited in the domestic country. In our analysis, we specifically consider an emission standard which good X does not satisfy but good Y does (i.e., $k \leq \lambda < 1$). Thus, in the presence of such a standard, firm f has to give up exporting to the domestic country.[10]

3.1 Monopoly

The standard leads firm d to be a monopolist in the market. In the equilibrium denoted by subscript M, the output and price are, respectively, given by

$$y_M^d = \frac{B}{2}, p_M = \frac{B}{2} + c^d. \tag{4}$$

[10] In this section, since only good Y is produced and consumed, subscript y is suppressed.

In view of (2), we can easily verify that $y_M^d > y_0^d$ and $y_M^d < x_0^f + y_0^d$. As expected, therefore, the standard benefits the domestic firm and reduces emissions. The change in CS is

$$\Delta CS_M \equiv CS_M - CS_0 = \frac{\left(8A + 4B\phi - 6A\phi^2 + B\phi^3\right)(B\phi - 2A)}{8(\phi+2)^2(\phi-2)^2} < 0.$$

Since $2A - \phi B > 0$, CS falls. Thus, the welfare effect is generally ambiguous.

3.2 R&D

In the presence of emission standards, firm f cannot serve the domestic market. Hence firm f may try to produce good Y to serve the domestic market. In the rest of the section, we examine such a situation. We specifically consider two possibilities. In the first case, firm f incurs fixed costs (FCs) of R&D, F, to develop good Y by itself. In the second, firm d licenses firm f a technology to produce good Y. Firm d may provide firm f with a key intermediate input such as a hybrid engine to produce good Y instead of a technology to produce the key input.

As long as firm f can make a positive profit from R&D, it has an incentive to invest in R&D. With R&D investment, both firms f and d supply good Y to the domestic market. Since there is only good Y in the market, the inverse demand is:

$$p = \beta - (y^f + y^d),$$

where y^f is the output of firm f. The profits of firms f and d are:

$$\begin{aligned} \pi^f &= (p - c^f)y^f - F, \\ \pi^d &= (p - c^d)y^d, \end{aligned}$$

where c^i $(i = f, d)$ is the constant MC of firm i to produce good Y. In the R&D equilibrium denoted by subscript R, we obtain:

$$y_R^f = \frac{B - 2\delta}{3}, y_R^d = \frac{B + \delta}{3},$$

where $\delta \equiv c^f - c^d$. We assume both $B > \max\{2\delta, -\delta\}$ and $0 < \pi_R^f (= (B - 2\delta)^2/9 - F) < \pi_0^d$.[11]

We compare the R&D equilibrium with the initial laissez-faire equilibrium. We first consider whether firm d gains from the standard. Noting that Lemma 1 is still valid for

[11] If $\pi_R^f > \pi_0^d$, firm f has no incentive to produce good X even without standards.

firm d, we check whether the output rises:

$$\begin{aligned}\Delta y_R &\equiv y_R^d - y_0^d = \frac{B+\delta}{3} - \frac{2B-\phi A}{4-\phi^2} \\ &= \frac{3A\phi - 2B - B\phi^2 + \delta(4-\phi^2)}{3(4-\phi^2)}.\end{aligned}$$

Thus, the R&D under the standard benefits firm d if and only if $\Omega \equiv 3A\phi - 2B - B\phi^2 + \delta(4-\phi^2) > 0$. This condition is likely to be satisfied when A is large relative to B, and δ and ϕ are large. A relatively large A implies relatively large demand for good X, and hence the prohibitive standard causes a relatively large demand shift to good Y. A large δ implies that firm d is much more efficient in production of good Y than firm f. Thus, the entry of firm f into the good-Y market does not decrease the output of firm d much. A large ϕ implies that goods X and Y are close substitutes. Thus, the entry of firm f into the good-Y market caused by the elimination of good X does not affect the output of firm d much.

