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TRADE LIBERALIZATION AND OPTIMAL ENVIRONMENTAL POLICIES IN VERTICAL RELATED MARKETS

YAN-SHU LIN[1]
National Dong-Hwa University, Taiwan.

Abstract

This paper establishes a symmetric two-country model with vertically related markets. In the downstream market, there is one firm in each country selling a homogeneous good, whose production generates pollution, to its home and the foreign markets a la Brander (1981). In the intermediate good market, there is also one upstream firm in each country, supplying the intermediate good only to its own country's downstream market. The upstream firms can choose either price or quantity to maximize their profits. With this setting, the paper examines the optimal environmental policy and how it is affected by the tariff on the final good. It is found that, under free trade, the optimal final-good output with imperfect intermediate-good market will have the same output level as that with perfect intermediate-good market after imposing the optimal emission tax. The optimal environmental tax is smaller and the optimal environmental policy is less likely to be a green strategy under trade liberalization if the market structure in the intermediate good market is imperfect than perfect competition. On the other hand, the optimal environmental tax is necessarily higher if the upstream firm chooses price than quantity. Moreover, the optimal environmental policy is less likely to be a green strategy under trade liberalization if the upstream firms choose quantity than price to maximize their profits.

Keywords: Environmental Policy; Intra-Industry Trade; Vertical Related Market.

JEL classification: D43; F13; H23

INTRODUCTION

[1] Corresponding author E-mail: ylin@mail.ndhu.edu.tw, Professor, Department of Economics, National Dong-Hwa University, No. 1, Sec. 2, Dahsueh Rd. Shou-Feng, Hualien, 97401, Taiwan.

As the WTO tightens restrictions on international trade policies, environmental regulations have increasingly turned to be the potential instruments for strategic trade. A literature has developed which studies how strategic environmental policies differ from efficient policies, see, for instance Conrad (1993), Barrett (1994), Ulph (1996), and Greaker (2003) provides a good review of literature. The main conclusion is that a rent-shifting or trade-related incentive distorts environmental policies. When firms play in a Cournot game, these incentives imply that environmental policies will be weaker than is efficient. This result is a straightforward application of theories of strategic behavior. By committing to a less restrictive environmental policy the government reduces the marginal costs of domestic firms and makes them more aggressive competitors in international markets.

On the other hand, environmentalists have generally considered international trade creates a threat to adequate environmental regulation. Kennedy (1994) points out "free trade will lead governments to relax their environmental standards in order to gain a competitive edge over their trading partners". A few studies support this argument (Walz and Wellisch, 1997; Tanguay, 2001). However, Burguet and Sempere (2003) examine how trade liberalization affects environmental policies in the context of bilateral trade and imperfect competition. They showed that the environmental policies may be more stringent in the face of a bilateral reduction in tariffs. Along the same line of thinking, Roelfsema (2007) develops a political economic model and shows that if the median voter cares sufficiently for the environment, he has an incentive to delegate policy making to a politician that cares more for the environment than himself.

In their setting of the environment-for-trade policy, however, the important of the element of vertical-related market has been ignored. In a trade theoretical field, there is a considerable body of literature on the trade policy in vertical-related market such as Spencer and Jones (1991, 1992), Ishikawa and Spencer (1999), and Hwang et al. (2007) etc.. From there, we have learned that the vertical-related market structure plays an important role in the decision of trade policy. In an environmental issue, it is interesting to know the role of vertical structure in the decision of environmental policies. One research towards this area was provided by Hamilton and Requate (2004), in which a competitive upstream market was constructed with vertical two-part tariff contracts to demonstrate that the optimal policy to levy on a polluting input under both quantity and price competition in the international market is the Pigouvian tax. More recently, Yu (2007) further investigate the horizontal “profit-shifting”, vertical “rent-extracting”, and “collusion-facilitating effect” in a model with a monopolistic upstream firm and oligopolistic downstream firms. Sugeta and Matsumoto (2007) found that the effect of change in emission tax on the degree of price discrimination in a vertical related model with one upstream firm discriminating the factor prices to the downstream firm. Canton et al. (2008) set a model with polluting firms selling final goods to consumers and outsourcing their abatement activities to an environment industry, and found the optimal tax rate is the result of trade-off that depends on the firms’ market power along the vertical structure.

We study these issues in a model of imperfect competition and bilateral trade. We establish a symmetric two-country model with vertically related markets. In the downstream market, there is one firm in each country selling a homogeneous good, whose production generates pollution, to its home and the foreign markets a la Brander (1981). In the intermediate good market, there is also one upstream firm in each country, supplying the intermediate good only to its own country’s downstream market. The upstream firms can choose either price or quantity to maximize their profits. With this setting, the paper examines the optimal environmental policy and how it is affected by the tariff on the final good. It is found that the optimal environmental tax is smaller and the optimal environmental policy is less likely to be a green strategy under trade liberalization if the market structure in the intermediate good market is imperfect than perfect competition. On the other hand, the optimal environmental tax is necessarily higher if the upstream firm chooses price than quantity. Moreover, the optimal environmental policy is less likely to be a green strategy under trade liberalization if the upstream firms choose quantity than price to maximize their profits.

