Trade Liberalization and Optimal Environmental Policy in a Vertically Related Market

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This paper studies the effects of trade liberalization on the optimal environmental policy, domestic pollution, and welfare in the presence of an intermediate good market. In the import model, there is a monopoly in the domestic intermediate good market. One domestic downstream firm generates pollution during production and competes against one foreign firm in the domestic downstream market. When the domestic environmental tax is endogenous, the presence of the intermediate good market increases the reduction of the optimal environmental tax caused by trade liberalization. Moreover, trade liberalization increases the domestic pollution and may lower domestic welfare. No matter whether the intermediate good market is monopolistic or perfectly competitive, under the optimal environmental tax the effects of trade liberalization on domestic pollution and welfare stay the same. Compared to the import case, under the intra-industry trade (IIT) model the optimal environmental tax may increase after trade liberalization. Although trade liberalization may increase the pollution tax rate, it always increases the environmental damage.

Keywords: environmental policy, vertically related market, trade liberalization
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1 Introduction

As the World Trade Organization (WTO) tightens restrictions on international trade policies, environmental regulations have increasingly become instruments used for strategic trade. One topic in the literature has studied how strategic environmental policies also serve as trade polices - for instance, Kou et al. (2001), Conrad (1993), Barrett (1994), Ulph (1996), and Greaker (2003). Their major conclusion is that the rent-shifting and trade-related incentives induce weaker environmental policies. When firms engage in Cournot competition, these incentives induce environmental policies to be weaker than the efficient level. This result is a straightforward application of the theories of strategic behavior. By committing to a less restrictive environmental policy, the home country government effectively reduces the marginal costs of domestic firms, making them more aggressive competitors in international markets.

Environmentalists have generally considered international trade as creating a threat to adequate environmental regulation. Kennedy (1994) points out that "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 (Tanguay, 2001; Walz and Wellisch, 1997). For example, trade liberalization promotes wood export and agricultural expansion in the Philippines, resulting in serious deforestation (McKenna and Bleck, 1996). However, Burguet and Sempere (2003) examine how trade liberalization affects environmental policies in the context of bilateral trade and imperfect competition, showing that the environmental policies may be more stringent in tariff reductions. Along the same line of thinking, Roelfsema (2007) develops a political economic model and presents that if the median voter cares sufficiently for the environment, then he has an incentive to delegate policy making to a politician who cares more about the environment than him. By both constructing an import model with pollution in consumption, Lai (2004) finds that trade liberalization reduces the domestic environmental damage while Lai (2007) further notes that trade liberalization reduces the foreign country's welfare in the presence of political donations.

In reviewing the existing literature's setting of the environment-for-trade policy, we find that the importance of the element of a vertical-related market has been ignored. In trade theory, there is a considerable body of literature on trade policy in a vertical-related market such as Spencer and Jones

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(1991, 1992), Ishikawa and Spencer (1999), and Hwang et al. (2007), etc. From the trade and environment literature, we learn that the vertical-related market structure plays an important role in the decision of trade policy. From an environmental issue standpoint, it is interesting to know the role of a vertical structure in the decision of environmental policies. Hamilton and Requate (2004) provide one research towards this area, constructing a competitive upstream market 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. Yu (2007) further investigates 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) find the effect of a change in the 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 up a model with polluting firms selling final goods to consumers and outsourcing their abatement activities to an environment industry, showing that the optimal tax is the result of a trade-off that depends on the firms' market power along the vertical structure.

We establish a two-country model with a vertically related market in the domestic country. In the downstream market, there is one firm in each country selling a homogeneous good, whose production generates pollution, in the domestic country. The WTO engages in promoting free trade agreements and countries sign regional trade agreements, in order to reduce the tariff barriers and hence facilitate trade liberalization. Catching the above trend in the real world, this paper studies the effects of trade liberalization which reduces the exogenous tariff rate on the optimal environmental policy, domestic pollution, and welfare. We find that trade liberalization reduces the optimal environmental policy in the import case. Moreover, the effect of trade liberalization on the optimal environmental policy is greater if the market structure in the intermediate good market is imperfect competition rather than perfect competition. However, it can be undetermined in an intra-industry trade model. This is because in an intra-industry model, the export increase caused by trade liberalization is more than the domestic sales decrease, hence increasing the pollution amount. As a result, trade liberalization may increase the environmental tax in the intra-industry model. No matter the intermediate good market is a monopoly or perfect competition, as long as the environmental tax is endogenous, trade liberalization results in

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the same degree of domestic pollution and may reduce the domestic social welfare.

The rest of the paper is structured as follows. Section 2 presents the basic trade model with a vertically related structure in the domestic country, with a focus on the additional effects caused by the intermediate-good industry. We discuss the effects of trade liberalization on the domestic optimal environmental policy, pollution, and welfare. Section 3 discusses the intra-industry trade case. Finally, Section 4 concludes this paper.

2 The import model

This paper establishes a two-country model with a vertically related market in the domestic country. There are two downstream firms, domestic (D) and foreign (F), producing a homogenous product and competing in the domestic market in a Cournot fashion. The inverse demand function for the final good in the domestic market is $p = p(Q)$ with $p' < 0$, $p'' = 0$; and $Q = x + y$ is the market output, where x and y represent the outputs of the domestic and foreign firms, respectively. For a neater exhibition, the demand function is assumed to be linear.

Suppose that the factors in the downstream market are immobile. Therefore, the domestic downstream firm can only purchase intermediate goods from the domestic upstream firm. Moreover, the production of one unit final good requires one unit of the intermediate good. The price of the intermediate good set by the upstream firm, with marginal production cost k, is r. The final good production generates pollution and the domestic government sets the value of pollution tax e against the polluted production. The foreign firm's exports to the domestic market are subject to a tariff, t. We further simplify the analysis by assuming zero marginal costs of the downstream foreign firm's production and no environmental tax on the foreign firm.

