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Environmental Policy and Trade Liberalization: The Case of Transboundary Pollution from Consumpion

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ENVIRONMENTAL POLICY AND TRADE LIBERALIZATION: THE CASE OF TRANSBOUNDARY POLLUTION FROM CONSUMPTION

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ABSTRACT. This paper develops a reciprocal market model of international duopoly with transboundary pollution from consumption to examine the effects of bilateral tariff reductions on the equilibrium pollution tax and welfare. We show that tariff reductions induce each country to raise an emission tax and that trade liberalization is welfare-improving if the parameter of pollution damages is sufficiently large. These results are in contrast to the case of production-generated pollution and we seek the reason for this contrast.

KEY WORDS: consumption-generated pollution, tariff reduction, emission tax, international duopoly.

1. Introduction. Over the last decades, trade liberalization in the form of tariff reductions has substantially progressed, leading to incremental trade flows. While freer trade improves well-being as the gains-from-trade propositions encompass, there emerge new concerns over modern world trade, e.g., intellectual property rights protection and labor standards. 'Trade and the environment' is also one such concern, bringing a large literature.[1]

Among others, there is a growing literature that studies the consequences of non-cooperative environmental policies under international oligopoly. Seminal contributions include Conrad [1993], Rauscher [1994], Barrett [1994], Kennedy [1994a] and Ulph [1996], who commonly find that countries will opt for a laxer environmental policy in open economies. Based on this strand of literature, Walz and Wellisch [1997], Burguet and Sempere [2003] and Baksi and Chaudhuri [2009] investigate welfare effects of trade liberalization, i.e., exogenous reductions of trade barriers.[2] One of their novel findings is that freer trade is welfare-improving.[3] Note that all of these predecessors presume production-generated pollution.

In contrast, this paper explores welfare effects of bilateral tariff reductions under international oligopoly by paying attention to transboundary pollution from consumption.[4] This is motivated by the observation that consumption makes a certain contribution to overall pollution. For example, uses of cars and air-conditioners by households help grow temperatures of a country and possibly the world. Increased uses of ozone-depleting aerosol sprays are another typical instance of consumption-generated pollution.[5]

To our knowledge, Copeland and Taylor [1995] are one of the earliest contributions in this line of research. Assuming perfectly competitive product markets, they show that the opening of trade is welfare-improving. Besides, we have a literature that relaxes perfect competition. In a home market model of duopoly with consumption-generated pollution, Lai [2004] shows that tariff reductions mitigate the damage from pollution. Using a monopoly model and allowing for variable marginal production cost, Ishikawa and Kuroda [2007] find ineffectiveness of emission taxes for preventing environmental degradation. Ishikawa and Okubo [2009] highlight the role of product differentiation to assess the effects of environmental and trade policies. Kayalica and Kayalica [2005] and Kayalica and Yilmaz [2006] compute the Nash equilibrium environmental and trade policies under international rivalry and local pollution from consumption. Furthermore, using a model of a small open economy, McAusland [2008] shows that tariff reductions give rise to a rise in emission taxes.

While we follow Kayalica and Kayalica's [2005] modeling, we are mainly interested in the effects of bilateral tariff reductions on equilibrium emission taxes and welfare.[6] Our main results are as follows.[7] First, the emission tax in the subgame perfect Nash equilibrium decreases with the tariff, i.e., tariff reductions induce higher emission taxes. Second, trade liberalization can improve welfare if the parameter of pollution damage is sufficiently large. This finding sharply contrast to the case of production-generated pollution where trade is more likely to guarantee welfare improvements under sufficiently small damage from pollution. As a by-product of this result, trade unambiguously reduces welfare under local pollution, which exhibits another contrast to the gains-from-trade propositions of the existing literature supposing production-generated pollution. Our attempt will be useful in obtaining deeper insights on welfare aspects of bilateral trade liberalization in a polluted world economy.

This paper is organized as follows. Section 2 formulates a basic model and characterizes the subgame perfect Nash equilibrium. Section 3 examines welfare effects of tariff reductions. Section 4 gives conclusions.

2. A model

2.1. Fundamentals Suppose a two-identical-country (Home and Foreign), two-good (Goods 1 and 2), one-factor (labor) model of reciprocal dumping.[8] We asterisk all the Foreign variables to distinguish them from the Home variables. One unit of labor produces one unit of Good 2 (numeraire), from which the wage rate is unity in both countries. Producing Good 1 incurs a constant marginal cost $c \geq 0$ and imports are subject to a specific tariff rate t.[9] The markets of Good 1 are segmented and duopolized by a Home firm (firm X) and a Foreign firm (firm Y). The product each firm supplies is a perfect substitute.