The relevant questions are how trade liberalization affects those trade-related incentives for environmental protection in a vertical related market. Note that a bilateral reduction in tariffs does not mean less protection for domestic firms. Indeed, while domestic firms face tougher competition in the domestic market, they also enjoy a better competitive position in the foreign market. Thus, the change in the level of domestic trade protection is itself ambiguous, and we should look rather at how the relative surplus from exports and imports conditions the trade-off between higher consumption and a cleaner environment. Moreover, by integrating the vertical related market, we also consider the outcome when the upstream market is perfect competitive.

The rest of the paper is structured as follows. Section 2 presents the model of vertical structure and downstream intra-industry trade with Cournot duopoly. The upstream firms can choose either price or quantity to maximize their profits. In Section 3, we will set out the market equilibrium conditions when the upstream firms' choice variable is price and examines the conditions under which the environmental policy can be a Pigouvian tax with a focus on the additional effects caused by the intermediate-good industry. Moreover, we discuss the effects of trade liberalization on the optimal environmental policies to see the movement is an eco-dumping strategy or a green strategy. The case where the upstream firms' choice variable is quantity is discussed in Section 4. Finally, Section 5 offers some concluding remarks.

THE MODEL

Consider a symmetric, vertically related structure model of downstream bilateral trade. In the final-good markets, there is a homogeneous, tradable good produced by two firms, each located in a different country, domestic (d) and foreign (f). The final-good production generates pollution. Each firm sells in both countries. For the home and foreign market, the demand for the good is given by an inverse linear demand function, $P(Q) = a - bQ$ and $P^*(Q^*) = a - bQ^*$ respectively, where $P' < 0$, $P^{*\prime} < 0$, and $P'' = P^{*\prime\prime} = 0$. Firms compete in quantities. Let $X(Y)$ be the output of domestic (foreign) firm for the home market and $X^*(Y^*)$ the output of domestic (foreign) firm for the foreign market. Thus, $Q = X + Y$ and $Q^* = X^* + Y^*$ stand for the total consumption in each of the markets. In addition, exports to each country are subject to a tariff, T, for simplicity, that we assume exogenous and the same in both countries. We further simplify the analysis by assuming of constant marginal costs of production. The marginal cost of the domestic firm for the home (foreign) market is C $(C+T)$, which is constant. Similarly, the marginal cost of the foreign firm for the home (foreign) market is $C^{*}+T\,(C^{*})$. We assume $C=C^{*}=0$, for simplicity.

In the intermediate-good markets, we frame our model around a decentralized vertical market structure that supports the downstream in its own country. The derived demand function for domestic and foreign market is p(x) and $p^{*}(y^{*})$ respectively. The notations in lower case represent the variables in upstream market. Let $x(y^{*})$ be the output of domestic (foreign) upstream firm for the home (foreign) market. Moreover, the technology of production of the final product is simplified by the assumption that one unit of the input is required to produce one unit of the final product. Thus, $x=X+X^{*}$ and $y^{*}=Y+Y^{*}$, the total input demand in each of the markets. The marginal cost of the upstream firm is c. For simplicity and without loss of generality, we assume the constant marginal cost is nil again.

In each country there is a government whose goal is to maximize national welfare by setting the value of pollution tax E and E^{*} against the polluted production. The model involves three stages of decision. In the first stage, the home and the foreign governments simultaneously commit to their environmental instruments. Next, the second stage the upstream firms choose input-price or input-quantity to maximize profits. In the third stage, the market for the final good involves a Cournot-Nash equilibrium. This section sets out the equilibrium conditions for our main model and also develops the effects of an import tariff and an environmental policy in the final-good markets.

Firm d and f set their outputs for the home market and their output for the foreign market so as to maximize profits taking rival's exports and also the input prices p and p^{*}, polices T, E and E^{*} as given. The home firm's profit is

$$\underset{\{X,X^{*}\}}{Max}\ \Pi^{d}=\left[P(Q)-p-E\right]X+\left[P^{*}(Q^{*})-p-E-T\right]X^{*}. \tag{1}$$

The first order conditions are:

$$\Pi^{d}_{X}=XP_{X}+P(Q)-p-E=0, \tag{2.1}$$

$$\Pi^{d}_{X^{*}}=X^{*}P^{*}_{X^{*}}+P^{*}\left(Q^{*}\right)-p-E-T=0. \tag{2.2}$$