This paper constructs a three-stage game in order to analyze the effects of trade liberalization on the optimal environmental policy when there is an intermediate good market. In stage one the home government decides on the optimal environmental tax. In stage two the upstream firm in the home country (denoted by U) chooses the intermediate good price. In stage three the downstream domestic firm and foreign firms engage in Cournot (quantity) competition in the final good market of the home country. The

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solution concept of the subgame-perfect Nash equilibrium (SPNE) is applied to solve this game and the backward induction approach is used.

The domestic and foreign downstream firms' profits are respectively:

$$\max_{\{x\}} \pi^D = [p(Q) - r - e]x, \tag{1.1}$$

$$\max_{\{y\}} \pi^F = [p(Q) - t]y. \tag{1.2}$$

The first-order conditions are:

$$\pi_x^D = xp' + p(Q) - r - e = 0, \tag{2.1}$$

$$\pi_y^F = yp' + p(Q) - t = 0. \tag{2.2}$$

We assume the demand function is well defined, and the second-order and stability conditions hold globally,[1] so that a unique solution exists. The Cournot equilibrium outputs are $x = x(r, e, t)$ and $y = y(r, e, t)$ and require $x > 0$ and $y > 0$.

From those first-order conditions, we obtain:

$$x_r = x_e = y_t = \frac{\pi_{yy}^F}{D_1} < 0 \text{ and } x_t = y_r = y_e = \frac{-\pi_{xy}^D}{D_1} > 0. \tag{3}$$

From Equation (3), a rise in pollution tax, input price, or tariff increases the production cost, and thus the firm's output will decrease, while the rival firm's output will increase. Observing this, we must have $x_r = x_e = y_t = 2/(3p') < 0$; and $x_t = y_r = y_e = -1/(3p') > 0$.

Since the production of one unit final good requires one unit of the intermediate good, the derived demand function of the intermediate good can be expressed as $X = x(r, e, t)$. The profit maximization problem of the domestic upstream firm is to choose the intermediate good price to maximize its own profit:

$$\max_{\{r\}} \Pi^U = (r - k)X(r, e, t). \tag{4}$$

The first-order condition for the upstream firm's profit maximization is:

$$\Pi_r^U = X + (r - k)X_r = 0. \tag{5}$$

[1] $\pi_{xx}^D = \pi_{yy}^F = 2p' < 0$, $\pi_{xy}^D = \pi_{yx}^F = p' < 0$, and $D_1 \equiv \pi_{xx}^D \pi_{yy}^F (\pi_{xy}^D \pi_{yx}^F) = 3(p')^2 > 0$.

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Equation (5) and the comparative statics in the third stage ensure that the second-order condition must hold; i.e., $\Pi^U_{rr} = 2X_r < 0$. As a result, the optimal intermediate good price is $r = r(e, t, k)$.[2] Totally differentiating Equation (5), we obtain the comparative statics:

$$r_e = \frac{-\Pi^U_{re}}{\Pi^U_{rr}} = \frac{-x_e}{2x_r} < 0, \quad r_t = \frac{-\Pi^U_{rt}}{\Pi^U_{rr}} = \frac{-x_t}{2x_r} > 0, \quad \text{and}$$
$$r_k = \frac{-\Pi^U_{rk}}{\Pi^U_{rr}} = \frac{1}{2} > 0. \tag{6}$$

The first derivative in (6) implies that an increase in the environmental tax raises the domestic downstream firm's cost, resulting in a drop in the derived demand for the intermediate good and hence a decrease in the intermediate good's price. The second derivative indicates that an increase in the tariff rate increases the domestic downstream firm's output, promotes the derived demand for the intermediate good, and hence raises the intermediate good's price. The third derivative describes that an increase in the upstream firm's marginal cost increases the intermediate good's price.

We now turn to examine the first stage: the determination of the environmental tax. The domestic government maximizes the social welfare, defined as the sum of consumer surplus, profit for upstream firm Π^U, profit for downstream firm π^D, environmental tax revenue, tariff revenues from foreign imports, and the damage in pollution, H. The damage function is assumed to be a function of the domestic output: $H = H(x)$, with $H' > 0$, $H'' \geq 0$. The welfare function can be defined as:

$$\max_{\{e\}} W = \int_0^Q p(u)du - p(Q)y - kX + ty - H(x). \tag{7}$$

The first-order condition is:

$$W_e = \underbrace{\left[(p - r)\frac{dx}{de} - p'y\left(\frac{dx}{de} + \frac{dy}{de}\right)\right]}_{\substack{\text{Final good market distortion effect} \\ (-)}} + \underbrace{(r - k)\frac{dx}{de}}_{\substack{\text{Intermediate good market} \\ \text{distortion effect } (-)}}$$

[2] Since the domestic upstream firm is a monopoly in the domestic intermediate good market, the choice of its quantity or price will result in the same outcomes.

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$$+ \underbrace{t\frac{dy}{de}}_{\substack{\text{Tariff revenue}\\ \text{effect (+)}}} \underbrace{-H'\frac{dx}{de}}_{\substack{\text{Enviromental damage}\\ \text{effect (+)}}} = 0. \tag{8}$$

There are four effects in the first-order condition depicted by Equation (8). The first and second effects are negative due to imperfect competition in the markets for the final and intermediate goods, such that the domestic government has an incentive to lower down the environmental tax to increase the output quantities. The third and fourth effects are positive, with the former due to increasing the imports and hence tariff revenues, while the latter due to reducing the domestic output and the environmental damage, such that the domestic government will increase the environmental tax. Comparing to Canton et al. (2008) which has a vertically related market without imports, we find that the optimal environmental tax without imports will be higher (lower) than that with imports if the amount of import (tariff revenue effect) is sufficiently large.[3]

The second-order condition is satisfied: $W_{ee} = p'[(dx/de)^2-(dy/de)^2] -H''(dx/de)^2 = (3p'-4H'')/36(p')^2 < 0$, where $dx/de = x_r r_e + x_e = 1/(3p') < 0$, and $dy/de = y_r r_e + y_e = -1/(6p') > 0$. Substituting the comparative static results obtained in (3) and (6) into (8), we obtain the optimal environmental policy $e = e(t, k)$.[4]

Let us now turn to the effect of a tariff reduction on the strength of an environmental policy. From (8) the effects of trade liberalization on the

[3]Canton et al. (2008) do not decompose the effects of the optimal environmental tax in the first-order condition for welfare maximization, as what is done here. After incorporating imports into this model, we find that there is an additional tariff revenue effect as well as expansion of the final good market distortion effect.