Assume a representative consumer of Home whose utility function is

$$u = aC_1 - \frac{C_1^2}{2} + C_2 - v(Z), \quad a > 0, \quad v' > 0, \quad v'' \geq 0, \tag{1}$$

where u is utility, $C_i, i = 1, 2$ is the consumption of each good, Z is pollution in Home, and $v(\cdot)$ represents the damage from pollution. To facilitate analysis and compute the explicit solution of subgame perfect Nash equilibrium, the subsequent subsections adopt two specifications of the damage function: linear damage $v(Z) = sZ, s > 0$ and quadratic damage $v(Z) = \widetilde{s}Z^2/2, \widetilde{s} > 0$, where s and $\widetilde{s}$ measure the degree of pollution damage.[10] The consumer chooses C_i to maximize (1) under the budget constraint by taking Z as given. Denoting by p the relative price of Good 1, utility maximization subject to the budget constraint yields a linear inverse demand function: $p = a - x - y$, where x (resp. y) is the supply of the Home (resp. Foreign) firm into the Home market. The Foreign counterpart is similarly obtained as $p^* = a - x^* - y^*$.

Suppose that consumption, which equals total supply in each country, generates an emission on which each government imposes an emission tax τ and τ^* per unit. In other words, the Home (resp. Foreign) government levies τ (resp. τ^*) on $x + y$ (resp. $x^* + y^*$). The model is a two-stage game. In the first stage, the Home and Foreign governments non-cooperatively determine an emission tax to maximize welfare, and duopolistic firms play a quantity-setting game in the second stage, taking the predetermined emission taxes as given.

2.2. A duopoly game To solve the model with backward induction, we first consider the second stage. Given the underlying assumptions, each firm's profit is defined by

$$\begin{aligned} \text{Home firm} &: (a - c - \tau - x - y)x + (a - c - \tau^* - t - x^* - y^*)x^* \\ \text{Foreign firm} &: (a - c - \tau - t - x - y)y + (a - c - \tau^* - x^* - y^*)y^*. \end{aligned}$$

Firms choose outputs to maximize profits with a Cournot-Nash conjecture. Then, the first-order conditions for profit maximization yield the equilibrium outputs:

$$x = \frac{a-c-\tau+t}{3}, \quad x^* = \frac{a-c-\tau^*-2t}{3} \tag{2}$$

$$y = \frac{a-c-\tau-2t}{3}, \quad y^* = \frac{a-c-\tau^*+t}{3}. \tag{3}$$

Substituting these into the above definitions of each firm's profit, the maximized profit of the Home (resp. Foreign) firm equals x^2+x^{*2} (resp. y^2+y^{*2}) where x, x^*, y and y^* are given by (2) and (3). Moreover, consumer surplus of Home (resp. Foreign) is computed as $(x+y)^2/2$ (resp. $(x^*+y^*)^2/2$).

As to transboundary pollution, we assume that $Z = x+y+\theta(x^*+y^*)$, namely, $\theta \in [0,1]$ fraction of Foreign's emission arrives in Home. Analogously, pollution in Foreign is $Z^* = \theta(x+y)+x^*+y^*$. By definition, $\theta = 0$ (resp. $\theta = 1$) corresponds to local (resp. global) pollution. From these assumptions and the equilibrium outputs in (2) and (3), Home's welfare is given by a function of τ and τ^*:

$$\begin{aligned} U(\tau,\tau^*,t) &= \frac{(x+y)^2}{2} + x^2 + x^{*2} + \tau(x+y) + ty - v\left(x+y+\theta\left(x^*+y^*\right)\right) \\ &= \frac{1}{2}\left[\frac{2(a-c-\tau)-t}{3}\right]^2 + \left(\frac{a-c-\tau+t}{3}\right)^2 + \left(\frac{a-c-\tau^*-2t}{3}\right)^2 \\ &\quad +\tau\cdot\frac{[2(a-c-\tau)-t]}{3} + t\cdot\frac{a-c-\tau-2t}{3} \\ &\quad -v\left(\frac{2(a-c-\tau)-t+\theta[2\left(a-c-\tau^*\right)-t]}{3}\right), \end{aligned} \tag{4}$$

where the first term of the right-hand side is consumer surplus, the second (resp. third) term is the Home firm's profit by serving the Home (resp. Foreign) market, the fourth term is emission tax revenue, the fifth term is tariff revenue, and the last term is pollution damage. The symmetry between countries allows us to express $U(\tau^*,\tau,t)$ as Foreign's welfare.

2.3. An environmental policy game

2.3.1. The linear damage case Having defined the payoff function of each government, we solve the first stage of the game. We begin with the simpler case of linear damage and then proceed to the case of quadratic damage.

Under the linear damage sZ, the first-order conditions for welfare maximization become

$$\frac{\partial U(\tau,\tau^*,t)}{\partial \tau} = \frac{-2\tau - 2t + 2s}{3} = 0$$
$$\frac{\partial U(\tau^*,\tau,t)}{\partial \tau^*} = \frac{-2\tau^* - 2t + 2s}{3} = 0.$$

Thus, a country's emission tax in the subgame perfect Nash equilibrium is independent of the rival country's tax. Not surprisingly, this extreme property comes from the assumption of linearity of pollution damage and demand, and constant marginal production cost.[11] This is because $U(\tau,\tau^*,t)$ is separable in τ and τ^*, i.e., strategic interactions disappear by carefully looking at (4).

