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Strategic Environmental Policies and the Gains from Trade Liberalization

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Abstract

The literature on strategic environmental policy has not fully addressed welfare effects of trade liberalization from autarky. In a reciprocal market model of duopoly with transboundary pollution, we study how reductions in transport costs and import tariffs affect the Nash equilibrium welfare of an environmental policy game as compared to any initial state including autarky. We show three patterns of gainfulness of trade depending on the interaction between marginal damage from pollution and the degree of transboundary pollution.
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1 Introduction

Rapidly growing trade flows over the decades have given rise to new trade-related concerns, e.g., service trade, intellectual property rights and labor standards and 'trade and the environment' is also increasing its relevance in international and environmental economics. One of the central interests in this field is welfare consequences of noncooperative choices of environmental policies.[1] Among others, using an international oligopoly model, Conrad (1993), Barrett (1994), Kennedy (1994a) and Rauscher (1994) find a now-classical result that each country has an incentive to employ laxer environmental policies, which renders welfare losses as compared to the efficient equilibrium.[2]

Based on this branch of works, Walz and Wellisch (1997) and Burguet and Sempere (2003) address welfare effects of trade liberalization when countries noncooperatively choose environmental policies. The former (resp. latter) paper regards a reduction in export subsidies (resp. import tariffs) as trade liberalization in a third market (resp. two-country) model. In addition, Kennedy (1994b), Waltz and Wellisch (1997) and Tanguay (2001) examine some properties of the subgame perfect Nash equilibrium by allowing governments to implement both environmental and trade policies. In a two-stage game model where governments determine a pollution tax and a production subsidy in the first stage and firms play a duopoly game in the second stage, Kennedy (1994b) explores under what condition the efficient outcome is decentralized. Using a similar setting, Tanguay (2001) considers simultaneous determination of a pollution tax and an import tariff, showing that the Nash equilibrium welfare exceeds the free trade welfare. Waltz and Wellisch (1997), on the other hand, employ a third market model and assume an emission tax and an export subsidy to show that the external costs associated with local pollution can be fully internalized. However, as Straume (2006, p. 537) points out that in these papers 'there are no costs of trade $\cdots$, so the issue of product market integration (or trade liberalization) is not tackled'. To fulfill this gap, Straume (2006) incorporates transport costs into a two-country duopoly model and compare the cooperative and Nash equilibria.

Given the above review of literature, to our knowledge, no predecessor deals with welfare effects of a movement from *autarky* to trade. Instead, the existing literature is mainly interested in comparison between the efficient (cooperative) and noncooperative outcomes and it is out of interest whether trade liberalization relative to autarky improves welfare. To overcome this gap in the literature, we consider welfare effects of trade liberalization (reductions in transport costs/tariffs) from any initial state including *autarky* in the presence of strategic environmental policies and transboundary pollution.

This paper has two big differentiations from the existing papers. First, as stressed above, our interest centers around the welfare change from two market equilibria including autarky instead of comparison between cooperative and noncooperative solutions. Second, we provide a *global* analysis on trade gains/losses with simple diagrams whereas the predecessors confine attention to marginal or *local* effects of reductions in transport costs/tariffs. Third, we treat two cases in which trade is costly due to transport costs or import tariffs. We will show in each case there are three possibilities on gainfulness of freer trade depending on two parameters one of which is marginal damage from pollution and the other of which is the degree of transboundary pollution.

The paper is organized as follows. Section 2 presents a model. Section 3 (resp. Section 4) derives the subgame perfect Nash equilibrium and considers how reductions in transport costs (resp. tariffs) affect the equilibrium welfare. Section 5 gives conclusions.

2 A Model

2.1 Fundamentals

Consider a world comprising two symmetric countries, Home and Foreign. All the Foreign variables are asterisked. Both countries produce a non-numeraire (Good 1) and a numeraire (Good 2) from labor. Without loss of generality, one unit of labor produces one unit of Good 2 so that the wage rate is fixed to unity. Production of Good 1 incurs a constant marginal cost $c \geq 0$. Firm X operates in Home and firm Y in Foreign, both of which compete in segmented markets in a Cournot-Nash fashion. Let x (resp. x^*) denote firm X's supply into the Home (resp. Foreign) market. Firm Y's supply is similarly decomposed into y and y^*. Thus, total supply in Home (resp. Foreign) equals $x + y$ (resp. $x^* + y^*$).

Assume a representative consumer whose preference is

$$u = aC_1 - \frac{C_1^2}{2} + C_2 - sZ, \quad a > c, \quad s \geq 0, \tag{1}$$

where u is utility, $C_i, i = 1, 2$ consumption of each good, Z pollution in Home, and s marginal damage from pollution. Maximizing (1) subject to the budget constraint yields linear inverse demand functions $p = a - x - y$ and $p^* = a - x^* - y^*$.

2.2 A Duopoly Game

Production of Good 1 emits a proportional pollutant which is subject to emission taxes τ and τ^*. In addition, there is a per-unit trade barrier with exports $t \geq 0$. Section 3 (resp. Section 4) regards t as a transport cost (resp. import tariff).[2] Our model consists of two stages. In the first stage, the Home and Foreign governments noncooperatively choose emission taxes and each firm plays a Cournot-Nash game in the second stage. In order to solve the game with backward induction, let us define the profit of each firm:

$$\text{Home firm} \;:\; (a - c - \tau - x - y)x + (a - c - \tau - t - x^* - y^*)x^* \tag{2}$$

$$\text{Foreign firm} \;:\; (a - c - \tau^* - t - x - y)y + (a - c - \tau^* - x^* - y^*)y^*. \tag{3}$$

The first term in (2) and (3) is a profit earned in the Home market and the second is the counterpart in the Foreign market. Each firm chooses outputs to maximize profits, which yields the Cournot-Nash equilibrium outputs:

$$x = \frac{a - c + t - 2\tau + \tau^*}{3} \tag{4}$$

$$y = \frac{a - c - 2t + \tau - 2\tau^*}{3} \tag{5}$$

$$x^* = \frac{a - c - 2t - 2\tau + \tau^*}{3} \tag{6}$$

$$y^* = \frac{a - c + t + \tau - 2\tau^*}{3}. \tag{7}$$

Making use of (4)-(7), each country's consumer surplus becomes $(x + y)^2/2$ and $(x^* + y^*)^2/2$ and the maximized profits π and π^* are $\pi = x^2 + x^{*2}$ and $\pi^* = y^2 + y^{*2}$. Using these preliminaries, the subsequent sections derive the subgame perfect Nash equilibrium emission tax and seek its welfare implications.