The change in CS is given by

$$\begin{aligned}\Delta CS_R &\equiv CS_R - CS_0 = \frac{(y_R^f + y_R^d)^2}{2} - \frac{(x_0^f)^2 + (y_0^d)^2}{2} - \phi x_0^f y_0^d \\ &= \frac{\left(\begin{array}{c} 28B^2 - 36A^2 - 18AB\phi^3 + 27A^2\phi^2 - 5B^2\phi^2 + 4B^2\phi^4 \\ +\delta\left(\phi-2\right)^2\left(\phi+2\right)^2\left(\delta - 4B\right)\end{array}\right)}{18\left(\phi+2\right)^2\left(\phi-2\right)^2}.\end{aligned}$$

In general, the sign of ΔCS_R is ambiguous. $\Delta CS_R > 0$ is likely to hold when when A is small relative to B. With $\Delta CS_R > 0$, a negative effect due to the decrease in variety is dominated by a positive effect due to the increase in good Y.

The change in emissions is given by

$$\Delta e_R \equiv k(y_R^f + y_R^d) - (z_0 + ky_0) = (k\frac{2B-\delta}{3}) - (\frac{2A-\phi B}{4-\phi^2} + k\frac{2B-\phi A}{4-\phi^2}).$$

If k is sufficiently small, then $\Delta e_R < 0$, that is, the emission standard decreases the total emissions. However, if k is close to 1, the total emissions may increase. Evaluating Δe_R at $k = 1$, we have

$$\begin{aligned}\Delta e_R|_{k=1} &= (\frac{2B-\delta}{3}) - (\frac{2A-\phi B}{4-\phi^2} + \frac{2B-\phi A}{4-\phi^2}) \\ &= \frac{B - 3A + 2B\phi - \delta(\phi+2)}{3\left(\phi+2\right)}.\end{aligned}$$

From the continuity argument, the total emissions increase if $\Psi \equiv B - 3A + 2B\phi - \delta(\phi+2) > 0$ and k is sufficiently close to 1. This condition is likely to be satisfied when

A is small relative to B, δ is small and ϕ is large. A prohibitive standard eliminates the consumption of good X, but increases that of good Y through the foreign R&D. Although the emission per unit of consumption of good Y is lower than that of good X, this could be dominated by the increase in the total consumption of good Y and hence the total emissions could rise. A small A, a small δ and a large ϕ tend to increase the output of good Y relative to the laissez-faire equilibrium when a prohibitive standard induces firm f to enter the good Y-market.

Again, the welfare effect is generally ambiguous. If $A = B$ and $\delta = 0$, for example, then $\Delta y_R < 0$, $\Delta CS_R < 0$ and $\Delta e_R < 0$ holds, that is, the profits of firm d and CS decrease but the environmental damage is mitigated. Thus, if the mitigation of environmental damage is large (small), domestic welfare could improve (deteriorate).

The above analysis establishes the following proposition:

Proposition 1 *Suppose that an emission standard leads firm f to incur fixed R&D costs to develop good Y. By comparing this R&D equilibrium with the equilibrium without the standard, there exists a range of parameterizations under which the total emissions increase. Firm d gains from the standard if and only if $\Omega > 0$. Domestic welfare may or may not improve.*

3.3 Licensing

We now examine firm d's technology licensing to firm f and compare this licensing equilibrium with the R&D equilibrium. We assume that before firm f decides whether or not to engage in R&D, firm d decides whether or not to offer a take-it-or-leave-it licensing offer to firm f.[12] When firm f will not develop good Y, firm d has no incentive for licensing. This is because firm d can enjoy the monopoly situation without licensing. Therefore, we consider the case where in the absence of licensing, firm f is willing to develop good Y through R&D, which harms firm d. In this situation, firm d has an incentive to grant firm f permission to use its technology to produce good Y in return for license fees, because licensing generates revenue for firm d and mitigates its loss. Thus, firm d designs a licensing contract so that firm f is willing to accept it. It should be noted that firm d cannot extract all the rent from firm f by license fees because of firm f's outside option, i.e., R&D.