In the equilibrium, the emission taxes are determined as

$$\tau^N = \tau^{*N} = s - t, \tag{5}$$

where superscript N refers to the subgame perfect Nash equilibrium. Note that the equilibrium emission tax is equal to marginal pollution damage in the absence of tariffs.

2.3.2. The quadratic damage case While linear pollution damages are a convenient specification and often employed in the literature, they yield a quite extreme outcome.[12] In order to check the robustness of the preceding analysis, we now employ another assumption that damages are quadratic $v(Z) = \tilde{s}Z^2/2$.[13]

Under this specification, the first-order conditions for welfare maximization are

$$\frac{\partial U(\tau,\tau^*,t)}{\partial \tau} = \frac{-2(2\tilde{s}+3)\tau - 4\tilde{s}\theta\tau^* + 4\tilde{s}(\theta+1)(a-c) - 2[\tilde{s}(\theta+1)+3]t}{9} = 0$$
$$\frac{\partial U(\tau^*,\tau,t)}{\partial \tau^*} = \frac{-4\tilde{s}\theta\tau - 2(2\tilde{s}+3)\tau^* + 4\tilde{s}(\theta+1)(a-c) - 2[\tilde{s}(\theta+1)+3]t}{9} = 0.$$

From these conditions, each country's emission tax is a strategic substitute. Solving these equations yields the equilibrium emission tax:

$$\tilde{\tau}^N = \tilde{\tau}^{*N} = \frac{2\phi(a-c) - (\phi+3)t}{2\phi+3}, \quad \phi \equiv \tilde{s}(\theta+1), \tag{6}$$

where a tilde indicates the quadratic damage case to distinguish it from the linear damage case.

Eqs. (5) and (6) give a result which will be useful in the subsequent arguments.

Lemma 1. *Trade liberalization, i.e., a bilateral tariff reduction, raises the emission tax in the subgame perfect Nash equilibrium.*

(Insert Table 1 around here)

It is helpful to follow the arguments of Kennedy [1994a,b] and Haufler et al. [2005] to develop the intuitions behind Lemma 1. In the present context, each government has four motives of taxation, which is summarized in Table 1. First, each country has an incentive to subsidize so as to mitigate the inefficiency that stems from under-supply associated with imperfect competition. This motive of taxation-subsidization is called the efficiency effect by Haufler et al. [2005]. Second, each country chooses a lower tax than the world efficient level because it does not take into account the effect of its emission on global pollution.[14] These two effects lead governments to under-tax.

The third is the rent-shifting (rent capture) effect. Recalling the fact that the effect of an import tariff is equivalent to that of a production subsidy plus a consumption tax, positive emission taxes (consumption taxes) are called for to shift the increased profit of the foreign firm due to tariff reductions into the domestic country. Finally, since the increased consumption inevitably expands domestic pollution, governments will raise emission taxes (pollution-reducing effect).

The overall effect of tariff reductions on emission taxes is determined by these four effects. The former two effects of tariff reductions tend to lower the emission tax, but the latter two tend to raise it. Lemma 1 claims that trade liberalization leads each country to raise the tax since the latter two effects are stronger than the former two. In particular, if pollution is local, the transboundary externality effect vanishes and hence the latter two effects play a more major role. Consequently, a tougher environmental policy is adopted as a result of trade liberalization.

3. Welfare effects of tariff reductions This section turns to the welfare effects of bilateral tariff reductions. As in the last section, we first address the linear damage case and then proceed to the quadratic damage case. We will show that completely the same conclusion holds in these cases. After formally proving the results, we will interpret them intuitively.

3.1. The linear damage case Substituting (5) into (4) and specifying $v(Z) = sZ$, the welfare level determined in the subgame perfect Nash equilibrium becomes

$$\begin{aligned} U\left(\tau^N, \tau^N, t\right) &= \frac{-t^2 + 2[a-c-s(3\theta+1)]t + 4(a-c-s)[2(a-c)-s(3\theta+2)]}{18} \\ &\equiv W(t). \end{aligned} \tag{7}$$

The rest of our task is to closely examine the properties of $W(t)$. Let us first compare welfare levels under free trade ($t = 0$) and autarky ($t = \bar{t}$), where $\bar{t}$ denotes a prohibitive tariff and defined by $\bar{t} = a - c - s$ by setting $x^* = y = 0$ after substituting (5) into (2) and (3). If the tariff is above $\bar{t}$, the situation reduces to autarky since neither firm exports. In what follows, we assume that $a - c > s$ to guarantee $\bar{t} > 0$.

Evaluating (7) at $t = 0$ and $t = \bar{t}$, we have

$$\begin{aligned} W(0) &= \frac{2(a-c-s)[2(a-c)-s(3\theta+2)]}{9} \\ W(\bar{t}) &= \frac{(a-c-s)[a-c-s(2\theta+1)]}{2}. \end{aligned}$$

Comparing these, we find that $W(0) > W(\bar{t})$ if and only if $s > (a-c)/(6\theta+1)$. What is striking is that free trade leaves each country better off if the pollution damage is sufficiently large. In the case of production-generated pollution, the opposite holds such that free trade is gainful if s is sufficiently small.