3 Gains from Trade: the Transport Cost Case

3.1 An Environmental Policy Game

This section assumes that t is a transport cost. Then, Home's welfare U is defined by

$$\begin{aligned} U &\equiv \frac{(x+y)^2}{2} + \pi - sZ + \tau(x+x^*) \\ &= \frac{(x+y)^2}{2} + x^2 + x^{*2} - s\left[x + x^* + \theta(y+y^*)\right] + \tau(x+x^*), \end{aligned} \tag{8}$$

where the first term is consumer surplus and the last term is emission tax revenue. In (8), we allow for transboundary pollution so that $Z = x + x^* + \theta(y+y^*)$, where $\theta \in [0,1]$ measures the degree of transboundary pollution. By definition, $\theta = 0$ (resp. $\theta = 1$) means local (resp. global) pollution.

Substituting (4)-(7) into (8), Home's welfare becomes a function of τ and τ^*.

$$\begin{aligned} U(\tau,\tau^*,t) \;=\; & \frac{1}{2}\left[\frac{2(a-c)-t-\tau-\tau^*}{3}\right]^2 + \left[\frac{a-c+t-2\tau+\tau^*}{3}\right]^2 + \left[\frac{a-c-2t-2\tau+\tau^*}{3}\right]^2 \\ & -s\left[\frac{2(a-c)-t-4\tau+2\tau^*}{3} + \theta\cdot\frac{2(a-c)-t+2\tau-4\tau^*}{3}\right] \\ & +\tau\cdot\frac{2(a-c)-t-4\tau+2\tau^*}{3}. \end{aligned} \tag{9}$$

The assumption of symmetry between countries enables us to define $U(\tau^*,\tau,t)$ as Foreign's welfare.

We solve the first stage of the two-stage game. Governments noncooperatively choose an emission tax to maximize welfare, from which the first-order condition for Home's welfare maximization is[4]

$$\frac{\partial U(\tau,\tau^*,t)}{\partial \tau} = \frac{-4(a-c)+6s(2-\theta)+2t-7\tau-\tau^*}{9} = 0.$$

Foreign's counterpart is obtained by replacing τ with τ^* in this equation. Therefore, the subgame perfect Nash equilibrium uniquely exists and the equilibrium emission tax is computed as

$$\tau = \frac{-2(a-c)+3s(2-\theta)+t}{4}. \tag{10}$$

In what follows, these results are utilized to evaluate welfare effects of an exogenous reduction in transport costs.

3.2 Gains from Trade

In order to examine welfare effects of transport cost reductions, we need to know how the Nash equilibrium welfare depends on t. Substituting (10) into (9) and rearranging terms, the equilibrium welfare is expressed as a quadratic function of t.

$$\begin{aligned} W(t) &= \frac{1}{2}\left[\frac{2(a-c)-s(2-\theta)-t}{2}\right]^2+\left[\frac{2(a-c)-s(2-\theta)+t}{4}\right]^2+\left[\frac{2(a-c)-s(2-\theta)-3t}{4}\right]^2 \\ &\quad +\frac{-2(a-c)+s(2-7\theta)+t}{4}\cdot\frac{2(a-c)-s(2-\theta)-t}{2} \\ &= \frac{10t^2-8t[a-c-s(\theta+1)]+2[2(a-c)-s(2-\theta)][2(a-c)-s(5\theta+2)]}{16}. \end{aligned} \tag{11}$$

The rest of this section closely examines the properties of $W(t)$. Noting that the export in the Nash equilibrium is

$$x^* = y = \frac{2(a-c)-s(2-\theta)-3t}{4},$$

after substituting (10) into (5) and (6). Hence, the prohibitive transport cost is defined by $\bar{t} = [2(a-c)-s(2-\theta)]/3$ above which exports are zero and welfare under autarky is measured by $W(\bar{t})$. Now, we make an assumption to ensure positivity of $\bar{t}$:

Assumption: $s < \frac{2(a-c)}{2-\theta}$.

Our task consists of a few auxiliary steps. The first is a welfare comparison between free trade (zero transport cost) and autarky (prohibitive transport cost). Substituting $t = 0$ and $t = \bar{t}$ into (11), welfare in these polar regimes is obtained as[5]

$$W(0) = \frac{[2(a-c)-s(2-\theta)][2(a-c)-s(5\theta+2)]}{8} \tag{12}$$

$$W(\bar{t}) = \frac{[2(a-c)-s(2-\theta)][4(a-c)-s(7\theta+4)]}{18}. \tag{13}$$

Then, the ratio between $W(0)$ and $W(\bar{t})$ becomes

$$\frac{W(0)}{W(\bar{t})} = \frac{18(a-c)-9s(5\theta+2)}{16(a-c)-4s(7\theta+4)},$$

from which we have $sign\{W(0)-W(\bar{t})\} = sign\{2(a-c)-s(17\theta+2)\}$. This result is straightforward since it merely states that both countries are better off under free trade than under autarky when marginal damage s is sufficiently small. The reason is that the procompetitive gains from trade dominate the losses from pollution expansion.

The second step is to investigate the slope of $W(t)$. For this purpose, let us differentiate (11) with respect to t to get

$$W'(t) = \frac{5t - 2[(a-c) - s(\theta+1)]}{4}, \quad W''(t) = \frac{5}{4}.$$

Thus, $W(t)$ is strictly convex but it is at this stage ambiguous whether $W(t)$ is monotonically increasing, monotonically decreasing or U-shaped.