Foreign firm earns profits,

$$\max_{\{Y,Y^*\}} \Pi^f = \left[P^*(Q^*) - p^* - E^*\right]Y^* + \left[P(Q) - p^* - E^* - T\right]Y, \tag{3}$$

and the first order conditions are:

$$\Pi^f_{Y^*} = Y^* P^*_{Y^*} + P^*(Q^*) - p^* - E^* = 0, \tag{4.1}$$

$$\Pi^f_Y = YP_Y + P(Q) - p^* - E^* - T = 0. \tag{4.2}$$

The constant marginal cost assumption implies that markets are separated: the output choice for one of the markets is independent of the output choice for the other. We assume the demand function is well defined, and the second order and stability conditions are hold globally, so that an interior, unique solution exists. The Cournot equilibrium outputs of firm d are $X(p, p^*, E, E^*; T)$ and $X^*(\bullet)$, and those for firm f are $Y(\bullet)$ and $Y^*(\bullet)$. From those first order conditions, we obtain

$$X_p = X_E = \frac{\Pi^f_{YY}}{\Phi_1} < 0,\; X_{p^*} = X_{E^*} = X_T = \frac{-\Pi^d_{XY}}{\Phi_1} > 0; \tag{5.1}$$

$$Y_p = Y_E = \frac{-\Pi^f_{YX}}{\Phi_1} > 0,\; Y_{p^*} = Y_{E^*} = Y_T = \frac{\Pi^d_{XX}}{\Phi_1} < 0; \tag{5.2}$$

$$X^*_p = X^*_E = X^*_T = \frac{\Pi^f_{X^*Y^*}}{\Phi_2} < 0,\; X^*_{p^*} = X^*_{E^*} = \frac{-\Pi^d_{X^*Y^*}}{\Phi_2} > 0; \tag{5.3}$$

$$Y^*_p = Y^*_E = Y^*_T = \frac{-\Pi^f_{Y^*X^*}}{\Phi_2} > 0,\; Y^*_{p^*} = Y^*_{E^*} = \frac{\Pi^d_{X^*X^*}}{\Phi_2} < 0, \tag{5.4}$$

Where $\Phi_1 = \Phi_2 = b^2/3 > 0$ are the stability conditions in two downstream markets respectively. From (5.1) and (5.2), the rise in intermediate-good price or pollution tax will increase the production cost, thus the firm's output will decrease, the rival firm's output will increase. Similar implication can be applied in (5.3) and (5.4). Observing the above, we have $X_p = X^*_p = Y_{p^*} = Y^*_{p^*} = X_E = X^*_E = Y_{E^*} = Y^*_{E^*} = X^*_T = Y_T = -2/3b$; and $X_{p^*} = X^*_{p^*} = Y_p = Y^*_p = X_{E^*} = X^*_{E^*} = Y_E = Y^*_E = X_T = Y^*_T = 1/3b$ with linear demand and symmetry.

Now we turn to the second-stage equilibrium. A general thinking to a monopoly model is each firm's disregard of the other firm's reactions to its price or quantity decisions.

The monopolist regards himself as having no rivals and then results in the same profit if the firm takes either quantity or price as a choice variable to maximize its profit when it faces the final product demand curve. Nevertheless, in our model here, in the intermediate good market, there is one upstream firm in each country, supplying the intermediate good only to its own country's downstream market. One may think the upstream firm acts as a monopolist. In reality, although the markets for the intermediate goods are segmented, they are connected through the decisions of the downstream firms how much to supply. The sudo-monopolistic upstream firm cannot decide any price or quantity without considering the reaction of upstream firm in the foreign country. In these circumstances each firm can anticipate that its price or quantity decisions may call forth a response from rivals. In view of existing literature, Sugeta and Matsumoto (2007) and Yu (2007) taking the prices as a choice variable, and Canton et al. (2008) taking the outputs as a choice variable in the intermediate-good market, we have never seen anyone to compare the differences between the two choice variables in intermediate-good markets.

Although the markets for the intermediate goods are segmented, they are connected through the decisions of the downstream firms how much to supply. The upstream firms can choose either price or quantity to maximize their profits. In next section, we will set out the optimal environmental policy when the upstream firms' choice variable is price and examines the conditions under which the environmental policy can be a Pigouvian tax with a focus on the additional effects caused by the intermediate-good industry. Moreover, we discuss the effects of trade liberalization on the optimal environmental policies to see the movement is an eco-dumping strategy or a green strategy. Section 4 will find out the equilibrium when the upstream firms' choice variable is quantity.

The Intermediate-Good Markets: Choose Input-Price

Now consider the intermediate-good market. To derive the demand for the input in each country, the first order conditions (2) are initially used to have the partial derivatives with respect to input price, shown in (5). The input price p is simply the domestic market-clearing price, which equates the demand by the firm d at the price p to the total amount of the input produced in country d in stage 2, that is $X + X^* = x$. Similarly, p^* is the market-clearing price in foreign intermediate-good market, $Y^* + Y = y^*$. According to this, we obtain the demand functions for input markets in two countries respectively:

$$x = x\left(p, p^*; E, E^*, T\right) = \frac{1}{3b}\left[2\left(a + p^* + E^*\right) - 4\left(p + E\right) - T\right],$$

$$y^* = y^*\left(p, p^*; E, E^*, T\right) = \frac{1}{3b}\left[2\left(a + p + E\right) - 4\left(p^* + E^*\right) - T\right].$$

The discussions above support us to find the optimal solution for the second stage.