Our next task is to compute the slope of $W(t)$ to know whether $W(t)$ is positively-sloped or negatively-sloped at $t = 0$ and $t = \bar{t}$. Differentiating (7) with respect to t yields

$$W'(t) = \frac{-t + a - c - s(3\theta + 1)}{9}, \quad W''(t) = -\frac{1}{9},$$

from which $W(t)$ is strictly concave and $W'(0) = [a - c - s(3\theta + 1)]/3 > 0$ if and only if $s < (a - c)/(3\theta + 1)$. On the other hand, the slope at $t = \bar{t}$ is non-positive because

$$W'(\bar{t}) = -\frac{s\theta}{9} \leq 0.$$

Summarizing these results, the locus of $W(t)$ has three shapes depending on the magnitude of s as follows.

(Insert Figures 1-3 around here)

Proposition 1. *The shape of $W(t)$ and welfare effects of trade liberalization are classified as follows.*

Case 1 (Figure 1). $W(t)$ is inverted-U shaped and free trade is Pareto inferior to autarky if $s < (a - c)/(6\theta + 1)$,

Case 2 (Figure 2). $W(t)$ is inverted-U shaped and free trade is Pareto superior to autarky if $(a - c)/(6\theta + 1) < s < (a - c)/(3\theta + 1)$,

Case 3 (Figure 3). $W(t)$ is monotonically decreasing and thus free trade is Pareto superior to autarky if $s > (a - c)/(3\theta + 1)$.

Proof. If s is small enough to have $s < (a - c)/(6\theta + 1)$, we have $W(0) < W(\bar{t})$ and $W'(0) > 0$, which enables us to depict Figure 1.

Under $(a - c)/(6\theta + 1) < s < (a - c)/(3\theta + 1)$, we see that $W(0) > W(\bar{t})$ and $W'(0) > 0$, from which Figure 2 is obtained.

When s is sufficiently large and $s > (a-c)/(3\theta+1)$, we have $W(0) > W(\bar{t})$ and $W'(0) < 0$ and hence Figure 3 can be depicted. Q.E.D.

We now consider the intuitions behind Proposition 1. As explained in detail in the last section, the governments raise the emission tax as tariffs decline. This bilateral rise in emission taxes discourages both the domestic and foreign firms' supply by shifting their reaction curve inward. While this decrease in consumption deteriorates welfare by reducing consumer surplus, it simultaneously enhances welfare by mitigating the damage from pollution.

If s is large enough, the net welfare effect of tariff reductions is positive for any tariff levels because mitigating pollution damages dominates losses in consumer surplus.[15] If s takes an intermediate value such that $(a-c)/(6\theta+1) < s < (a-c)/(3\theta+1)$ holds, free trade still ensures welfare gains as compared to autarky, but tariff reductions at $t \approx 0$ can yield losses. This is because reductions in pollution damages are not as strong as the above case. Furthermore, if s is so small that Case 1 emerges, free trade is no longer welfare-improving relative to autarky. In this case, consumers' losses are dominant in the overall effect, resulting in Pareto inferiority of free trade over autarky.

3.2. The quadratic damage case In order to check whether Proposition 1 hinges on the assumption of linear damage, this subsection considers welfare effects of tariff reductions in the case of quadratic damage.

Substituting (6) into (4) and using $v(Z) = \tilde{s}Z^2/2$, the subgame perfect Nash equilibrium welfare is

$$\begin{aligned} U\left(\tilde{\tau}^N, \tilde{\tau}^N, t\right) &= \frac{-(\theta\phi+\phi+1)t^2 + 2(-2\theta\phi+1)(a-c)t + 4(-\theta\phi+\phi+2)(a-c)^2}{2(2\phi+3)^2} \\ &\equiv \widetilde{W}(t). \end{aligned} \tag{8}$$

In what follows, it suffices to sketch the proof of the result since it is substantially the same as that in the linear damage case.

We first evaluate (8) at $t = 0$ and the prohibitive tariff denoted by $\tilde{t}$. Because exports in the equilibrium are $x^* = y = [a - c - (\phi+1)t]/(2\phi+3)$, the prohibitive tariff is $\tilde{t} = (a-c)/(\phi+1)$. Substituting $t = 0$ and $t = \tilde{t}$ into

(8), we have

$$\widetilde{W}(0) = \frac{2(-\theta\phi+\phi+2)(a-c)^2}{(2\phi+3)^2}$$
$$\widetilde{W}\left(\tilde{t}\right) = \frac{(-\theta\phi+\phi+1)(a-c)^2}{2(\phi+1)^2}.$$

Comparing these allows us to know that

$$W(0) > W\left(\tilde{t}\right) \iff \tilde{s} > \frac{-5\theta+1+\sqrt{25\theta^2+6\theta+1}}{8\theta(\theta+1)}.$$

While there is a quantitative difference, this is qualitatively parallel to the case of linear damage in that positive trade gains are ensured if $\tilde{s}$ is large enough.