Summing these results up, we have three possibilities which are depicted in Figures 1-3. The condition for each of them is given by Figure 4. They are formally stated in:

Proposition 1: *Welfare effects of transport cost reductions are classified as follows.*
Case 1 (Figure 1): welfare in trade is U-shaped in t and free trade Pareto dominates autarky if $s < 2(a-c)/(17\theta+2)$,
Case 2 (Figure 2): welfare in trade is U-shaped in t and free trade is Pareto dominated by autarky if $2(a-c)/(17\theta+2) < s < (a-c)/(\theta+1)$,
and
Case 3 (Figure 3): welfare in trade monotonically increases with t and free trade is Pareto dominated by autarky if $(a-c)/(\theta+1) < s < 2(a-c)/(2-\theta)$.

Proof. We know that $W(0) > W(\bar{t})$ if and only if $s < 2(a-c)/(17\theta+2)$. And it is easy to see that $W'(0) = [-(a-c) + s(\theta+1)]/2 < 0$, i.e., $W(t)$ is U-shaped if and only if $s < (a-c)/(\theta+1)$.[6] Invoking that $2(a-c)/(2-\theta) \geq (a-c)/(\theta+1) \geq 2(a-c)/(17\theta+2)$, we obtain Figure 4.

When s is so small that $s < 2(a-c)/(17\theta+2)$, we have $W(0) > W(\bar{t})$ and $W(t)$ is U-shaped, which corresponds to Figure 1. If $2(a-c)/(17\theta+2) < s < (a-c)/(\theta+1)$, it follow that $W(t)$ is U-shaped and that $W(0) < W(\bar{t})$ as in Figure 2. Finally, if s is large enough to have $(a-c)/(\theta+1) < s < 2(a-c)/(2-\theta)$, $W(t)$ is monotonically increasing in t and $W(0) < W(\bar{t})$, which is depicted in Figure 3. Q.E.D.

Having mathematically proved the welfare effects of reductions in transport costs, we turn to intuitively interpreting them. To do it, it is convenient to decompose the overall effects into (i) a direct effect and (ii) an indirect effect through the influence on τ. The direct effect indicates that transport cost reductions simply encourage the supply abroad while they discourage the supply into the domestic market. On the other hand, a reduction in t induces a reduction in emission taxes (ecological dumping), which in turn increases the supply into the domestic market and decreases the export. Nevertheless, the direct effect outweighs the indirect effect, resulting in the increase in exports and the decrease in the supply into the domestic market. Moreover, it is easy to confirm that the total supply in each country is enhanced by smaller transport costs.

Having this in mind, let us consider how each component of welfare changes with liberalized trade. Looking at (11), we see that consumer surplus, the firm profit and pollution necessarily increases. In contrast, it is ambiguous whether pollution tax revenue increases depending on the initial level of t; pollution tax revenue increases only if the initial trade cost is very high.

Case 1 in Proposition 1 states that free trade with zero transport cost involves higher welfare than autarky because pollution expansion has no significant effect (s is small enough). In contrast, the opposite occurs in Cases 2 and 3 since the negative effect through pollution expansion is dominant.

We draw attention to two points on Figures 1-3. The first is that W is U-shaped in Cases 1 and 2. This is because increased imports through trade liberalization lead to expansion of wasteful resources due to transport costs.[7] In other words, trade liberalization boosts inefficiencies associated with transport costs. When t is initially high, this increase in efficiency overweighs the positive gains from promoted competition. The conclusion is that trade liberalization can worsen welfare. However, if reductions in transport costs are substantial, welfare improves as a result of freer trade since procompetitive effects are stronger than any other negative effects.

The second noteworthy point is that the above non-monotonic relationship between welfare and transport costs no longer holds if s is sufficiently large. This is because the pollution expansion effect dominates all the favorable effects of trade liberalization. Consequently, W becomes monotonically increasing in t, i.e., transport cost reductions unambiguously deteriorate welfare.

In view of that some existing literature such as Walz and Wellisch (1997) and Burguet and Sempere (2003) focuses on local pollution ($\theta = 0$ in our model), it is useful to look at this extreme situation. In this situation, we have:

Corollary 1.: *Under local pollution ($\theta = 0$), only Case 1 arises.*

Proof. When $\theta = 0$, we have $2(a-c)/(17\theta+2) = (a-c)/(\theta+1) = 2(a-c)/(2-\theta) = a-c$, which allows us to find that (i) $W(t)$ is U-shaped and that (ii) $W(0) > W(\bar{t})$. Q.E.D.

This implies that the existing literature cited above has *a priori* ruled out Cases 2 and 3. However, the assumption of local pollution is quite strict in light of environmental problems in reality. For instance, global warming and destruction of the ozone layer are a typical example of global pollution ($\theta = 1$ in our model). In this sense, Proposition 1 has an important implication which the existing literature overlooks.[8]

4 Gains from Trade: the Tariff Case

4.1 An Environmental Policy Game

While the last section has presumed that a transport cost is a cause of costly trade, this section assumes that t is an import tariff. What differs between the two cases is that governments determine emission taxes, taking into account their influences on tariff revenue. We will show that this difference in assumptions leads to interesting implications distinct from the transport cost case.

To derive the subgame perfect Nash equilibrium, we define welfare in the tariff case. Adding tariff revenue ty to Home's welfare in the transport cost case, we have

$$\begin{aligned}\widetilde{U} &\equiv \frac{(x+y)^2}{2} + \pi - sZ + \tau(x+x^*) + ty \\ &= \frac{(x+y)^2}{2} + x^2 + x^{*2} - s\left[x + x^* + \theta(y+y^*)\right] + \tau(x+x^*) + ty,\end{aligned}$$

where a tilde refers to the tariff case. Substituting (4)-(7) into this, the Home government's payoff becomes

$$\begin{aligned}\widetilde{U}(\tau,\tau^*,t) &= \frac{1}{2}\left[\frac{2(a-c)-t-\tau-\tau^*}{3}\right]^2+\left[\frac{a-c+t-2\tau+\tau^*}{3}\right]^2+\left[\frac{a-c-2t-2\tau+\tau^*}{3}\right]^2\\ &\quad -s\left[\frac{2(a-c)-t-4\tau+2\tau^*}{3}+\theta\cdot\frac{2(a-c)-t+2\tau-4\tau^*}{3}\right]\\ &\quad +\tau\cdot\frac{2(a-c)-t-4\tau+2\tau^*}{3}+t\cdot\frac{a-c-2t+\tau-2\tau^*}{3}. \end{aligned} \tag{14}$$

From the symmetry between countries, the Foreign government's objective is $\widetilde{U}(\tau^*,\tau,t)$.