Optimal Intermediate-Good Price

The profit earned by the domestic firm is then given by

$$\underset{\{p\}}{Max}\ \pi^d = px. \tag{6}$$

At the second-stage equilibrium in each market, upstream firm sets the input price to maximize profit. The first-order condition is

$$p_p^d = x + px_p = 0. \tag{7}$$

Similarly, the profit for the foreign firm and the first-order condition:

$$\underset{\{p^*\}}{Max}\ p^f = p^* y^*, \tag{8}$$

$$\pi_{p^*}^f = y^* + p^* y_{p^*}^* = 0. \tag{9}$$

From (7) and (9), the quantity of the intermediate good for two countries depends on both the prices p and p^*. Although the markets for the intermediate goods are segmented, they are connected through the decisions of the downstream firms how much to supply. Solve the two equations together and yield the equilibrium $p = p\left(E, E^*, T\right)$ and $p^*(\bullet)$. The effects of pollution tax and import tariff on the input price can be found by totally differentiating the two first-order conditions, then using the linear demand to obtain. The second order conditions and the stability conditions in two markets $\phi_p = \pi_{pp}^d \pi_{p^*p^*}^f - \pi_{p^*p}^f \pi_{pp^*}^d > 0$ are assumed to be satisfied. It is easy to obtain

$$p_E = p_{E^*}^* = \frac{-1}{\phi_p \Phi_1^2}\left[2\left(\Pi_{XX}^d + \Pi_{X^*X^*}^d\right)^2 + \left(-\Pi_{XY}^d - \Pi_{X^*Y^*}^d\right)^2\right] = \frac{-7}{15} < 0, \tag{10.1}$$

$$p_{E^*} = p_E^* = \frac{1}{\phi_p \Phi_1^2}\left(\Pi_{XX}^d + \Pi_{X^*X^*}^d\right)\left(\Pi_{XY}^d + \Pi_{X^*Y^*}^d\right) = \frac{2}{15} > 0, \tag{10.2}$$

$$p_T = p_T^* = \frac{-1}{\phi_p \, \Phi_1^2}\left[2\left(-\Pi_{XY}^d + \Pi_{Y^*Y^*}^f\right)\left(\Pi_{XX}^d + \Pi_{X^*X^*}^d\right) + \left(\Pi_{XX}^d - \Pi_{Y^*X^*}^f\right)\left(\Pi_{XY}^d + \Pi_{X^*Y^*}^d\right)\right] \quad (10.3)$$

In (10.1), higher emission tax in their own country means less production and the less derived demand to intermediate-good that comes along with these causes the input prices to decrease in their own country. Similarly, in (10.2), higher emission tax in their rival country means more production in home and thus causes the input prices to increase in their own country. The effect in (10.1) is higher than that in (10.2). Finally, the similar induction can be applied in (10.3).

OPTIMAL ENVIRONMENTAL POLICIES AND THE EFFECT OF TRADE LIBERALIZATION

This section will examine the conditions under which the policy is an eco-dumping strategy or a green strategy, analyzes the welfare effects of a pollution tax with a focus on the additional effects caused by the intermediate-good industry, and comparison with perfect competition in the intermediate-good industry is also studied.

Governments decide the environmental policies to maximize national welfare, defined as the sum of consumer surplus, CS; profits of upstream firm π, and downstream firm Π; pollution tax revenue, ETR; tariff revenues from downstream imports, TR; and the damage of pollution, H. The damage function is assumed to be a form in total output: home's and foreign's social damage function can be set $H = H\left(X, X^*\right)$, $H^* = H^*\left(Y, Y^*\right)$ respectively, with $H' > 0$, $H'' > 0$. The welfare functions for the two countries can be defined respectively as

$$\max_{\{E\}} W^d = \int_0^{X+Y} P(Q)dQ - P(Q)(X+Y) + \pi^d\left(p\left(E, E^*; T\right), p^*(\cdot)\right)$$

$$+\Pi^d\left(X\left(p(\cdot), p^*(\cdot), E, E^*; T\right), X^*(\cdot), Y(\cdot), Y^*(\cdot), p(\cdot), E; T\right)$$

$$+E\left(X + X^*\right) - H\left(X, X^*\right) + TY, \quad (11.1)$$

$$\underset{\{E^*\}}{Max}\ W^f = \int_0^{X^*+Y^*} P^*(Q^*)dQ^* - P^*(Q^*)(X^*+Y^*) + p^f\left(p(E,E^*;T), p^*(\cdot)\right)$$
$$+\Pi^f\left(X\left(p(\cdot), p^*(\cdot), E, E^*;T\right), X^*(\cdot), Y(\cdot), Y^*(\cdot), E^*;T\right)$$
$$+E^*(Y+Y^*) - H^*(Y,Y^*) + TX^*. \qquad (11.2)$$

We will discuss the optimal environmental policy and examine the effects of trade liberalization on the optimal policy.