[4]From (8), we obtain the optimal emission tax in terms of the marginal damage cost H': $e = H' + p'Q - (r - k) - p(dy/de)(dx/de)^{-1}$. Assuming $k = 0$ and free trade $t = 0$, it shows that the environmental tax is smaller than the Pigouvian tax ($e = H'$- that is, the emission tax should be set equal to the marginal damage cost). We assume that the market demand is linear and environmental damage is quadratic in the domestic country; i.e., $p = a - b(x + y)$, $p^* = a - b(x^* + y^*)$, and $H(X) = h(x + x^*)^2/2$. The parameter a represents the market size and parameter b is the slope of the demand curve. We obtain the optimal emission tax is $e = [a(4h - 15b) + t(9b + 4h) + 2k(9b - 4h)]/2(3b + 4h)$.

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optimal emission tax can be obtained as:

$$e_t = \frac{-W_{et}}{W_{ee}} = \frac{-1}{W_{ee}^D}\left\{\underbrace{\left[p'\left(\frac{dx}{de}\frac{dx}{dt} - \frac{dy}{de}\frac{dy}{dt}\right) - r_t\frac{dx}{de}\right]}_{(+)} + \underbrace{r_t\frac{dx}{de}}_{(-)}\right.$$
$$\left. + \underbrace{\frac{dy}{de}}_{(+)}\underbrace{-H''\frac{dx}{dt}\frac{dx}{de}}_{(+)}\right\} = \frac{3p'}{2\,(3p' - 4H'')} + \frac{-3p'}{(3p' - 4H'')}$$
$$+ \frac{6p'}{(3p' - 4H'')} + \frac{-2H''}{(3p' - 4H'')} > 0, \tag{9}$$

where $dx/dt = x_r r_t + x_t = -1/(6p') > 0$, $dy/dt = y_r r_t + y_t = 7/(12p') < 0$, and $dQ/dt = dx/dt + dy/dt < 0$. Equation (9) further depicts the effects of trade liberalization on the optimal environmental tax when the intermediate good market is a monopoly. The first item is positive since trade liberalization reduces the distortion in the final good market, hence providing the domestic government an incentive to increase the environmental tax. The second item is negative, because trade liberalization reduces the derived demand for intermediate goods by downstream firms, hence increasing the distortion in the intermediate good market and inducing the domestic government to decrease the environmental tax. The third item is positive, indicating that trade liberalization increases the import, reduces the tariff revenue effect, and hence induces the domestic government to reduce the environmental tax. The fourth item is positive, implying that trade liberalization reduces the domestic output, decreases the environmental damage, and hence induces the domestic government to lower down the environmental tax. Thus, we find that the tariff revenue effect dominates the intermediate good distortion effect such that trade liberalization will reduce the optimal environmental tax. As a result, the optimal environmental tax decreases with trade liberalization when the intermediate good market is a monopoly. The economic intuitions behind the above discussions are: In the import model, since a reduction in the domestic tariff rate brings competitive disadvantage to the domestic firm, the domestic government then has an incentive to decrease the environmental tax rate at the same time to maintain the domestic firm's competitive advantage.

In order to further analyze the effects of trade liberalization on the op-

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timal environmental policy when the intermediate good market is perfect competition, let us assume that e^C is the optimal environmental policy for the home country when the intermediate good market is perfectly competitive. Substituting the conditions $r_e = r_t = 0$ into (9), we then obtain the marginal effect of the tariff on the environmental tax ($e_t^C \equiv e_t|_{r_e=r_t=0}$):[5].

$$e_t^C = \frac{-1}{W_{ee}^D\big|_{r_e=r_t=0}} \left[\underbrace{p'(x_e x_t + y_e y_t)}_{(0)} + \underbrace{y_e}_{(+)} \underbrace{-H'' x_e x_t}_{(+)} \right]$$
$$= \frac{3p'}{(3p' - 4H'')} + \frac{-2H''}{(3p' - 4H'')} > 0. \tag{10}$$

Comparing (9) and (10), we find that the presence of the intermediate good market not only generates the intermediate good market distortion effect, but also raises the magnitudes of the final good market distortion and tariff revenue effects, showing that the monopolistic intermediate good market will further expand the magnitude of reducing the optimal environmental tax caused by trade liberalization - that is, $e_t > e_t^C > 0$. Proposition 1 summarizes the above results.

Proposition 1. (1) When the intermediate good market is a monopoly, trade liberalization reduces the optimal environmental tax; that is $e_t > 0$. (2) Compared to the case when the domestic intermediate good market is perfectly competitive, we have $e_t > e_t^C > 0$.

The intuition behind Proposition 1 is as follows. Compared to the case when the upstream market is perfectly competitive, if the upstream market structure is a monopoly, the domestic downstream firm's marginal cost increases due to double marginalization. Therefore, in order to cope with the double marginalization problem, the reduction in the optimal environmental tax caused by trade liberalization will be greater when the upstream market is a monopoly rather than perfectly competitive.

After the environmental tax is decided, the optimal output for the domestic firm can be expressed as $x = x(r(e(t,k),t,k),\ e(t,k),t)$. The total effect of trade liberalization on pollution can be described by the following equation.