The Home government maximizes (14) by setting τ, which yields the following first-order condition:

$$\frac{\partial\widetilde{U}(\tau,\tau^*,t)}{\partial\tau}=\frac{-4(a-c)+6s(2-\theta)+5t-7\tau-\tau^*}{9}=0.$$

Solving the system of the first-order conditions $\partial\widetilde{U}(\tau,\tau^*,t)/\partial\tau=0$ and $\partial\widetilde{U}(\tau,\tau^*,t)/\partial\tau^*=0$, the subgame perfect Nash equilibrium emission tax is

$$\tau=\frac{-4(a-c)+6s(2-\theta)+5t}{8}. \tag{15}$$

The next subsection considers welfare effects of tariff reductions by utilizing this preliminary result.

4.2 Gains from Trade

Since our task in this subsection is the same as that in the previous section, it suffices to briefly sketch the core argument. Let us first define the equilibrium welfare as a function of t. Substituting (15) into (14), we have

$$\begin{aligned}\widetilde{W}(t) &= \frac{1}{2}\left[\frac{4(a-c)-2s(2-\theta)-3t}{4}\right]^2\\ &\quad +\left[\frac{4(a-c)-2s(2-\theta)+t}{8}\right]^2+\left[\frac{4(a-c)-2s(2-\theta)-7t}{8}\right]^2\\ &\quad +\frac{-4(a-c)+2s(2-7\theta)+5t}{8}\cdot\frac{4(a-c)-2s(2-\theta)-3t}{4}\\ &\quad +\frac{t\left[4(a-c)-2s(2-\theta)-7t\right]}{8}\\ &= \frac{-9t^2+36s\theta t+4[2(a-c)-s(2-\theta)][2(a-c)-s(5\theta+2)]}{32}. \end{aligned} \tag{16}$$

As in the transport cost case, let us decompose our tasks. First, we compare welfare levels under free trade ($t = 0$) and autarky ($t = \widetilde{t}$), where $\widetilde{t}$ is the prohibitive tariff rate, which is computed as follows. Substituting (15) into exports yields

$$x^* = y = \frac{4(a-c) - 2s(2-\theta) - 7t}{8},$$

and thus the prohibitive tariff is $\widetilde{t} = [4(a-c) - 2s(2-\theta)]/7$ above which exports are zero.

Then, welfare levels in the two polar regimes are

$$\begin{aligned} \widetilde{W}(0) &= \frac{[2(a-c) - s(2-\theta)][2(a-c) - s(5\theta+2)]}{8} \\ \widetilde{W}\left(\widetilde{t}\right) &= \frac{2[2(a-c) - s(2-\theta)][5(a-c) - s(8\theta+5)]}{49}. \end{aligned}$$

Taking the ratio between these two polar cases, we have

$$\frac{\widetilde{W}(0)}{\widetilde{W}\left(\widetilde{t}\right)} = \frac{49[2(a-c) - s(5\theta+2)]}{16[5(a-c) - s(8\theta+5)]},$$

from which it follows that $sign\left\{\widetilde{W}(0) - \widetilde{W}(\widetilde{t})\right\} = sign\{18(a-c) - s(117\theta + 18)\}$. Note here that this result parallels the transport cost case since gains from free trade are possible unless s is sufficiently large.

Second, the slope of $\widetilde{W}(t)$ is examined. Differentiating (16) with respect to t, we obtain

$$\widetilde{W}'(t) = \frac{-9t + 18s\theta}{16}, \quad W''(t) = \frac{-9}{16}.$$

Hence, $\widetilde{W}(t)$ is strictly concave. Substituting $\widetilde{t}$ into $\widetilde{W}'(t)$, we get

$$\widetilde{W}'\left(\widetilde{t}\right) = \frac{-9[a - c - s(3\theta+1)]}{28},$$

which enables us to find that $\widetilde{W}'\left(\widetilde{t}\right) < 0$ if and only if $s < (a-c)/(3\theta+1)$.

In view of these auxiliary analyses, we have three possibilities. They are depicted in Figures 5-7 and two thresholds which distinguish them are given by Figure 8. Our result can be summarized in:

Proposition 2: *Welfare effects of tariff reductions are classified as follows.*

Case 1 (Figure 5): welfare in trade is inverted U-shaped in t and free trade Pareto dominates autarky if $s < 18(a-c)/(117\theta+18)$,
Case 2 (Figure 6): welfare in trade is inverted U-shaped in t and free trade is Pareto dominated by autarky if $18(a-c)/(117\theta+18) < s < (a-c)/(3\theta+1)$,
and
Case 3 (Figure 7): welfare in trade monotonically increases with t and free trade is Pareto dominated by autarky if $(a-c)/(3\theta+1) < s < 2(a-c)/(2-\theta)$.

Proof. We see that $\widetilde{W}(0) > \widetilde{W}\left(\tilde{t}\right)$ if and only if $s < 18(a-c)/(117\theta+18)$ and that $\widetilde{W}'\left(\tilde{t}\right) < 0$, namely, $\widetilde{W}(t)$ is inverted U-shaped if and only if $s < (a-c)/(3\theta+1)$.[9] Considering the ranking that $2(a-c)/(2-\theta) \geq (a-c)/(3\theta+1) \geq 18(a-c)/(117\theta+18)$, we have Figure 8.

Under $s < 18(a-c)/(117\theta+18)$, we have $W(0) > W(\bar{t})$ and $W(t)$ is inverted U-shaped, which gives Figure 5. If $18(a-c)/(117\theta+18) < s < (a-c)/(3\theta+1)$, it follow that $W(t)$ is inverted U-shaped and that $W(0) < W(\bar{t})$ as in Figure 6. Finally, if s is large enough to have $(a-c)/(3\theta+1) < s < 2(a-c)/(2-\theta)$, $W(t)$ is monotonically increasing in t and $W(0) < W(\bar{t})$, which is depicted in Figure 7. Q.E.D.