Let us next compute the slope of $\widetilde{W}(t)$. Differentiating $\widetilde{W}(t)$ yields

$$\widetilde{W}'(t) = \frac{-(\theta\phi+\phi+1)t+(-2\theta\phi+1)(a-c)}{(2\phi+3)^2}, \quad \widetilde{W}''(t) = -\frac{\theta\phi+\phi+1}{(2\phi+3)^2} < 0,$$

namely, $\widetilde{W}(t)$ is strictly concave. The slope at $t = 0$ is

$$W'(0) = \frac{(-2\theta\phi+1)(a-c)}{(2\phi+3)^2} = -\frac{[2\tilde{s}\theta(\theta+1)-1](a-c)}{(2\phi+3)^2}.$$

Thus, we find that $W'(0) > 0$ if and only if $\tilde{s} < 1/[2\theta(\theta+1)]$. On the other hand, the slope at the prohibitive tariff is

$$\widetilde{W}'\left(\tilde{t}\right) = -\frac{\theta\phi(a-c)}{(2\phi+3)(\phi+1)} \leq 0.$$

Summarizing the results so far, we can establish:

Proposition 2. *The shape of $\widetilde{W}(t)$ and welfare effects of trade liberalization are classified as follows.*

Case 1 (Figure 1). $\widetilde{W}(t)$ is inverted-U shaped and free trade is Pareto inferior to autarky if $s < (-5\theta+\sqrt{25\theta^2+6\theta+1})/[8\theta(\theta+1)]$, *Case 2 (Figure 2).* $\widetilde{W}(t)$ *is inverted-U shaped and free trade is Pareto superior to autarky if* $(-5\theta + \sqrt{25\theta^2 + 6\theta + 1})/[8\theta(\theta + 1)] < s < 1/[2\theta(\theta + 1)]$*,*

Case 3 (Figure 3). $\widetilde{W}(t)$ *is monotonically decreasing and thus free trade is Pareto superior to autarky if* $s > 1/[2\theta(\theta + 1)]$*.*

Proof. The proof is the same as that of Proposition 1 by noting that $(-5\theta + \sqrt{25\theta^2 + 6\theta + 1})/[8\theta(\theta + 1)] < 1/[2\theta(\theta + 1)]$. Q.E.D.

The intuitions of this result parallel with those of Proposition 1. Trade liberalization induces higher emission taxes, which lowers consumption. Therefore, both consumer surplus and damages from pollution decrease. Consequently, if s is sufficiently large, trade is more likely to improve welfare since the pollution contraction effect dominates. The opposite reasoning applies to the case where s is small enough.

At this stage, we provide two remarks. First, when there is no pollution, free trade leaves both countries worse off than autarky regardless of the specification of the pollution damage.[16] The driving force of detrimental trade comes from the fact that a consumption tax is an imperfect substitute for an import tariff as mentioned in the previous section. By imposing a consumption tax, not only imports but also domestic supply is discouraged. As a result, the rent-shifting effect is weaker than a tariff and hence both countries seek to tax further. In other words, 'the nationally optimal tax rate will always be 'too high' (i.e., subsidies are 'too low') from the perspective of global welfare maximization. (Haufler et al. [2005, p. 291]) This distortion caused by 'too high' taxes leads to welfare losses.

The second remark is the case of local pollution. It is useful to focus on this case since it helps to shed light on the role of transboundary pollution in the foregoing argument and some predecessors, e.g., Walz and Wellisch [1997] and Burguet and Sempere [2003], restrict their attention to local pollution. In this special case, we have:

(Insert Figure 4 around here)

Corollary 1. *Under local pollution, trade liberalization unambiguously involves welfare losses.*

Proof. We begin with the case of linear damage. Comparing $W(0)$ and $W(\bar{t})$, we have $W(0) < W(\bar{t})$. Moreover, it is verified that $W'(0) > 0$ and $W'(\bar{t}) = 0$. These observations allow us to get Figure 4. By making the same calculations in the case of quadratic damages, Figure 4 is rehabilitated. Q.E.D.

As Table 1 shows, the transboundary externality effect of emission taxation is absent under local pollution. If pollution is transboundary, each country under-taxes because it ignores the effect of its emission on the other country. In contrast, when pollution is local, this tendency for under-taxation is no longer present. This leads to a higher tax than in the case of transboundary pollution. To summarize, the tendency for 'too high' taxes is stronger under local pollution than under transboundary pollution.

The resulting taxes not only reduce the damage from pollution but also yield the losses in consumer surplus and firm profits. Accordingly, trade liberalization is unambiguously welfare-reducing as Figure 4 shows. Note that this finding, together with the other results, exhibits another contrast to the production-generated pollution case. As Burguet and Sempere [2003] prove in a model similar to ours, both countries enjoy gains from bilateral trade liberalization when pollution is generated by production and local. However, the above result predicts the opposite.

4. Concluding remarks We have developed a two-country model of international duopoly to highlight the role of consumption-generated pollution for welfare implications of trade liberalization. It is shown that (i) the subgame perfect Nash equilibrium emission tax is decreasing in tariffs and that (ii) gains from trade liberalization are more likely if the parameter of pollution damage is sufficiently great. Moreover, (iii) trade liberalization inevitably entails welfare losses if pollution is local. All of these results predict the opposite to the case of production-generated pollution and thus which between production and consumption causes pollution has a considerable influence on welfare implications of trade liberalization.