[5]According to the demand and damage functions in Footnote 4, under a perfectly competitive upstream market we can derive the optimal environmental tax rate as $e_t^C = [a(2h - 3b) + t(3b + 2h) + r(3b - 4h)]/(3b + 4h)$

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$$\frac{dx}{dt} = \underbrace{x_r\,(r_e e_t + r_t)}_{\substack{\text{Intermediate good}\\ \text{market effect } (+)}} + \underbrace{x_e e_t}_{\substack{\text{Environmental}\\ \text{tax effect } (-)}} + \underbrace{x_t}_{\substack{\text{Direct effect}\\ (+)}}$$
$$= \frac{-1}{(3p' - 4H'')} + \frac{9p' - 4H''}{3p'\,(3p' - 4H'')} + \frac{-1}{3p'}$$
$$= \left(3p' - 4H''\right)^{-1} < 0, \tag{11}$$

Equation (11) shows that when the environmental tax is endogenous, trade liberalization always increases the domestic pollution at the same level, no matter whether the upstream market is monopoly or perfectly competitive. However, when the environmental tax is exogenous (fixed), trade liberalization reduces the domestic pollution; i.e., $dx/dt|_{e_t=0} = -1/6p' > 0$. Comparing $dx/dt|_{e_t=0}$ and (11), we know that as long as the environmental tax is endogenous, trade liberalization always increases domestic pollution. Moreover, it induces the intermediate good firm to adopt the marginal cost pricing, no matter whether the market structure of the intermediate good is monopoly or perfectly competitive, hence making their effect of trade liberalization on the domestic pollution be the same; i.e., $x^{\mathrm{C}}|_{r=k} = x$, $y^{\mathrm{C}}|_{r=k} = y$. To go a step further, the effect of trade liberalization on domestic downstream firm's output and foreign firm's output remain the same. Proposition 2 summarizes the above results.

Proposition 2. (1) When the environmental tax is endogenous (exogenous), trade liberalization increases (reduces) the domestic pollution. (2) No matter whether the market structure of the intermediate good is monopoly or perfectly competitive, as long as the environmental tax is endogenous, trade liberalization results in the same degree of the domestic pollution.

In the proposition 2 (2) trade liberalization will result in the same degree of the domestic pollution. Lai (2004) finds that trade liberalization increases the optimal environmental rate and the pollution decreased by a higher pollution rate will dominate the pollution increased by more domestic consumption, making the total pollution decrease. The main difference is that he studies pollution generated by consumption, whereas we study the pollution generated by production.

We next investigate the welfare effect of tariff reductions. Substituting the optimal environmental tax into the Nash equilibria in each stage of the game, we obtain the domestic welfare function as:

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$$W(t,k) = \int_0^Q p(u)du - p(Q)y(r(e(t,k),t,k),e(t,k),t) - kX(r(e(t,k),t,k),e(t,k),t) + ty(\cdot) - H(x).$$

The effects of trade liberalization on the domestic social welfare are:

$$\frac{dW}{dt} = \underbrace{\left[(p-r)\frac{dx}{dt} - p'y\frac{dQ}{dt}\right]}_{\substack{\text{Final good market distortion effect} \\ (-)}} + \underbrace{(r-k)\frac{dx}{dt}}_{\substack{\text{Intermediate good market} \\ \text{distortion effect } (-)}} + \underbrace{\left(y + t\frac{dy}{dt}\right)}_{\substack{\text{Tariff revenue effect} \\ (?)}} \underbrace{-H'\frac{dx}{dt}}_{\substack{\text{Environmental} \\ \text{damage effect } (+)}}$$

$$= \frac{(p-r) - 2y\left(p' - H''\right)}{(3p' - 4H'')} + \frac{(r-k)}{(3p' - 4H'')} + \left[y + \frac{\left(p' - 2H''\right)t}{p'(3p' - 4H'')}\right] - \frac{H'}{(3p' - 4H'')}, \quad (12)$$

where $dr/dt = r_e e_t + r_t = -3p'/2(3p' - 4H'') < 0$, $dx/dt = x_r(dr/dt) + x_e e_t + x_t = 1/(3p' - 4H'') < 0$, and $dy/dt = y_r(dr/dt) + y_e e_t + y_t = (p' - 2H'')/p'(3p' - 4H'') < 0$. Equation (12) tells that trade liberalization increases the domestic social welfare via the final good distortion market and intermediate good market distortion effects, while it decreases the domestic social welfare via the environmental damage effect. Therefore, the effect of trade liberalization on welfare will depend on these effects.

As we mentioned earlier, the output levels of the upstream monopoly and perfect competition are the same. Thus, the effect of trade liberalization on the domestic welfare is independent of the upstream market structure. Proposition 3 summarizes the above findings.

Proposition 3. No matter whether the market structure of the intermediate good is monopoly or perfect competitive, trade liberalization always increases domestic pollution and may reduce the domestic social welfare.

3 The intra-industry trade model

This section extends the import model to take into account the domestic exports. Brewer and Boyd (2000) point out that during 1970–1986 the U.S.

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imported 90% of its motorcycles in its domestic market from Japan. In order to relieve the import competition threat faced by the American manufacturer Harley Davidson, the U.S. began imposing a tariff on Japanese motorcycles starting from 1983, resulting in an export expansion of American motorcycles since 1987. In other words, the U.S. motorcycle industry was import-oriented in the 1970s and early 1980s, turning towards a two-way trade pattern since the late 1980s.

The downstream firms engage in Cournot competition in both countries' markets a la Brander (1981). Both governments impose the environmental tax on the final goods and enact tariffs on the imported goods. The inverse demand function of the foreign final good market is $p^* = p^*(Q^*)$, where $Q^* = x^* + y^*$, $p^{*'} < 0$, and $p^{*''} = 0$. We further assume that there is no upstream market in the foreign country.[6] The rest of game structure is the same as that in Section 2.