The intuitions behind Proposition 2 parallel those behind Proposition 1. Only one difference between the two cases is that tariff revenue must be taken into account in the present case. As mentioned in the last section, trade liberalization has a direct effect of encouraging imports and exports and an indirect effect through lowering pollution taxes. The direct effect replaces a part of the domestic supply with imports and vice versa through the indirect effect. Considering these conflicting effects, we see that tariff reductions decrease the supply into the domestic market, increase the import and increase the total supply. This, in turn, increases consumer surplus, the firm profit and pollution. Revenue from emission taxes and tariffs increases only if the initial tariff is high enough.

Case 1 asserts that free trade (zero tariff) Pareto dominates autarky since the pollution expansion effect is dominated by the procompetitive effect. However, Cases 2 and 3 no longer ensure such a positive evaluation of free trade because pollution expansion is relevant. Particularly, Case 3 illustrates a pessimistic assessment of trade liberalization in that not only free trade but also *any* trade involves welfare losses as compared to autarky.

As in the transport cost cases, two points are noted. First, welfare is inverted U-shaped in Case 1 (Figure 5) because revenue from emission taxes and tariffs can decrease if t becomes too small. In other words, there is a threshold at which highest welfare is achieved. Second, there is a qualitative difference between the transport cost case and the tariff case. This stems from the fact that there is no wasteful resource in the tariff case while the transport cost case involves an inefficiency. Therefore, welfare at any t is higher than welfare under autarky in the tariff case (see Figure 5) but the same is impossible in the transport cost case (see Figure 1).

Let us at this stage address the local pollution case. Then, we see:

Corollary 2: *Under local pollution ($\theta = 0$), only Case 1 with $W'(0) = 0$ arises.*

Proof. When $\theta = 0$, we have $18(a-c)/(117\theta+18) = (a-c)/(3\theta+1) = 2(a-c)/(2-\theta) = a-c$, which allows us to find that (i) $W(t)$ is inverted U-shaped and that (ii) $\widetilde{W}(0) > \widetilde{W}\left(\tilde{t}\right)$. Moreover, it is easy to check that $\widetilde{W}'(0) = 0$ under $\theta = 0$. Q.E.D.

Indeed, this result has little new because Walz and Wellisch (1997) and Burguet and Sempere (2003) have already confirmed it. While there is a modeling difference between these two predecessors, they establish that free trade leads to a welfare improvement.[1]0 However, we must once again notice that both of these authors commonly restrict attention to local pollution. Once this assumption is relaxed, we have three possibilities on gainfulness of trade, which is a new finding in this paper.

5 Concluding Remarks

Making use of a two-country model of polluting duopoly, we have considered welfare effects of two types of trade liberalization. We have shown three possibilities depending on the parameters measuring marginal damage from pollution and the degree of transboundary pollution. And we have pointed out that the existing literature, e.g., Walz and

Wellisch (1997) and Burguet and Sempere (2003) overlook two important possibilities that free trade is Pareto inferior to autarky by confining attention to local pollution. In addition, there is a substantial difference between the transport cost case and the tariff case.

While we believe that this paper makes certain contribution to the literature on 'trade and the environment,' there remain limitations. Among others, our results rest on many simplifying assumptions such as linearity of demand, production cost and pollution damage. Although they considerably facilitate analysis, our results lack generality. It is our future research agenda to elaborate our results in a more general setting.

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Notes

1. Copeland and Taylor (2003) provide a comprehensive survey on the theoretical and empirical analysis on 'trade and the environment' based on perfectly competitive product markets.
2. For recent extensions of these works, see, e.g., Cassing and Kuhn (2003) and Bayindir-Upmann (2003).
3. Throughout this paper, t is assumed to be exogenous. While it is worth considering the case where t is endogenously determined particularly in the tariff case, such a richer analysis is beyond the scope of this paper.
4. The second-order condition and the stability of the Nash equilibrium are satisfied.

5. Assumption made above ensures $W(0) > 0$ and $W(\bar{t}) > 0$.

6. Note that $W'(\bar{t})$ is necessarily positive since $W'(\bar{t}) = [4(a-c) + s(11\theta - 4)]/12 > 0$ under Assumption.

7. This waste of resources vanishes in the tariff case. See the next section.

8. Similar notes are recast in the next section as well.

9. Note that $\widetilde{W}'(0) = 9s\theta/8 \geq 0$ and thus $\widetilde{W}$ is non-negatively sloping at $t = 0$ in all subcases.