[12] The qualitative nature of our results would remain unchanged even if licensing fees are determined by bargaining between the two firms.

In the presence of licensing, profits of the two firms are given by

$$\begin{aligned} \pi^f &= (p - c^f)y^f - (R + ry^f) = (p - c^f - r)y^f - R \\ \pi^d &= (p - c^d)y^d + (R + ry^f), \end{aligned}$$

where we consider two-part tariff and hence R and r are, respectively, a fixed fee and a per-unit royalty.[13] For simplicity, we assume that firm f's MC under licensing and that under R&D are the same. We can regard $(c^f + r)$ as the effective MC of firm f.

Since the outside option for firm f is R&D, firm d faces the following maximization problem:

$$\pi_L^d \equiv \max_{r,R} \pi^d; \; s.t. \; \pi^f \geq \pi_R^f, \tag{5}$$

where π_R^f is firm f's profits with R&D. In the equilibrium, firm f is indifferent between R&D and licensing. The appendix proves the following lemma.

Lemma 2 *Firm d sets $r = \overline{r}(\equiv (B - 2\delta - 3\sqrt{(\frac{B-2\delta}{3})^2 - F}/2)$ and $R = 0$.*

This lemma implies that even if two-part tariffs are available, firm d charges only per-unit royalty as license fees.[14] In the licensing equilibrium, we have:

$$y_L^f = \frac{B - 2\delta - 2\overline{r}}{3}, y_L^d = \frac{B + \delta + \overline{r}}{3}.$$

Comparing with the R&D case, the profits of firm d are larger, because licensing generates a license fee and makes firm f less competitive due to the higher effective MC. CS and the total emissions are smaller, because the total consumption of good Y is smaller. The difference in the total emissions is given by

$$e_L - e_R = -\frac{k\overline{r}}{3} < 0.$$

Thus, we establish the following proposition.

Proposition 2 *Licensing increases the profits of firm d relative to R&D. CS and the total emissions under licensing are less than those under R&D.*

[13] In the case where firm d supplies a key input to firm f instead of licensing, the constant MC to produce the input is normalized to be zero and $R = 0$.

[14] This result depends on the assumption that firms f and d produces a homogenous good. If the good firm f produces under prohibitive standards is differentiated from good Y, then $R > 0$ could arise.

4 Rent-shifting in the Presence of R&D and Licensing

In the presence of licensing, firm d sets license fees to extract rent from firm f as much as possible. However, there are opportunities for the foreign government to shift the rent back from firm d through simple taxes and subsidies. By facing such opportunities, the domestic government may try to shift the rent from firm d to the domestic government before the foreign government moves. In this section, we explore the rent-shifting by the foreign government as well as the domestic government.

4.1 Rent-shifting by the Foreign Government

In this subsection, we consider three measures to shift the rent from firm d to the foreign government. One is direct measures and the other two are indirect ones. First, we explore direct measures when firm d supplies a key intermediate input to firm f. Suppose that the foreign government imposes a tariff on the input. This usually causes tariff shifting. That is, the tariff increases the input price which firm f faces. In our model, however, firm d cannot directly shift the tariff to firm f, because the tariff shifting leads firm f to engage in R&D. In fact, the foreign government could generate more than full rent-shifting through tariffs, that is, the shifted rent could exceed the payment from the foreign firm to the domestic firm.

Suppose that the foreign government imposes a specific tariff, t, on the import of the key input. Even if a tariff is imposed, firm d cannot raise the price beyond $\overline{r}$. When $t = \overline{r}$, therefore, the payment by firm f are fully shifted from firm d to the foreign government. However, we should note that the profits of firm d are still larger under licensing than under R&D even with $t = \overline{r}$, because firm f's effective MC under licensing, $c^f + \overline{r}$, is higher than that under R&D, c^f. This implies that the foreign government can increase the tariff rate beyond $\overline{r}$ without affecting the price firm f faces. We should mention that a foreign tariff on the input does not affect the output of each firm and hence the total emissions.