In the case, the first order conditions are:

$$W_E^d = \frac{dCS}{dE} + \frac{d\pi^d}{dE} + \frac{d\Pi^d}{dE} + \frac{dETR}{dE} - \frac{dH}{dE} + \frac{dTR}{dE}, \qquad (12.1)$$

$$W_{E^*}^f = \frac{dCS^*}{dE^*} + \frac{d\pi^f}{dE^*} + \frac{d\Pi^f}{dE^*} + \frac{dETR^*}{dE^*} - \frac{dH^*}{dE^*} + \frac{dTR^*}{dE^*}, \qquad (12.2)$$

where

$$\frac{dCS}{dE} = \frac{-2}{9}(X+Y) < 0,\ \frac{d\pi^d}{dE} = px_{p^*}p_E^* = \frac{4}{45b}p > 0,\quad \frac{d\Pi^d}{dE} = \frac{-28}{45}(X+X^*) < 0,$$
$$\frac{dETR}{dE} = (X+X^*) - \frac{28E}{45b},\quad \frac{dH}{dE} = \frac{-28}{45b}H' < 0,\quad \frac{dTR}{dE} = \frac{4T}{45b} > 0, \qquad (13)$$

Using (13), (12.1) and (12.2) can be reduced into:

$$W_E^d = -(X+X^*)p_E + px_{p^*}p_E^* + \left[b(X+Y) + 2(E-H')\right]\left(X_p p_E + X_{p^*}p_E^* + X_E\right)$$
$$+T\left(Y_p p_E + Y_{p^*}p_E^* + Y_E\right) = 0, \qquad (14.1)$$

$$W_{E^*}^f = -(Y+Y^*)p_{E^*}^* + p^* y_p^* p_{E^*} + \left[b\left(X^*+Y^*\right) + 2\left(E^*-H^{*\prime}\right)\right]\left(Y_p^* p_{E^*} + Y_{p^*}^* p_{E^*}^* + Y_{E^*}^*\right)$$
$$+T\left(X_p^* p_{E^*} + X_{p^*}^* p_{E^*}^* + X_{E^*}^*\right) = 0. \qquad (14.2)$$

On the other hand, the upstream firms are not acting strategically when the intermediate-good market is perfect competition. For notation convenience, E^C and E^P stand for the emission tax imposed by the domestic government on final polluting production in a competitive upstream market and in an imperfect competitive upstream market. We have a two-stage game in which the first order conditions for welfare maximization are

$$W_{E^C}^d = \left[b(X+Y) + 2(E-H')\right]X_E + TY_E = 0, \qquad (15.1)$$

$$W^{f}_{E^{*C}} = \left[b\left(X^{*}+Y^{*}\right)+2\left(E^{*}-H^{*\prime}\right)\right]Y^{*}_{E^{*}}+TX_{E^{*}}=0. \qquad (15.2)$$

Assuming the second order conditions are satisfied, substituting the comparative - static results obtained in (5), (10) and (13) into (14) and (15), and integrating the symmetric assumption, $E = E^{*}$. For a neater exhibition, the damage functions of domestic and foreign can be specified to be a quadratic form in total output as shown in literature commonly: $H = h\left(X + X^{*}\right)^{2}/2$, $H^{*} = h\left(Y + Y^{*}\right)^{2}/2$, $H' = H^{*\prime} > 0$, $H'' = H^{*\prime\prime} = h > 0$. We obtain the optimal emission tax in terms of the marginal damage cost H',

$$E^{P} = E^{*P} = H'^{P} - \frac{70ab - T(53b + 8h)}{56(b + h)}, \qquad 16.1)$$

$$E^{C} = E^{*C} = H'^{C} - \frac{4ab - T(5b + 2h)}{8(b + h)}. \qquad (16.2)$$

In a free trade world, T = 0, (16) shows that the emission taxes are smaller than Pigouvian tax ($E = E^{*} = H'$; emission tax should be set equal to the marginal damage cost) no matter what the structure of intermediate-good market is. By examining (16.2), since there is no distortion in the perfect competitive intermediate-good market, the optimal emission tax is not the usual first-best tax rule (so called Pigouvian tax). The reason is that the downstream market is imperfect. The emission tax is a single instrument used to regulate two sorts of distortions, one negative externality, and one restriction in production, which can be found in (15).

Substituting the damage functions into (16), it can be rewritten as

$$E^{P} = E^{*P} = \frac{14a(4h - 5b) - T(28h - 53b)}{56(b + h)}, \quad E^{C} = E^{*C} = \frac{4a(2h - b) - T(4h - 5b)}{8(h + b)}, \qquad (17)$$

Equation (17) shows that, under free trade, the higher increasing rate of marginal damage is, the more likely to be tax the optimal environmental policy is, see also (16). The optimal environmental policy is subsidy with imperfect intermediate-good market, whereas it is tax with perfect intermediate-good market when $b/2 < h < 5b/4$.

In the case of free trade, using E^{P} we obtain the optimal intermediate-good price in the second stage and thus yield the optimal final-good output in the third stage when the intermediate-good market is imperfect, so does the optimal final-good output when the intermediate-good market is perfect by using E^C; that is $\left(X^P + X^{P*}\right)\Big|_{T=0}$ = $\left(X^C + X^{C*}\right)\Big|_{T=0}$ = $a/(b+h)$ ◦ Summarize the result in proposition 1.

Proposition 1

Under free trade, the optimal final-good output with imperfect intermediate-good market will have the same output level as that with perfect intermediate-good market after imposing the optimal emission tax.