10. Walz and Wellisch (1997) (resp. Burguet and Sempere (2003)) employ a third-market (resp. reciprocal market) model.

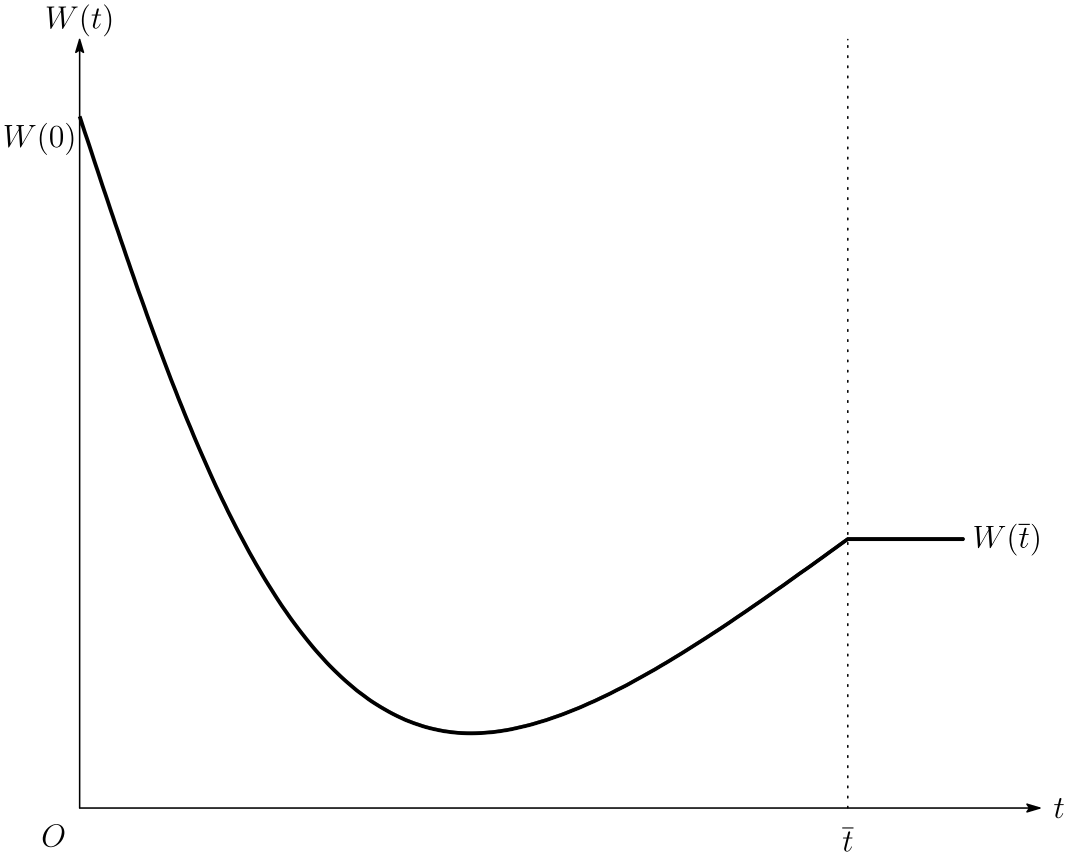

Figure 1: Case 1 (transport cost)

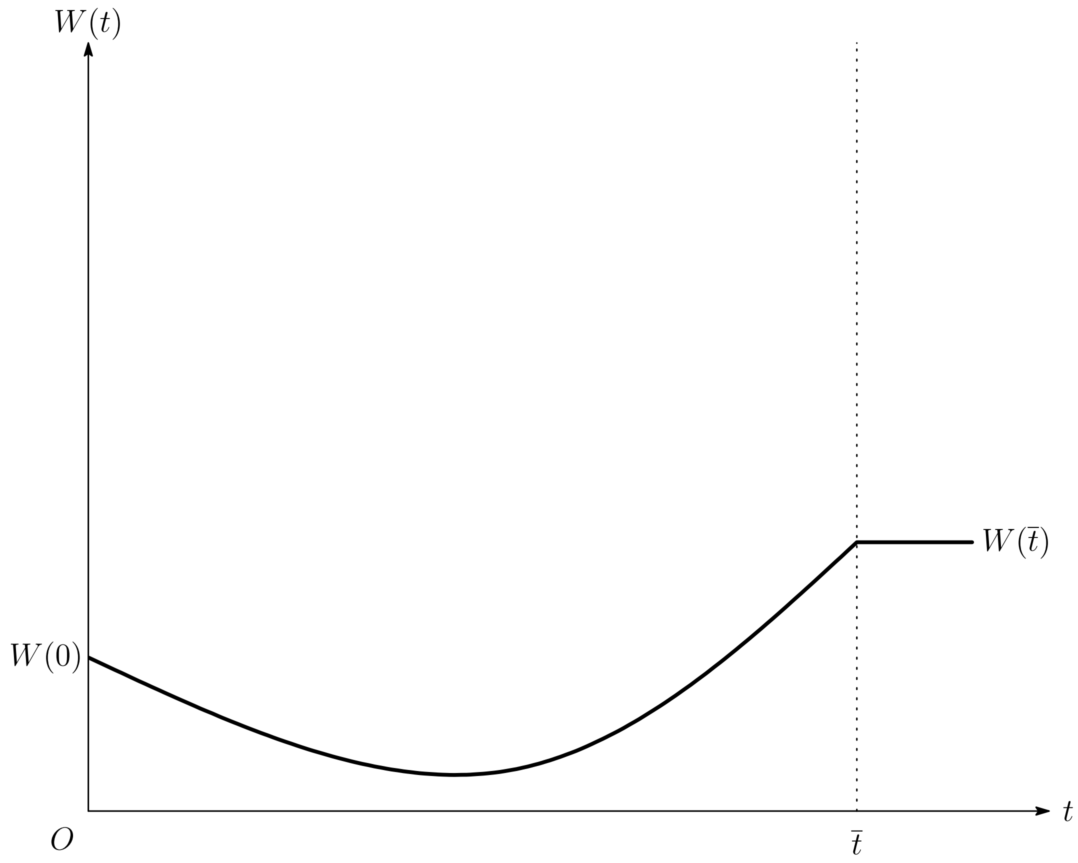

Figure 2: Case 2 (transport cost)