Firms D and F set their outputs for the home market and their outputs for the foreign market so as to maximize profits taking their rival's exports, polices t and e as given. Following Burguet and Sempere (2003), the two countries have the same import tariff. The home firm's profit maximization problem is then:

$$\max_{\{x,x^*\}} \pi^D = [p(Q) - r - e]x + \left[p^*\left(Q^*\right) - r - e - t\right]x^*. \tag{13}$$

The first-order conditions are:

$$\pi_x^D = xp' + p(Q) - r - e = 0, \tag{14.1}$$

$$\pi_{x^*}^D = x^* p^{*'} + p^*\left(Q^*\right) - r - e - t = 0. \tag{14.2}$$

The foreign firm's profit maximization problem is:

$$\max_{\{y,y^*\}} \pi^F = p^*\left(Q^*\right) y^* + [p(Q) - t]y, \tag{15}$$

and the first-order conditions are:

$$\pi_{y^*}^F = y^* p^{*'} + p^*\left(Q^*\right) = 0, \tag{16.1}$$

$$\pi_y^F = yp' + p(Q) - t = 0. \tag{16.2}$$

The constant marginal cost assumption implies that markets are separated: the output choice for one of the markets is independent of the output choice

[6]Our main results still hold for an upstream market in the foreign country.

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for the other. We assume the demand function is well defined, and the second-order and stability conditions hold globally, so that an unique solution exists. The Cournot equilibrium outputs of firm D are $x(r, e, t)$ and $x^*(\cdot)$, and those for firm F are $y(\cdot)$ and $y^*(\cdot)$. From those first-order conditions, we obtain:

$$x_e = x_r = \frac{\pi^F_{yy}}{\Phi_1} < 0, \quad x_t = \frac{-\pi^D_{xy}}{\Phi_1} > 0;$$
$$y_e = y_r = \frac{-\pi^F_{yx}}{\Phi_1} > 0, \quad y_t = \frac{\pi^D_{xx}}{\Phi_1} < 0; \tag{17.1}$$
$$x^*_r = x^*_e = x^*_t = \frac{\pi^F_{y^*y^*}}{\Phi_2} < 0; \quad y^*_r = y^*_e = y^*_t = \frac{-\pi^F_{y^*x^*}}{\Phi_2} > 0, \tag{17.2}$$

where $\Phi_1 = \pi^D_{xx}\pi^F_{yy} - \pi^D_{xy}\pi^F_{yx} > 0$ and $\Phi_2 = \pi^D_{x^*x^*}\pi^F_{y^*y^*} - \pi^D_{x^*y^*}\pi^F_{y^*x^*} > 0$. Since the final goods are homogeneous and the output quantities of these two downstream firms are mutually strategic substitutes, i.e., $\pi^D_{xx} = \pi^F_{yy} = \pi^D_{x^*x^*} = \pi^F_{y^*y^*} < 0$, $\pi^D_{xy} = \pi^F_{yx} = \pi^D_{x^*y^*} = \pi^F_{y^*x^*} < 0$, $\pi^D_{xx} < \pi^D_{xy}$, and $\Phi_1 = \Phi_2$ must hold. Therefore, at equilibrium $x_r = x^*_r = x_e = x^*_e = x^*_t = y_t = 2/(3p') < 0$ and $x_t = y_r = y^*_r = y_e = y^*_e = y^*_t = -1/(3p') > 0$ will hold. Equation (17.1) shows that a rise in the environmental tax and input price increases the domestic downstream firm's production cost, hence making the firm's output decrease, while the rival firm's output increases. Similar implications can apply to (17.2).

We now turn to the second stage. The derived demand in the intra-industry trade model is $X = x(r, e, t) + x^*(\cdot)$. The domestic upstream firm chooses its price to maximize its own profit:

$$\max_{\{r\}} \Pi^U = (r - k)X(r, e, t). \tag{18}$$

The first-order condition for the domestic downstream firm's profit maximization is:

$$\Pi^U_r = X + (r - k)X_r = 0. \tag{19}$$

Equation (19) and the comparative statics in the third stage guarantee that the second-order condition must hold; i.e., $\Pi^U_{rr} = 4x_r < 0$. The optimal intermediate good pricing can be further derived from (20), which is $r = r(e, t, k)$. Total differentiation of Equation (20) results in the following comparative statics:

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$$r_e = \frac{-\Pi^U_{re}}{\Pi^U_{rr}} = -\frac{1}{2} < 0, \quad r_t = \frac{-\Pi^U_{rt}}{\Pi^U_{rr}} = \frac{-1}{8} < 0, \quad \text{and}$$
$$r_k = \frac{-\Pi^U_{rk}}{\Pi^U_{rr}} = \frac{1}{2} > 0. \tag{20}$$

A comparison of Equations (6) and (20) tells that an increase in the domestic environmental tax still reduces the price of the intermediate good at the same level when the trade pattern changes from being unilateral to being bilateral. Moreover, the effect of a tariff rate on the intermediate good's price turns negative under the intra-industry trade model, compared to the positive impact in the import model. This is because the increase of domestic exports dominates the reduction in sales in the domestic market from a tariff decrease, resulting in a net increase in derived demand for the intermediate good and hence increasing its price. However, the effect of the upstream firm's marginal cost on the intermediate good's price is not affected by the trade pattern.

The welfare function for the home country can be defined as:

$$\max_{\{e\}} W = \left[\int_0^Q p(u)du - p(Q)y\right] - kX + \left(p^* - t\right)x^* + ty - H(X), \tag{21}$$

We now examine the effects of trade liberalization on the optimal policy. The first-order condition for welfare maximization is:

$$W_e = \underbrace{\left[(p-r)\frac{dx}{de} - p'y\frac{dQ}{de}\right]}_{\substack{\text{Final market distortion}\\ \text{effect } (-)}} + \underbrace{(r-k)\frac{dX}{de}}_{\substack{\text{Intermediate good}\\ \text{distortion effect } (-)}} + \underbrace{t\frac{dy}{de}}_{\substack{\text{Tariff revenue}\\ \text{effect } (+)}}$$
$$\underbrace{-H'\frac{dx}{de}}_{\substack{\text{Environmental}\\ \text{damage effect } (+)}} + \underbrace{\left[\left(p^* - r - t\right)\frac{dx^*}{de} + p^{*\prime}x^*\frac{dQ^*}{de}\right]}_{\text{Export revenue effect } (?)}$$
$$\underbrace{-H'\frac{dx^*}{de}}_{\substack{\text{Export environmental}\\ \text{damage effect } (+)}} = 0, \tag{22}$$