Regardless of upstream market structure, the government imposes the optimal emission tax will drive the final-good output level to be the same. This finding is interesting. To know why they all achieve the same output, we assume there is no social damage caused by the pollution first, H = 0. The emission tax can be seen as a production tax. By doing some simple mathematic exercise, we find out the optimal production tax moves the equilibrium price to what would, in the absence of pollution and ignorance of input price, be the margin cost pricing position in output space. Without pollution damage, there is only one distortion in the market, which comes from the imperfect competition output market. Consequently, the production subsidy will move away the distortion and to be the social optimal. Next, we consider the pollution. If we can have one more tool, such as emission tax, then the optimal emission tax should be the Pigouvian tax. However, in our model, there is only one policy, which should be lower than Pigouvian tax.

Moreover, under free trade, if we compare the optimal emission tax when the intermediate-good market is imperfect to that when the intermediate-good market is perfect we see immediately that the discrepancy between the optimal emission tax and the Pigouvian tax with imperfect is $E^P - H\text{¢}^P = -5ab/4(b+h)$, while it is $E^C - H\text{¢}^C = -ab/2(b+h)$ with perfect; in other words, the discrepancy is bigger if the intermediate-good market is imperfect than if it is perfect. Combining this result and proposition 1 shows the optimal emission tax ranking in proposition 2.

Proposition 2

Under free trade, the ranking of the optimal emission tax with imperfect competitive intermediate-good market E^P, the optimal emission tax with perfect competitive intermediate-good market E^C and the Pigouvian emission tax H'^P is $E^P < E^C < H'^P = H'^C$. The discrepancy between the optimal emission tax and the Pigouvian tax is bigger if the intermediate-good market is imperfect than if it is perfect.

The reason is that when the intermediate-good market is imperfect, the productions in downstream are less, the deadweight loss is bigger, and so the government will lower emission tax to stimulate outputs. Furthermore, the environmental policy to give consideration to reduce pollution and to improve export competency under free trade. Consequently, the optimal emission tax is lower marginal damage.

Next, we turn to the effect of a reduction of tariffs on the strength of environmental policies. From (17) the effects of trade liberalization on the optimal emission tax can be obtained,

$$E_T^P = E_T^{*P} = \frac{53b - 28h}{56(b+h)} \gtrless 0,\ if\ h \lessgtr \frac{53}{28}b, \quad E_T^C = E_T^{*C} = \frac{5b - 4h}{8(h+b)} \gtrless 0,\ if\ h \lessgtr \frac{5}{4}b, \quad (18)$$

The answer here depends on the increasing rate of marginal damage (or the convexity of damage function); that is, on h. A reduction in tariffs causes two effects: an incentive for tougher environmental regulations because of an increase in output of domestic firm, and then an increase in the marginal social cost; the other incentive for less strict regulations because of an increase in output of foreign firm selling to domestic market, and then cost advantage for domestic firm. Generally speaking, there is more stringent (looser) environment regulation, so called “green strategy” (“eco-dumping”) as a consequence of moves towards freer trade when the increasing rate of marginal damage is higher (smaller). More interestingly, by comparing E_T^P to E_T^C, the optimal environmental policy is less likely to be a green strategy in the situation of bilateral reductions in tariffs if the intermediate-good market is imperfect than if that is perfect. Proposition 3 shows the problem some environmentalists concern, which is trade liberalization might damage the environment.

Proposition 3

The optimal environmental policy is less likely to be a green strategy under trade liberalization if the upstream firms act imperfectly than they act perfectly.

When h is smaller (higher), "eco-dumping" ("green strategy") happens. Furthermore, $E_T^P - E_T^C = 9b/28(b+h) > 0$, shows it could be more green strategy as the intermediate-good market is perfect. The intuition can be explained as follows. A reduction in the tariff lowers the export cost of the downstream firms and will produce more. It can be proved easily that the effect of trade liberalization on the output of final good is bigger under perfect intermediate-good market than imperfect. Thus, the environmental tax should be higher due to more pollution with more output when the intermediate-good market acts perfectly.

THE INTERMEDIATE-GOOD MARKETS: CHOOSE INPUT QUANTITY

In this section, we will set out the optimal environmental policy when the upstream firms' choice variable is output. In our model, the upstream firms only sell the intermediate good to his own country's downstream firm. They seem to be monopolists. However, the two upstream firms compete together through the downstream firm's competition in the intra-industry trade model.

Optimal Quantities of Intermediate Good

Using $X + X^* = x$ and $Y^* + Y = y^*$, the inverse derived demand functions for intermediate-good are: $p = a - bx - \frac{1}{2}(by^* + T) - E$, $p^* = a - by^* - \frac{1}{2}(bx + T) - E^*$. The profit earned by the domestic firm is then given by

$$\underset{\{x\}}{Max}\ \pi^d = px, \tag{19}$$

At the second-stage equilibrium in each market, upstream firm sets the input quantity to maximize profit. The first-order condition is

$$p_x^d = p_x x + p = 0. \tag{20}$$

Similarly, the profit for the foreign firm and the first-order condition:

$$\underset{\{y^*\}}{Max}\ p^f = p^* y^*, \tag{21}$$

$$\pi_{y^*}^f = p_{y^*}^* y^* + p^* = 0. \tag{22}$$

From (20) and (22), the quantity of the intermediate good for two countries depends on both the prices p and p^*. Although the markets for the intermediate goods are segmented, they are connected through the decisions of the downstream firms how much to supply. Solve the two equations together and yield the equilibrium $x = x\left(E, E^*, T\right)$ and $y^*(\bullet)$. The effects of pollution tax and import tariff on the input quantity can be found by totally differentiating the two first-order conditions, then using the linear demand to obtain. The second order conditions and the stability conditions in two markets $\phi_q = \pi^d_{xx}\pi^f_{y^*y^*} - \pi^f_{y^*x}\pi^d_{xy^*} > 0$ are assumed to be satisfied. It obtains

$$x_E = y^*_{E^*} = \frac{\pi^f_{y^*y^*}}{\phi_q} = \frac{-8}{15b} < 0, \; x_{E^*} = y^*_E = \frac{\pi^d_{xy^*}}{\phi_q} = \frac{2}{15b} > 0, \; x_T = y^*_T = \frac{-1}{5b} < 0, \; x_T = y^*_T = \frac{-1}{5b} < 0. \tag{23}$$

The intuition behind (23) is more direct than in (10). For example, in (23.1), higher emission tax in their own country means less production and then less derived demand to intermediate-good in their own country.

Optimal Environmental Policy and the Effect of Trade Liberalization

The welfare functions where the intermediate-good firms choose quantity show bellows.

$$\underset{\{E\}}{Max}\; W^d = \int_0^{X+Y} P(Q)dQ - P(Q)(X+Y) + p^d + \Pi^d + E\left(X + X^*\right) - H + TY, \tag{24.1}$$

$$\underset{\{E^*\}}{Max}\; W^f = \int_0^{X^*+Y^*} P(Q^*)dQ^* - P(Q^*)(X^* + Y^*) + p^f + \Pi^f + E^*\left(Y + Y^*\right) - H^* + TX^*, \tag{24.2}$$

We will discuss the optimal environmental policy and examine the effects of trade liberalization on the optimal policy.

The first order conditions are:

$$W^d_E = \frac{dCS}{dE} + \frac{d\pi^d}{dE} + \frac{d\Pi^d}{dE} + \frac{dETR}{dE} - \frac{dH}{dE} + \frac{dTR}{dE}, \tag{25.1}$$

$$W^f_{E^*} = \frac{dCS^*}{dE^*} + \frac{d\pi^f}{dE^*} + \frac{d\Pi^f}{dE^*} + \frac{dETR^*}{dE^*} - \frac{dH^*}{dE^*} + \frac{dTR^*}{dE^*}. \tag{25.2}$$

Assume free trade $T = 0$, substituting the comparative-static results obtained before, and integrating the symmetric assumption; $E = E^*$, and we are now in a position to compare the optimal emission tax setting by the government under the upstream firm taking output as a variable with that under the upstream firm taking price as a variable. To investigate this point, we can evaluate (25.1) at $E^Q = E^P$ and then use (14.1) to yield the following equation $W^d_{E^Q_d}\Big|_{W^d_{E^P_d}=0,\, E^Q_d=E^P_d,\, E^Q_f=E^P_f,\, T=0} < 0$. It follows that $E^Q < E^P$. Proposition 4 summaries the result.

Proposition 4. The optimal emission tax will be lower when the upstream firms take the output as a choice variable than they take the price as a choice variable.

The optimal emission tax with quadratic social damage function in total output and quantity as a decision variable is $E^Q = E^{*Q}$. An increase in h tends to move the optimal emission taxes towards positive. In the area of $5b/4 < h < 3b/2$, the optimal environmental policy is to tax (subsidy) when the upstream firms choose price (quantity) as a variable.

Moreover, the degree of diversification E^Q and H'^Q is $E^Q = E^{*Q} = H¢^Q -$ $- [24ab - T(17b + 2h)]/[16(b + h)]$. In a free trade world, T = 0 in (29), the environmental tax is smaller than Pigouvian tax ($H¢^Q$). Moreover, we can prove the optimal output in the downstream firm with quantity as a choice variable under the optimal emission tax is the same as that with price as a choice variable.

Proposition 5. With free trade, the Pigouvian tax with price as a choice variable for the upstream firm is the same as that with quantity as a choice variable.

In the case of free trade, using (20) we obtain the optimal intermediate-good output in the second stage and thus yield the optimal final-good output in the third stage with quantity as a choice variable, that is $\left(X^Q + X^{Q*}\right)\Big|_{T=0} = a/(b+h)$. Combining this proposition with proposition 2 yields $\left(X^Q + X^{Q*}\right)\Big|_{T=0} = \left(X^P + X^{P*}\right)\Big|_{T=0} = \left(X^C + X^{C*}\right)\Big|_{T=0}$. This concludes to the result: under free trade, no matter what the choice variable is price or output for the upstream firm, when the intermediate-good market is imperfect the optimal emission tax maximizes domestic welfare by moving the upstream firm to what would have been the output in upstream with perfect competition. Similarly, an aim of the government imposes environmental policy is to make that the price equilibrium to be the margin cost pricing.