Despite these novelties, we admittedly recognize the limitations of our analysis. First, we rest on many simplifying assumptions, e.g., linear demand, constant marginal cost, and symmetry between countries. In addition, we have assumed away abatement activities by firms although there are evidences suggesting that firms engage in abatements.[17] Second, we have assumed only one environmental instrument, i.e., an emission tax. If we allow for multiple environmental policies as in Burguet and Sempere [2003], our results may be modified. Third, while we presume that tariffs are exogenous, a few papers such as Kennedy [1994b], Walz and Wellisch [1997] and Tanguay [2001] analyze the interactions between environmental and trade policies by assuming that trade policies as well as environmental policies are determined to maximize welfare.[18] Finally, we observe *coexistence* of production-generated and consumption-generated pollution in reality. Therefore, it is more desirable to allow for both types of pollution for a richer analysis. It is our future research agenda to elaborate our results by taking into account these directions of generalizations.

ENDNOTES

1. Copeland and Taylor [2003] provide a comprehensive survey on perfectly competitive theories and empirics of 'trade and the environment.'
2. Walz and Wellisch [1997] (resp. the other two works) model trade liberalization as an exogenous reduction in export subsidies (resp. import tariffs) in a third-market (resp. reciprocal market) model.
3. As Burguet and Sempere [2003] note, this conclusion rests on the assumption that the environmental policy is a pollution tax. Moreover, Baksi and

Chaudhuri [2009] point out that trade liberalization can reduce welfare if the degree of transboundary pollution is large enough.
4. Empirical evidence that tariff reductions greatly contribute to the growth of world trade is found in Baier and Bergstrand [2001].
5. There is an empirical literature that addresses the implications of consumption-generated pollution for the Environmental Kuznetz Curve Hypothesis. See, for example, Rothman [1998] and Bagliani et al. [2008].
6. Kayalica and Kayalica [2005] confine attention to characterizations of the Nash equilibrium tariff and emission tax, and policy reforms.
7. In this paper, trade liberalization is equivalent to an exogenous reduction in import tariffs and we presume an emission tax as a sole environmental policy.
8. See Brander and Krugman [1983] and Brander and Spencer [1984] for the basic model.
9. If t is negative, it is an import subsidy.
10. The same analytical strategy is also employed by Straume [2006].
11. Note that the same does not survive the case of production-generated pollution.
12. Tanguay [2001] is an example that assumes linear pollution damage.
13. Although it is almost impossible to determine which specification of damage is realistically more plausible between linear and quadratic functions, it may be fair to say that the quadratic function fits better transboundary pollution such as global warming. If the temperature were to be doubled, anyone would feel uncomfortable more than proportionally.
14. If pollution is local, this effect vanishes.
15. Of course, trade liberalization affects the firm profit, emission tax revenue, and tariff revenue, but these effects are not clear.
16. This is confirmed by noting that welfare in free trade is $4(a-c)^2/9$ and that in autarky is $(a-c)^2/2$. This finding is in accordance with the result of Haufler et al. [2005].
17. See, for example, Frondel et al. [2008], Aiken et al. [2009], and Kellen-

berg [2009].
18. Kayalica and Kayalica [2005] address the case where both emission taxes and import tariffs are a strategic variable of governments in a context of consumption-generated pollution. Simple calculations reveal that exports become zero in the subgame perfect Nash equilibrium of this extended model. This is still true even if an export subsidy is incorporated.

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	transboundary pollution	local pollution
efficiency effect	−	−
transboundary externality effect	−	0
rent capture effect	+	+
pollution reducing effect	+	+
total	+	+

Table 1: Effects of Tariff Reductions on Taxation: '+' indicates that higher taxes are chosen as a result of tariff reductions