Formally, in the presence of tariffs on the key intermediate input, (5) is modified as follows:

$$\pi^d_{Lt} \equiv \max_{r,R} \pi^d - ty^f_L; \ s.t. \ \pi^f \geq \pi^f_R.$$

Then, the foreign government faces the following maximization problem:

$$\max_t ty^f_L; \ s.t. \ \pi^d_{Lt} \geq \pi^d_R, \tag{6}$$

where π_R^d is the profits of firm d with R&D. In the equilibrium, $\pi_{Lt}^d = \pi_R^d$ holds, that is, firm d is indifferent between R&D and licensing.

Next we investigate indirect measures to shift the rent. Firm d can charge license fees, because firm f's profits become larger under licensing without any fees than under R&D. That is, the licensing results in room for arbitrage for firm d. The foreign government can indirectly shift the rent by reducing the room. Suppose that a production tax is collected from firm f under only licensing.[15] If a production tax, τ, is introduced before firm d makes a licensing offer, we have $r + \tau = \overline{r}$. This is because firm f will engage in R&D if the effective MC (which equals $c^f + r + \tau$) exceeds $c^f + \overline{r}$. By increasing τ, therefore, the license fee, r, falls. That is, a production tax reduces room for arbitrage. In particular, by setting $\tau = \overline{r}$, firm f gets technologies without any payment to firm d. As in the case of tariffs on a key input, the foreign government can raise the tax rate further, because firm f's effective MC (which equals $c^f + \overline{r}$ in the case of production taxes) is higher under licensing than under R&D. Therefore, we have $r < 0$ with $\tau > \overline{r}$ in the equilibrium. Moreover, a production tax does not affect the total emissions, because both firm f's effective MC, $c^f + r + \tau = c^f + \overline{r}$, and firm d's MC are constant.

Formally, in the presence of production taxes, (5) becomes

$$\pi_{L\tau}^d \equiv \max_{r,R} \pi^d;\ s.t.\ \pi^f - \tau y_L^f \geq \pi_R^f.$$

By affecting the constraint, production taxes make indirect rent-shifting possible. The maximization problem for the foreign government is

$$\max_{\tau} \tau y_L^f;\ s.t.\ \pi_{L\tau}^d \geq \pi_R^d.$$

The foreign government can also indirectly shift the rent from firm d through a lump-sum R&D subsidy, S, to firm f, which is committed before firm d moves. We first consider a case in which $y_R^f > 0$ but $\pi_R^f = (y_R^f)^2 - F < 0$ hold and hence firm f does not engage in R&D. In this case, by setting the subsidy $S \geq -\pi_R^f$, the foreign government can induce R&D. Since firm d prefers licensing to R&D, however, firm d offers a licensing contract whenever the subsidy leads firm f to engage in R&D. This implies that the foreign government does not pay the subsidy in equilibrium. Even if firm f engages in R&D without the subsidy, the foreign government could use R&D subsidies as a device to shift the rent from firm d. With R&D subsidies, (5) is modified as

$$\pi_{Ls}^d \equiv \max_{r,R} \pi^d;\ s.t.\ \pi^f \geq \pi_R^f + S.$$

[15]It is assumed that no production tax is imposed when firm f engages in R&D.

Thus, the license fees become lower as the subsidy rises. To maximize the shifted rent, the foreign government sets $S = F$ so that $\pi^d_{Ls} = \pi^d_R$ holds. With $S = F$, firm f obtains the license without any payment. Moreover, with $S = F$, the total emissions are the same with those under R&D if $\pi^f_R > 0$.