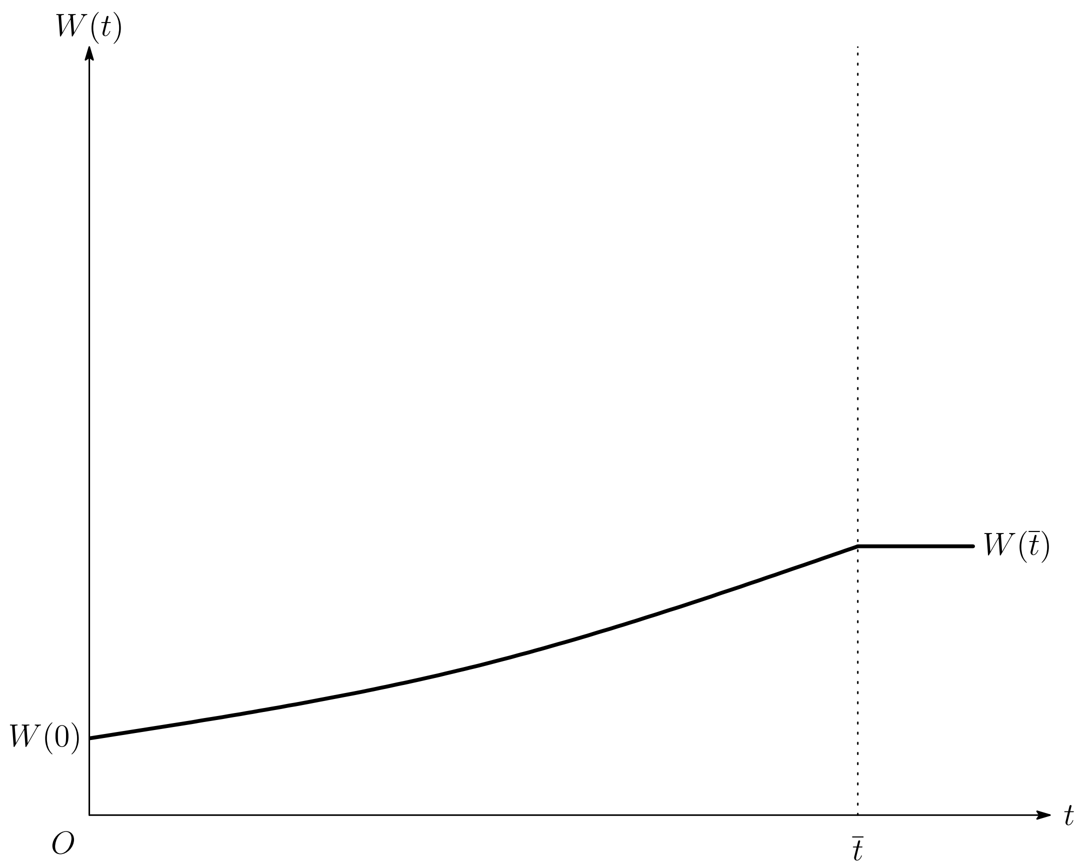

Figure 3: Case 3 (transport cost)

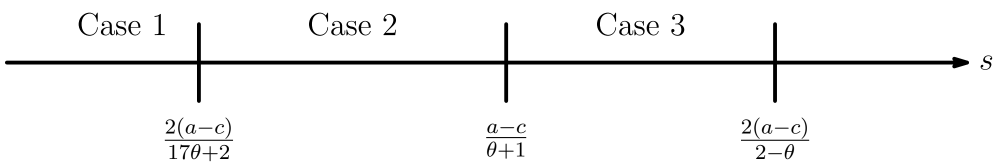

Figure 4: Classification of equilibria (transport cost)

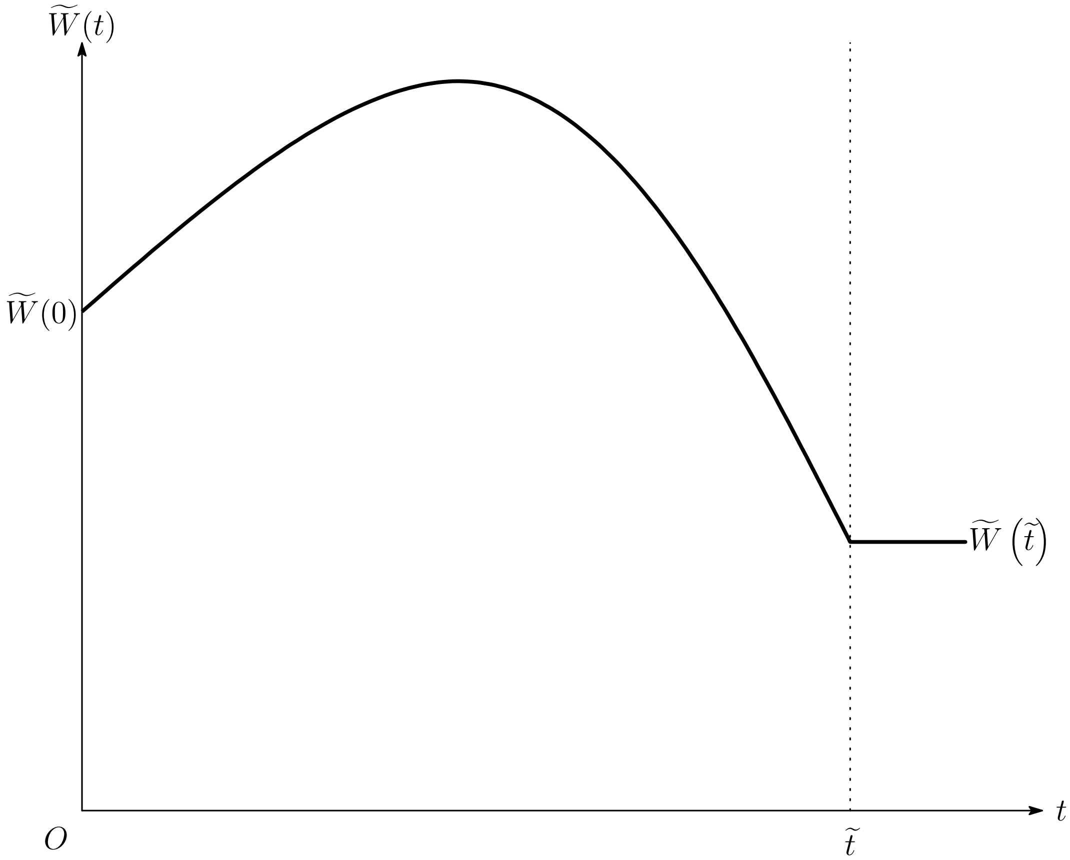

Figure 5: Case 1 (tariff)