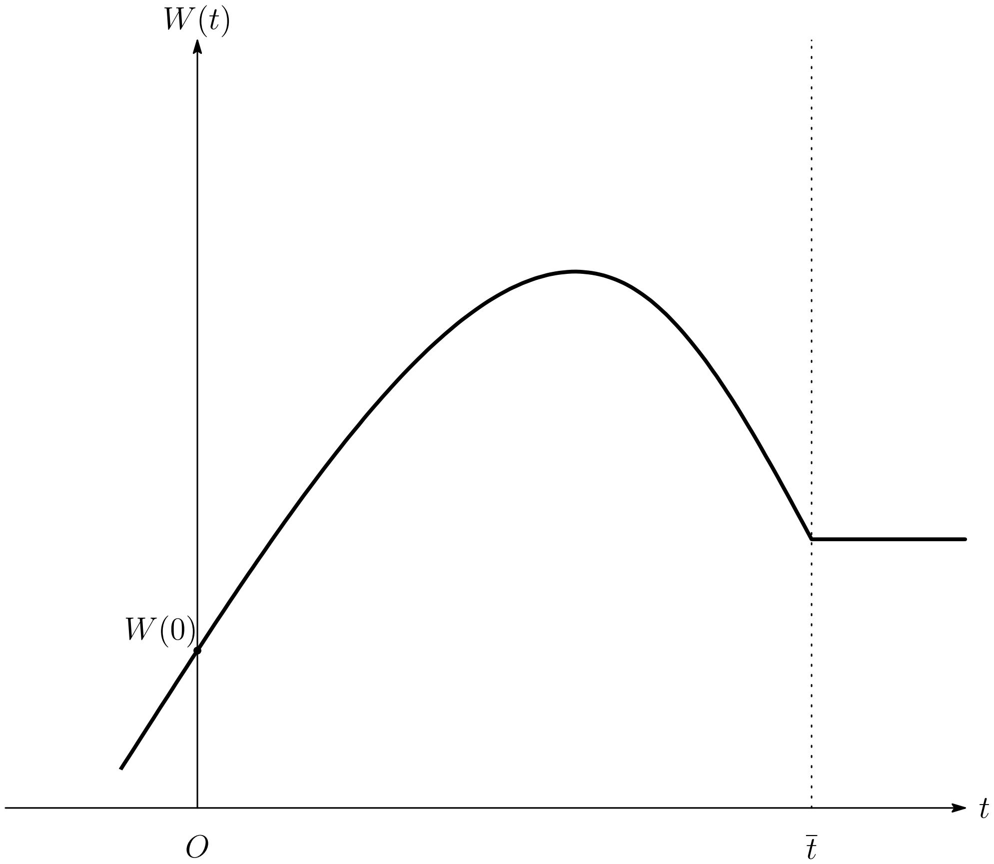

Figure 1: Case 1

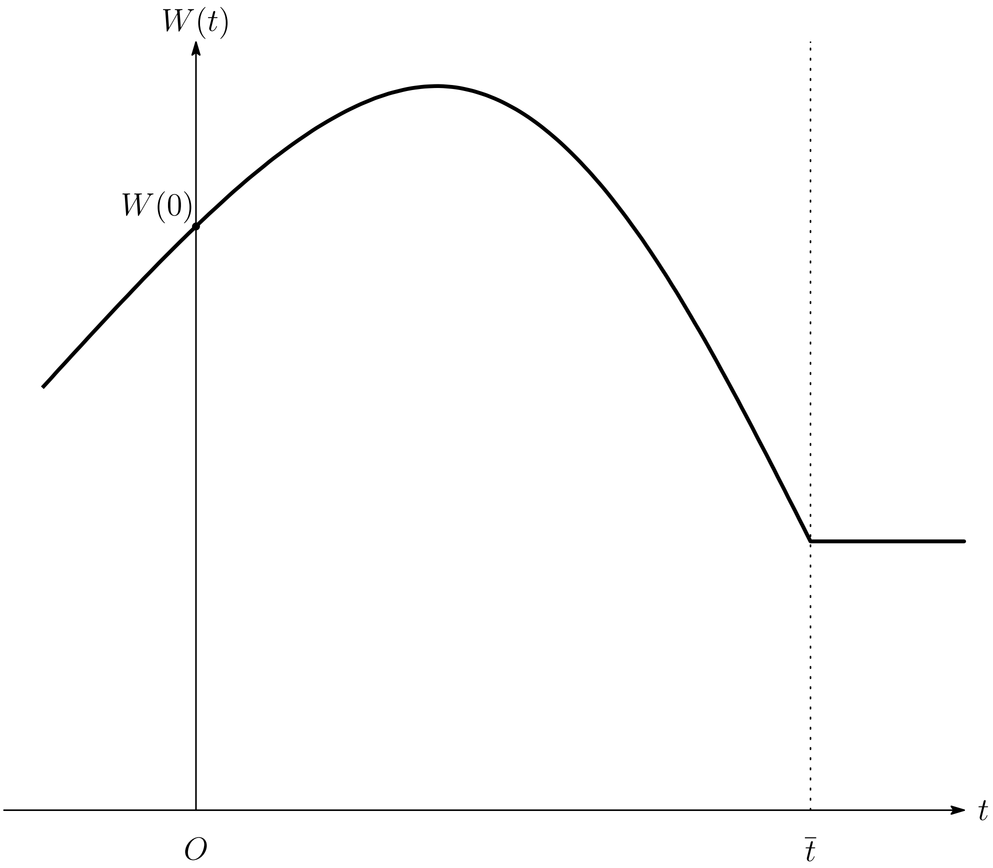

Figure 2: Case 2