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where $dx/de = dx^*/de = x_r r_e + x_e = 1/3p' < 0$, $dy/de = dy^*/de = y_r r_e + y_e = -1/6p' > 0$, and $dQ/de = dx/de + dy/de < 0$. The total effect in Equation (22) can be decomposed into six items. The first four effects are the same as those in Equation (8). Comparing Equation (22) to Equation (8), we know that two-way trade further generates the export revenue effect and the export environmental damage effect, which are the fifth and sixth items in Equation (22). The sign of the fifth item in Equation (22) is indeterminate, which depends on the demand elasticity. The sixth item is positive since two-way trade increases the domestic firm's exports and total output, increases the environmental damage, and hence induces the domestic government to raise the environmental tax. Equation (22) guarantees that the second-order condition must hold; i.e., $W_{ee} = (7p' - 16H'')/36(p')^2 < 0$. The optimal environmental tax in the presence of intra-industry trade, $e^I = e^I(t, k)$, can be solved by using Equation (22).[7]

The effects of trade liberalization on the optimal domestic environmental tax under the intra-industry trade model are:

$$
\begin{aligned}
e_t^I = \frac{-1}{W_{ee}^D} \Bigg\{ & \underbrace{\left[p' \left(\frac{dx}{de}\frac{dx}{dt} - \frac{dy}{de}\frac{dy}{dt} \right) - r_t \frac{dx}{de} \right]}_{(-)} + \underbrace{r_t \frac{dX}{de}}_{(+)} + \underbrace{\frac{dy}{de}}_{(+)} \underbrace{-H'' \frac{dX}{dt}\frac{dx}{de}}_{(-)} \\
& + \underbrace{\left[\left(p^{*\prime} \frac{dQ^*}{dt} - r_t - 1 \right) \frac{dx^*}{de} + p^{*\prime} \frac{dQ^*}{de}\frac{dx^*}{dt} \right]}_{(+)} \underbrace{-H'' \frac{dX}{dt}\frac{dx^*}{de}}_{(-)} \Bigg\} \\
= & \frac{-3p'}{4(7p' - 16H'')} + \frac{3p'}{(7p' - 16H'')} + \frac{6p'}{(7p' - 16H'')} \\
& + \frac{2H''}{(7p' - 16H'')} + \frac{7p'}{2(7p' - 16H'')} + \frac{2H''}{(7p' - 16H'')} \gtreqless 0, \quad \text{if} \\
& H'' \lesseqgtr -\frac{47}{16}p'. \qquad (23)
\end{aligned}
$$

Using (17) and (20), we know that in (23) $dx/dt = x_r r_t + x_t = -5/12p' >$

[7] According to the demand and damage functions in Footnote 4, under a monopolized upstream market and a intra-industry final product market we can derive the optimal environmental tax rate as $e_t^I = [2a(16h - 23b) + t(47b - 16h) + 4k(17b - 16h)]/4(7b + 16h)$.

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$0, dx^*/dt = x_r^* r_t + x_t^* = 7/12p' < 0, dy/dt = y_r r_t + y_t = 17/24p' < 0$, $dy^*/dt = y_r^* r_t + y_t^* = -7/24p' > 0$, $dQ/dt < 0$, $dQ^*/dt < 0$, $dX/dt < 0$, and $dX/de = 1/6p' < 0$. From the above comparative statics, we see that in the IIT model and an exogenous environmental tax, trade liberalization will increase the domestic pollution. This result differs from that in the import model since in the IIT model the increase in the domestic firm's exports dominates the reduction in its domestic sales, hence making the domestic pollution increase. Equation (23) shows that the effect of trade liberalization on the optimal environmental tax of the home country is indeterminate, which is summarized in Proposition 4(1).

Denote e_t^{IC} as the effect of trade liberalization on the optimal environmental tax rate under the IIT model with a perfectly competitive upstream market. Further substituting the condition $r_e = r_t = 0$ into Equation (23), we obtain $e_t^{IC} = (5p' + 4H'')/(7p' - 16H'') \gtreqless 0$ if $H'' \lesseqgtr -5p'/4$ and $e_t^I - e_t^{IC} = 27p'/4(7p' - 16H'') > 0$. This result, $e_t^I > e_t^{IC}$, is the same as that in proposition 1(2), whereas e_t^I and e_t^{IC} can be negative here. If $-5p'/4 < H'' < -47p'/16$ (where $e_t^I > 0$ and $e_t^{IC} < 0$), then the presence of the intermediate good market will *revert* the effect of trade liberalization on the optimal environmental tax rate. Note that, similar to the import model, no matter whether the upstream market is a monopoly or perfectly competitive, the optimal tax rates imposed by the domestic government always induce the same pollution amount and hence the effects of trade liberalization on pollution and welfare stay the same.

Substituting the optimal domestic environmental tax $e^I = e^I(t, k)$ into the firms' outputs and the domestic social welfare functions and then differentiating them with respect to the domestic tariff rate, we obtain $dX/dt = dx/dt + dx^*/dt = 2e_t^I/3p' + 1/6p' = 9/(7p' - 16H'') < 0$.[8] Therefore, trade liberalization definitely increases the domestic pollution. Comparing this result with that in Equation (11), trade liberalization increases the domestic pollution in both models; however, the effect of trade liberalization on domestic pollution in IIT model is higher than that in import model due to expanding domestic output as tariff reduction in IIT model.