Finally, differentiating E^Q with respect to T, the effects of trade liberalization are $E_T^Q = E_T^{*Q} > (=,<)0$, $if\ h < (=,>)17b/8$. Comparing (18.1) and this result, proposition 6 shows the effect of trade liberalization on the optimal emission tax.

Proposition 6. The optimal environmental policy is less likely to be a green strategy under trade liberalization if the upstream firms choose quantity than price to maximize their profits**.**

The intuition behind proposition 6 is similar to proposition 3. The downstream firms produce more if the upstream firms choose price than quantity to maximize their profits. Thus, the environmental tax should be higher when the upstream firms choose price in intermediate-good market.

Burguet and Sempere (2003) analyze how trade liberalization affects environmental policies in the context of bilateral trade in downstream industry. They argued Kennedy's (1994) statement may not hold in their model. We employ a vertical structure with downstream bilateral trade, the difference between ours and Burguet and Sempere (2003) can be seen in the above proposition.

CONCLUDING REMARKS

As the WTO tightens restrictions on international trade policies, environmental regulations have increasingly turned to be the potential instruments for strategic trade. This paper has established a symmetric two-country model with vertically related markets to examine the optimal environmental policy and how it is affected by the tariff on the final good. It is found that the optimal environmental tax is smaller and the optimal environmental policy is less likely to be a green strategy under trade liberalization if the market structure in the intermediate good market is imperfect than perfect competition. On the other hand, the optimal environmental tax is necessarily higher if the upstream firm chooses price than quantity. Furthermore, the optimal environmental policy is less likely to be a green strategy under trade liberalization if the upstream firms choose quantity than price to maximize their profits. We attributed the foregoing result to the degree of competition of upstream market.

REFERENCES

Barrett, S. (1994). Strategic environmental policy and international trade. *Journal of Public Economics*, 54, 325-338.

Bernhofen, D. M. (1997). Strategic trade policy in a vertically related industry. *Review of International Economics*, 5, 429-433.

Brander, J. A. (1981) Intra-industry trade in identical commodities. *Journal of International Economics*, 11, 1-14.

Burguet, R. and Sempere, J. (2003). Trade liberalization, environmental policy, and welfare. *Journal of Environmental Economics and Management*, 46, 25-37.

Canton, J., A. Soubeyran, and Stahn, H. (2008). Environmental taxation and vertical Cournot oligopolies: How Eco-industries Matter. *Environmental and Resource Economics*, 40, 369-382.

Conrad, K. (1993). Taxes and subsidies for pollution-intensive industries as trade policy. *Journal of Environmental Economics and Management*, 25, 121-135.

Greaker, M. (2003). Strategic environmental policy; eco-dumping or a green strategy?. *Journal of Environmental Economics and Management*, 45, 692-707.

Hamilton S. F. and Requate, T. (2004). Vertical structure and strategic environmental trade policy. *Journal of Environmental Economics and Management*, 47, 260-269.

Hathaway, J. and Richard, J. A. (1979). Equilibria of price-setting and quantity setting duopolies. *Economics Letters*, 3, 133-137.

Hwang, H., Y. S. Lin and Yang, Y. P. (2007). Optimal trade policies and production technology in vertically related market. *Review of International Economics*, 15, 823-835.

Ishikawa, J. and Spencer, B. J. (1999). Rent-shifting export subsidies with an imported intermediate product. *Journal of International Economics*, 48, 199-232.

Kamien, M. I. and Schwartz, N. L. (1983). Conjectural variations. *Canadian Journal of Economics*, 16, 191-211.

Kennedy, P. W. (1994). Equilibrium pollution taxes in open economics with imperfect competition. *Journal of Environmental Economics and Management*, 27, 49-63.

Levitan, R. E. and Shubik, M. (1971). Noncooperativeequilibria and strategic spaces in an oligopolistic market. In H. W. Kuhn and C. P. Szego, eds., Differential Games and Related Topics, Amsterdam: North-Holland.

Roelfsema, H. (2007). Strategic delegation of environmental policy making. *Journal of Environmental Economics and Management*, 53, 270-275.

Spencer, B. J. and Jones, R. W. (1991). Vertical foreclosure and international trade policy. *Review of Economic Studies*, 58, 153-170.

Spencer, B. J. and Jones, R. W. (1992). Trade and protection in vertically related markets. *Journal of International Economics*, 32, 31-55.

Sugeta, H. and Matsumoto, S. (2007). Upstream and downstream pollution taxations in vertically related markets with imperfect competition. *Environmental and Resource Economics*, 38, 407-432.

Tanguay, G. A. (2001). Strategic environmental policies under international duopolistic competition. *International Tax and Public Finance*, 8, 793-811.

Ulph, A. (1996). Environmental policy and international trade when governments and products act strategically. *Journal of Environmental Economics and Management*, 30, 265-281.

Walz, U. and Wellisch, D. (1997). Is free trade in the interest of exporting countries when there is ecological dumping? *Journal of Public Economics*, 66, 275-291.

Yu, Z. (2007). Strategic trade policy aspects of the Kyoto Protocol: extracting oil rents. *Asia-Pacific Journal of Accounting & Economics*, 14, 219-234.