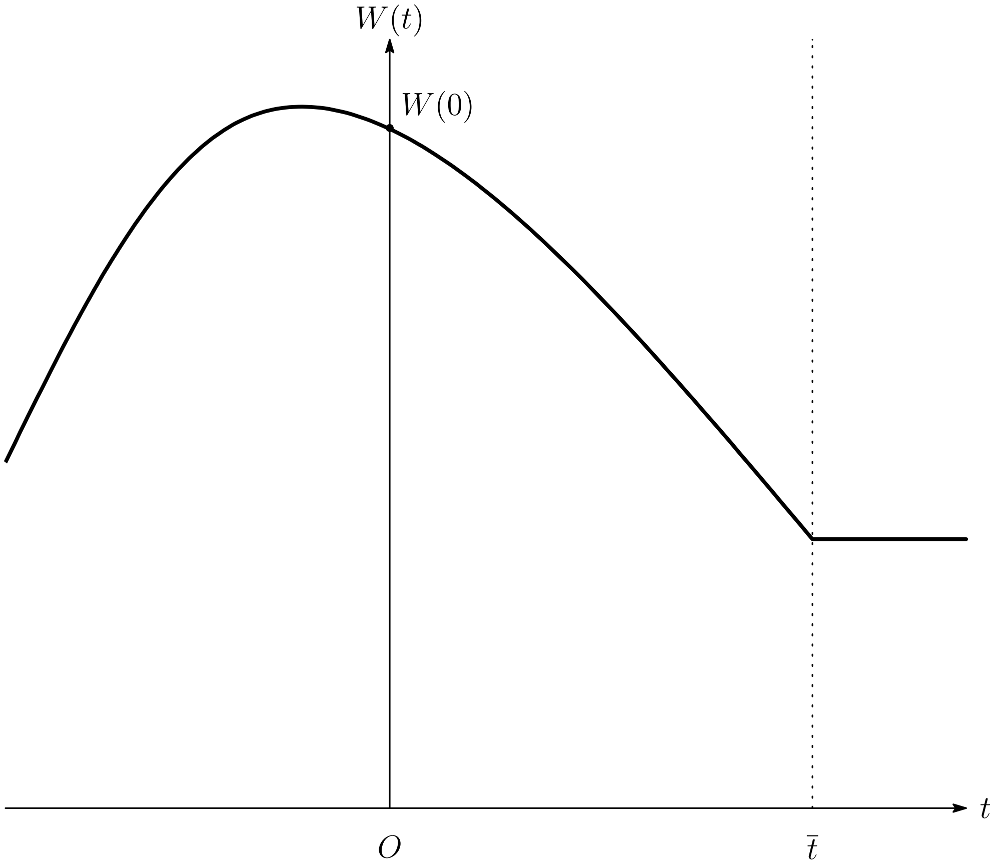

Figure 3: Case 3

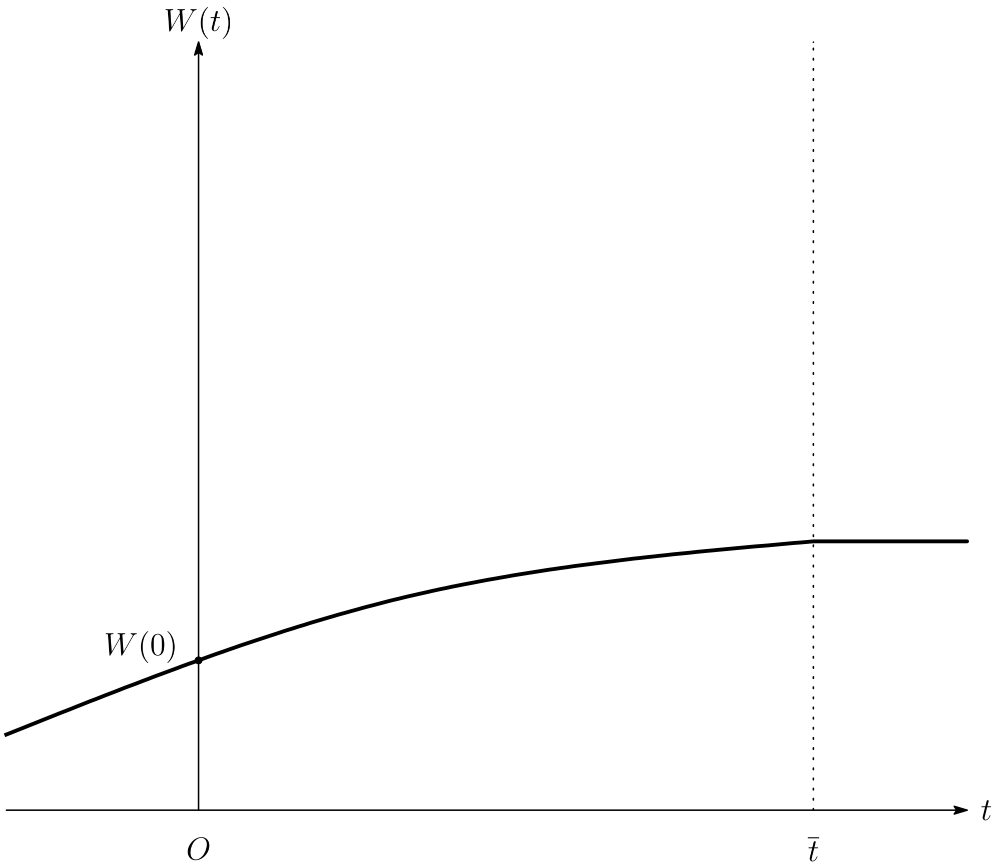

Figure 4: The Case of Local Pollution