The effects of trade liberalization on the domestic welfare are thus:

[8]The effects of trade liberalization on domestic output and export are, respectively: $dx/dt = x_r(r_e e_t^I + r_t) + x_e e_t^I + x_t = e_t^I/3p' - 5/12p'$ and $dx^*/dt = x_r^*(r_e e_t^I + r_t) + x_e^* e_t^I + x_t^* = e_t^I/3p' + 7/12p'$.

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$$\frac{dW^I}{dt} = \left[(p-r)\frac{dx}{dt} - p'y\frac{dQ}{dt}\right] + (r-k)\frac{dX}{dt} + \left(y + t\frac{dy}{dt}\right) - H'\frac{dx}{dt} + \left[\left(p^* - r - t\right)\frac{dx^*}{dt} + \left(p^{*'} - 1\right)x^*\frac{dQ^*}{dt}\right] - H'\frac{dx^*}{dt}, \tag{24}$$

The six effects in Equation (24) refer to the categorization of effects in Equation (22). Using the above comparative statics, we know that $dy/dt = y_r(r_e e_t^I + r_t) + y_e e_t^I + y_t = -e_t^I/6p' + 17/24p'$, $dy^*/dt = y_r^*(r_e e_t^I + r_t)$, $e_t^I + y_t^* = -e_t^I/6p' - 7/24p'$, and $dQ/dt = dQ^*/dt = e_t^I/6p' + 7/24p'$. Equation (24) hence tells us that the effect of trade liberalization on the domestic welfare is indeterminate. Proposition 4 summarizes the above discussions.

Proposition 4. Taking into account the two-way trade: (1) Trade liberalization may increase the optimal environmental tax. (2) The effect of trade liberalization on the domestic welfare is indeterminate, depending on the sign of the domestic optimal environmental tax and the effect of trade liberalization on this environmental tax.

The reasons for the results in Proposition 4(1) are as follows. A further comparison of Equations (9) and (23) shows that two-way trade expands the magnitude of the marginal effect of the environmental tax on the domestic social welfare (W_{ee}). Trade liberalization not only affects the export revenue and environmental damage, but also reverts the final good market distortion and environmental damage effects and expands the tariff revenue effect. Consequently, in the intra-industry trade mode, the effect of trade liberalization on the domestic optimal environmental tax is indeterminate.[9] This is

[9]This paper differs from Tanguay (2001). There are fundamental differences in the model set-ups of these two papers. In Tanguay (2001) there is no intermediate good market and the two countries are symmetric, the firms face a transaction cost to export. Under these different assumptions, Tanguay (2001) concludes that trade liberalization always increases the environmental tax. Due to the modeling difference, Equation (23) shows that the intermediate good distortion effect is an addition in this paper and the export revenue effect are higher herein, resulting in the different conclusion that trade liberalization may reduce the environmental tax.

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because in the IIT model, there are two effects of tariff reduction on the optimal environmental tax rate: First, tariff reduction brings competitive disadvantage to the domestic downstream firm in the domestic market; however, this competitive disadvantage is more severe under the import model than under the IIT model. Second, the domestic firm's export expansion dominates the drop in its domestic sales, making the total pollution increase. The first (second) effect induces the domestic government to decrease (increase) the environmental tax rate.

In order to explain the results of Proposition 4(2), we further compare the effects of trade liberalization on the domestic social welfare under the import and the intra-industry trade models. In Sections 2 and 3 there is no specific functional form assumed for the environmental damage, and it is not feasible to find out the reduced-form Nash equilibria in each stage of the game such that the relation between (12) and (25) cannot be clearly determined.

According to the linear demand function and quadratic damage function setups in footnote 4, Equations (12) and (25) can be simplified to be $dW/dt = [ha - t(2b + 3h)]/b(4h + 3b)$ and $dW^I/dt = [3a(2h - b) + t(2b - 7h)]/b(16h + 7b)$, respectively. Figure 1 illustrates the relation of these two functions. Let $a = b = 1$ and $k = 0$, and we can obtain the two curves $dW/dt = 0$ and $dW^I/dt = 0$ in Figure 1. The left-hand [right-hand] side is the regime where trade liberalization decreases [increases] the domestic welfare; i.e., $dW/dt > 0$ and $dW^I/dt > 0$ [$dW/dt < 0$ and $dW^I/dt < 0$]. The curve $e^I = 0$ is the free environmental tax under the intra-industry trade model, and the upper [underneath] side implies a positive (negative) environmental tax. The AA′ curve is where the foreign firm has zero exports in the import model; $y = 0$. The BB′ curve is where the foreign firm has zero exports in the intra-industry trade model; $y^I = 0$. The CC′ curve is where the domestic downstream firm has zero exports in the intra-industry trade model; $x^* = 0$.

The left sides of these three curves are where both downstream firms have positive outputs and hence the focus regime of the discussion is area ADC, which can be categorized into four regimes. Regime I [III] is where trade liberalization reduces [promotes] the domestic welfare in both the import and intra-industry trade models. Regime II [IV] is where trade liberalization reduces [promotes] the domestic welfare in the import model, while it promotes [reduces] the domestic welfare in the intra-industry trade model. Therefore, when the parameters of the import tariff rate (t) and in-

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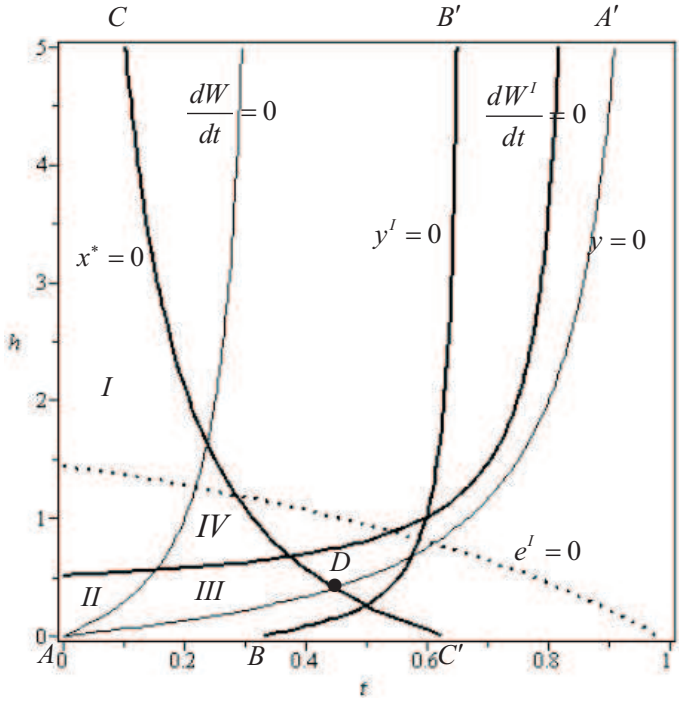