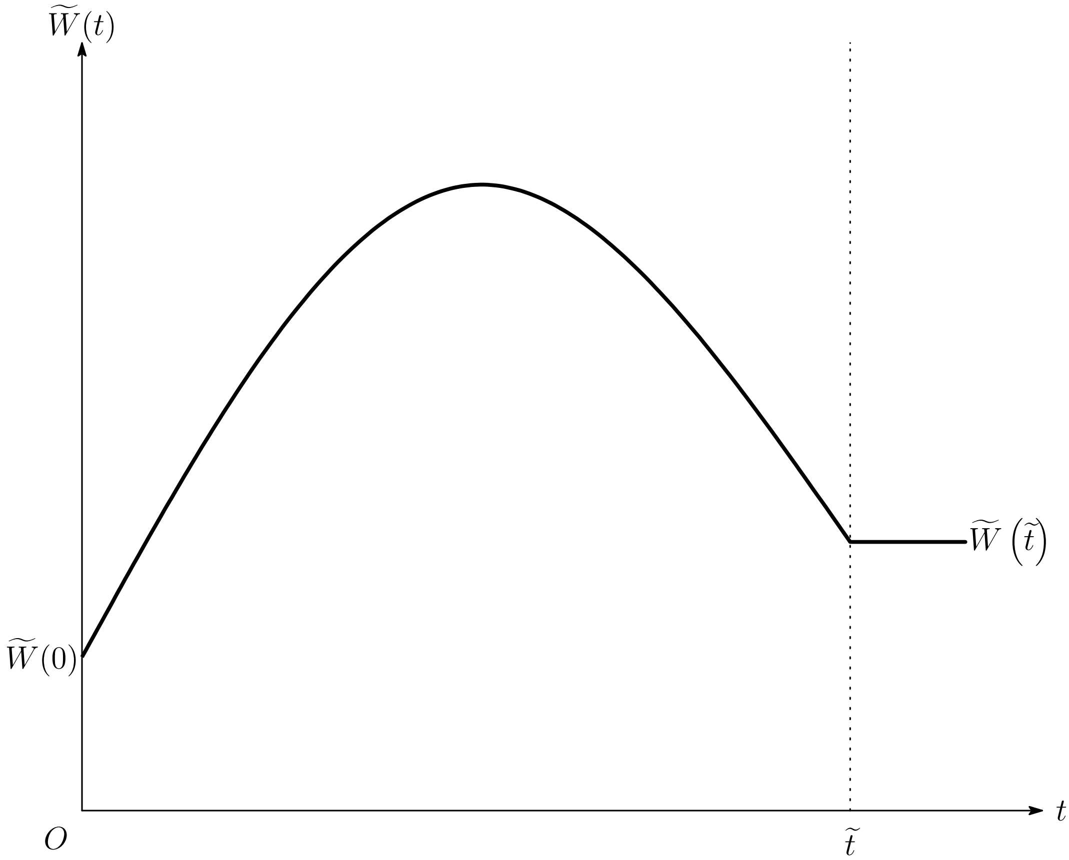

Figure 6: Case 2 (tariff)

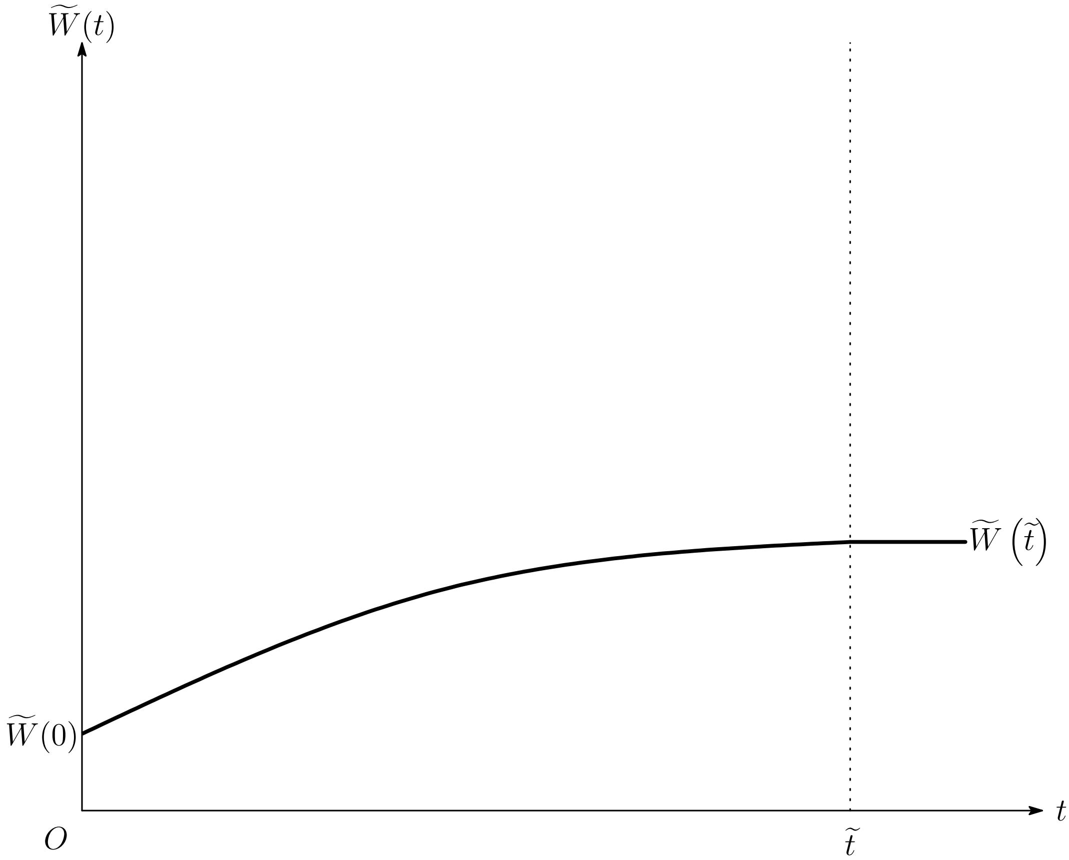

Figure 7: Case 3 (tariff)

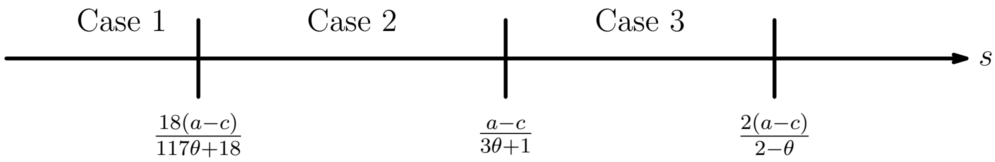

Figure 8: Case 3