Thus, we obtain:

Proposition 3 *The foreign government can shift the rent associated with licensing from firm d to the foreign country directly by levying a tariff on the key intermediate input and indirectly by imposing a production tax on firm f under licensing or by committing itself to an R&D subsidy. The shifted rent could exceed the payment by firm f with the tariff on the key input. The license fees could be negative with the production tax on firm f. The rent-shifting does not affect CS and the total emissions.*

In the licensing equilibrium where the foreign government completely shifts the rent from firm d, the profits of firms f and d are the same with those in the R&D equilibrium. When the rent-shifting is caused by taxes, CS and the total emissions are less under R&D, because the rent-shifting does not affect the total consumption and emissions. In this case, therefore, domestic welfare is higher in the licensing equilibrium with complete rent-shifting than in the R&D equilibrium if and only if the mitigation of environmental damage dominates the reduction of CS.

4.2 Rent-shifting by the Domestic Government

In this subsection, we point out that the domestic government can prevent the foreign government from shifting rent from firm d by using simple taxes if the domestic government can move before the foreign government. We explore both direct and indirect measures.

First, we consider direct measures: a tax on the licensing fees or an export tax on the key input. When a specific tax on the licensing fees or a specific export tax on the input, ρ, is imposed, (5) becomes

$$\pi^d_{L\rho} \equiv \max_{r,R} \pi^d - \rho y^f_L; \ s.t. \ \pi^f \geq \pi^f_R.$$

Then, the maximization problem for the domestic government is

$$\max_{\rho} \rho y^f_L; \ s.t. \ \pi^d_{L\rho} \geq \pi^d_R.$$

Even if the tax is imposed, firm d cannot shift the tax to firm f. This is because the tax shifting leads firm f to engage in R&D instead of licensing. Thus, the license fees faced by firm f remain to be $\overline{r}$. Under the optimal tax, the tax rate is greater than $\overline{r}$. The above case is similar to the case in which the foreign government sets a tariff on the input to shift the rent from firm d.[16]

Next we consider tariffs on the final good as indirect measures. A tariff on the final good usually decreases the profits of firm f. When $r = \overline{r}$, a tariff induces firm f to switch from licensing to R&D. Thus, firm d lowers the license fee to prevent such a switch. In the presence of a specific tariff, T, on the final good, (5) is modified as follows:

$$\pi_{LT}^{d} \equiv \max_{r,R} \pi^{d};\ \ s.t.\ \pi^{f} - Ty_{L}^{f} \geq \pi_{R}^{f}.$$

Then, the domestic government faces the following maximization problem:

$$\max_{T} Ty_{L}^{f};\ \ s.t.\ \pi_{LT}^{d} \geq \pi_{R}^{d}.$$

This is similar to the case in which the foreign government shifts the rent from firm d through a production tax. By imposing a tariff on the final good, the domestic government can indirectly shift the rent from firm d to the domestic government. In particular, the domestic government can eliminate the room for the rent-shifting by the foreign government.

Thus, the following proposition is established:

Proposition 4 *If the domestic government can move before the foreign government, then the domestic government can prevent the foreign government from shifting rent from firm d by imposing either a tax on the licensing fees (an export tax on the key input) or a tariff on the final good.*

5 Concluding Remarks

Using an international duopoly model, we have analyzed the effects of environmental standards in the presence of consumption externalities. We have focused on a plausible situation under which both domestic and foreign products generate emissions during consumption, but the foreign product results in more damage to environment than the domestic product and an emission standard drives the foreign product out of the domestic market.

[16] If an export tax on the input and an import tariff on the input are imposed simultaneously, then any combination (t, ρ) satisfying $t + \rho = \rho^{*}$ (where $\rho^{*} \equiv \arg\max_{\rho} \rho y_{L}^{f}$; $s.t.\ \pi_{L\rho}^{d} \geq \pi_{R}^{d}$) is a Nash equilibrium.

Such prohibitive standards may induce the foreign firm to produce a good meeting the standard through R&D or licensing, but do not guarantee an improvement in environment. This is because the effect of an increase in the consumption of the environmentally friendly good dominates the effect of the elimination of the environmentally unfriendly good. By comparing between R&D and licensing, the environmental damage is less under licensing, because the effective MC of the foreign firm is higher under licensing than under R&D and hence the consumption is smaller under licensing. Moreover, prohibitive standards may not benefit the domestic firm when the foreign firm starts serving the domestic market with R&D or licensing.