Figure 1: The Effects of Trade Liberalization on Domestic Social Welfare in the Import and the Intra-industry Trade Models

creasing velocity of marginal damage (h) lie in Regime II, then under the intra-industry trade model the home government has an incentive for trade liberalization. The economic intuitions are: When t and h are relatively small, trade liberalization promotes exports and hence enhances the domestic social welfare. This welfare-improving effect caused by export expansion dominates the welfare-losing effect caused by an increase in environmental damage. Thus, in the intra-industry trade model the trade liberalization will improve the domestic social welfare.

If the parameters lie in Regime IV, then under the intra-industry trade model the home government has no incentive to seek trade liberalization. In Regime IV, trade liberalization increases the exports and domestic environmental damage, but the welfare loss caused by environmental damages dominates the welfare gains from export expansion, resulting in a net welfare loss for the home country after trade liberalization. From the above discus-

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sion, we know under the import model that trade liberalization always improves the social welfare of the home country, but it may not hold under the intra-industry trade model. For example, we look at a tariff reduction case from region III to region II. In the import model, because import output increases as reducing tariff, the degree of decreasing in profits is higher than the degree of increasing in consumer surplus, and then it results in a lower welfare. In the intra-industry trade model, because export output increases as reducing tariff, the degree of decreasing in profits is not so large, and then it remains in a higher welfare.

Proposition 4(3), in which trade liberalization under environmental taxation may lower the domestic welfare, also differs from Burguet and Sempere (2003) in which when the optimal environmental policy is pollution taxation, trade liberalization always improves the domestic welfare.[10] This is because in our paper there are additional intermediate good market distortion effects, asymmetric countries, and environmental tax revenues in the welfare function, etc. Moreover, Burguet and Sempere (2003) assume that the two countries are symmetric, environmental taxation will reduce social cost, and the social cost reduction is independent of the pollution.

4 Concluding remarks

This paper constructs a three-stage game in order to analyze the effects of trade liberalization on the optimal environmental policy, pollution, and domestic social welfare when there is an intermediate good market. There are both upstream and downstream markets in the home country. The basic model is an import model, and the downstream domestic and foreign firms engage in Cournot competition in the domestic final good market. The extended model is an intra-industry trade model, in which both domestic and foreign downstream firms export to each other's country market.

In the import model, when the domestic intermediate good market is a monopoly, trade liberalization reduces the optimal environmental tax. Compared to the case when the domestic intermediate good market is perfectly competitive, the case of a domestic intermediate good monopoly expands the magnitude of reducing the optimal environmental tax caused by trade liberalization. When the environmental tax is endogenous (exoge-

[10] In our intra-industry trade model, when the optimal environmental policy is pollution taxation, trade liberalization always deteriorates the domestic welfare.

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nous), trade liberalization increases (reduces) the domestic pollution. No matter whether the market structure of the intermediate good is monopoly or perfect competitive, as long as the environmental tax is endogenous, trade liberalization results in the same degree of domestic pollution. Trade liberalization may reduce the domestic social welfare.

In the intra-industry trade model, trade liberalization may increase the optimal environmental tax when its effect on export expansion dominates that on domestic sales reduction. The effect of trade liberalization on the domestic welfare is indeterminate, depending on the sign of the domestic optimal pollution tax and the effect of trade liberalization on this environmental tax. Moreover, the two models with an endogenous environmental tax generate different policy implications. Moreover, the environmental damage caused by trade liberalization will be higher in the presence of intermediate good market.

References

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

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

Brewer, T. L. and Boyd, G. (2000), *Globalizing America: The USA in World Integration*, Cheltenham, UK: Edward Elgar.

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

Canton, J., Soubeyran, A., 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

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environmental trade policy", *Journal of Environmental Economics and Management*, 47, 260–269.

Hwang, H., Lin, Y. S., 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.

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

Kou, H. I., Hu, J. L., and Hwang, H. (2001), "Tariff policy and environmental qualities of imported goods", *Journal of Economic Integration*, 16, 313–343.

Lai, Y. B. (2004), "Trade liberalization, consumption externalities and the environment", *Economics Bulletin*, 17, 1–9.

——— (2007), "The political economy linkage between trade liberalization and domestic environmental regulations", *Public Choice*, 133, 57–72.

McKenna, K. and Bleck, A. (1996), "Philippine deforestation, trade and environment database", Working Paper, American University.

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.

——— (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 export-

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ing 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 and Economics*, 14, 219–234.

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垂直相關市場下貿易自由化與最適環境政策

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本文探討存在中間財市場下, 貿易自由化對最適環境政策、國內污染量及福利的影響。在進口模型中, 當本國之環境稅率爲內生下, 存在中間財市場將擴大貿易自由化降低最適環境稅率的幅度; 此外, 貿易自由化將提高本國之污染量, 可能降低本國福利。再者, 不論中間財市場爲獨占或完全競爭, 當政府課徵最適環境稅率, 貿易自由化對本國污染量與本國福利的影響皆相同。相較於進口模型, 在產業內貿易模型下, 貿易自由化可能提高最適環境稅率。儘管貿易自由可能提高污染稅, 本國環境傷害必定提高。

關鍵詞: 環境政策, 垂直相關市場, 貿易自由化
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