We have also pointed out possible strategic interactions between the domestic firm and the foreign government in the presence of R&D and licensing. The foreign government can shift rent from the domestic firm by levying a tariff on a key intermediate input, by imposing a production tax on the foreign firm under licensing, or by committing itself to R&D subsidies. In particular, the shifted rent could exceed the payment by the foreign firm with the tariff and the license fees could be negative with the production tax on the foreign firm. The presence of an outside option (i.e. R&D) plays a crucial role to derive the results. However, the domestic government may intervene to prevent the foreign government from shifting the rent from the domestic firm by imposing a tax on the licensing fees or an export tax on the key input or by levying a tariff on the final good.

The final three remarks are in order. First, we have not fully explored the welfare effects. This is because to examine domestic welfare in details, we need to specify the damage function, V. The welfare analysis depends on the specification of the damage function. In particular, when only good Y is produced, the environmental damage is mitigated if and only if CS falls. Thus, the welfare effects are in general ambiguous. If the environment is evaluated highly enough, then domestic welfare could improve whenever the total emissions fall.

Second, the analysis can directly be applied to the case with production externalities as long as the emissions are completely trans-boundary. Examples include emissions of greenhouse gases during production. However, the GATT/WTO have regarded trade restrictions based on processes and production methods as illegal. For example, the GATT judged that the US ban on imports of yellowfin tuna and their related processed products from Mexico was against the GATT agreement. Thus, even if foreign production generates negative externalities, the domestic government may not be allowed to ban the imports of foreign goods.

Last, the analysis of R&D and licensing is valid even if standards are not prohibitive. For example, suppose that the domestic country introduces an eco-labelling scheme under which a label can be affixed only on the domestic product. Although the foreign product can still be sold in the domestic market, the sales may decrease. If the decrease is large enough, then the foreign firm may have an incentive to produce a product on which the label can be put.

In this paper, we have focused on a plausible situation in which a domestic prohibitive standard induces the foreign firm to produce the domestic product meeting the standard through R&D or licensing. However, one can think of many other situations. The analyses under these situations are left for future research.

Appendix

Proof of Lemma 2. Given r, the equilibrium outputs are

$$y^f = \frac{B-2(\delta+r)}{3}, y^d = \frac{B+(\delta+r)}{3}.$$

Thus, we have

$$\pi^d = (\frac{B+(\delta+r)}{3})^2 + R + r\frac{B-2(\delta+r)}{3}.$$

Noting

$$\begin{aligned} R &= (\frac{B-2(\delta+r)}{3})^2 - \pi^f_R \\ &= (\frac{B-2(\delta+r)}{3})^2 - (\frac{B-2\delta}{3})^2 + F, \end{aligned}$$

We obtain

$$\begin{aligned} \pi^d &= (\frac{B+(\delta+r)}{3})^2 + (\frac{B-2(\delta+r)}{3})^2 - (\frac{B-2\delta}{3})^2 + F + r\frac{B-2(\delta+r)}{3} \\ &= \frac{2B\delta + B^2 + \delta^2 - r^2 + r\,(B+4\delta)}{9} + F, \end{aligned}$$

which takes the maximum value at $r = (B+4\delta)/2 \equiv r^*$. If firm d sets $r = r^*$, then the output of firm f becomes zero. Thus, the maximum royalty firm d can charge, $\overline{r}$, satisfies

$$(\frac{B-2(\delta+r)}{3})^2 = (\frac{B-2\delta}{3})^2 - F.$$

Thus,

$$\overline{r} = \frac{1}{2}B - \delta - \frac{3}{2}\sqrt{(\frac{B-2\delta}{3})^2 - F}.$$

■

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