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Market Integration, Environmental Policy, and Transboundry Pollution from Consumption

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Abstract

Recent empirics report that transport cost reductions significantly contribute to rapidly growing world trade. This paper develops a reciprocal market model of intra-industry trade with transboundary pollution from consumption to consider how market integration in the form of transport cost reductions affects the noncooperative choice of an environmental policy and the equilibrium welfare. I show that market integration can improve welfare locally, but that welfare under any non-prohibitive trade cost can not be higher than welfare under autarky. This possibility of trade losses exhibits a sharp contrast to the case of production-generated pollution.

Keywords: transboundary pollution; consumption-generated pollution; gains from trade; environmental policy

Running Head: *Market integration and transboundary pollution*

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1 Introduction

Recent empirical studies suggest that transport cost reductions are an important factor of growth in world trade flows along with reductions in protectionist trade policies. For example, in an influential work, Baier and Bergstrand (2001, p. 19) conclude that 'income growth, tariff rate reductions, and transport-cost declines all contributed nontrivially to the real growth of world trade.'[1] Despite this fact, Krugman (1995, p. 328) states that 'international economists $\cdots$ tend to view much, though not all, of the growth of trade as having essentially political causes, seeing its great expansion after World War II largely as a result of the removal of the protectionist measures.'

On the other hand, growth of trade flows over the last decades has generated new concerns to be tackled. 'Trade and the environment' is one such concern and there is a large literature in this field.[2] Particularly, Conrad (1993), Barrett (1994), Kennedy (1994), Rauscher (1994), Ulph (1996), and Tanguay (2001) explore the consequences of noncooperatively chosen environmental policies in open economies with oligopoly. These papers commonly find that countries choose laxer environmental regulation than the efficient level. Incorporating trade barriers such as import tariffs and export subsidies into the above literature, Walz and Wellisch (1997), Burguet and Sempere (2003), Baksi and Chaudhuri (2009), and Fujiwara (2010) consider how reductions in trade barriers affect the equilibrium environmental policy and welfare. While the former two papers prove that trade liberalization is welfare-improving under local pollution, Baksi and Chaudhuri (2009) show that the same is no longer true of transboundary pollution.

However, the above claim of Krugman (1995) also applies to environmental economics and there is no literature except for Straume (2006) that addresses the impacts of transport cost reductions in a context of 'trade and the environment.' Employing a framework similar to the above literature, Straume (2006) examines how transport cost reductions affect the incentive

toward policy coordination, concluding that market integration may reduce the need for policy coordination.

This paper studies the effect of transport cost reductions on the environmental policy and welfare, but my purpose differs from Straume's (2006) as follows. First, I pay much attention to transboundary pollution from consumption.[3] This comes from the observation that a certain share of pollution is caused by consumption, but it receives less attention in the literature. For instance, use of cars and air-conditioners by households helps raise temperatures of an individual country and possibly the world. Increased use of ozone-depleting aerosol sprays is another instance of consumption-generated pollution.[4] Second, I focus on how transport cost reductions affect welfare. While Kayalica and Kayalica (2005) and Kayalica and Yilmaz (2006) develop a model similar to mine, they are interested in coordination and reform of policies, not in gains from market integration. In this sense, my motivation is closer to that of Walz and Wellisch (1997), Burguet and Sempere (2003), and Baksi and Chaudhuri (2009).

Making use of a reciprocal market model which shares much with Kennedy (1994) and Straume (2006) except for pollution from consumption, I establish the following results. First, market integration in the form of transport cost reductions raises the emission tax. This is contrasting to the case of production-generated pollution where trade cost declines lead to a reduction in emission taxes.[5] Second, for any non-prohibitive transport cost, welfare under trade can not exceed welfare under autarky. In other words, market integration involves no positive welfare gains relative to autarky. This possibility of trade losses exhibits another contrast to the case of production-generated pollution in which market integration can improve welfare as compared to autarky. These findings provide a simple example suggesting that welfare implications of market integration are crucially influenced by whether pollution is caused by production or consumption.[6]

The paper is organized as follows. Section 2 presents a model and derives

the subgame perfect Nash equilibrium. Section 3 considers welfare effects of market integration and proves the impossibility of trade gains. Section 4 concludes the paper.

2 A model

2.1 Fundamentals

Consider two symmetric countries (Home and Foreign), two goods (goods 1 and 2) and one factor (labor).[7] We asterisk all the Foreign variables to distinguish them from the Home variables. One unit of Good 2 (numeraire) is produced from one unit of labor so that the wage rate is unity in both countries. Production of Good 1 incurs a constant marginal cost $c \geq 0$ and imports are subject to a per-unit transport cost $t \geq 0$. The market of Good 1 in each country is segmented and duopolized by a Home firm (firm X) and a Foreign firm (firm Y).[8] The product each firm produces is a perfect substitute.

Assume a representative consumer whose utility function is

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

where u is utility, $C_i, i = 1, 2$ is the consumption of each good, Z is pollution in Home, and $v(\cdot)$ represents damages from pollution. To compute the closed form of equilibrium, I will specify $v(Z) = sZ$ (linear damage) and $v(Z) = sZ^2/2$ (quadratic damage) as in Straume (2006). Letting p denote the relative price of Good 1, utility maximization under 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 demand is analogously obtained as $p^* = a - x^* - y^*$.

Suppose that consumption generates a proportional emission on which each government imposes an emission tax τ and τ^*. That is, the Home (resp. Foreign) government levies τ (resp. τ^*) on $x + y$ (resp. $x^* + y^*$). I allow

pollution to be transboundary. The model consists of two stages. In the first stage, two governments noncooperatively set an emission tax to maximize welfare. Taking the determined taxes given, firms play a Cournot-Nash game in the second stage. The game is solved with backward induction.

2.2 A duopoly game

This subsection solves the second stage of the game. Given assumptions above, the duopolistic firms' profit is defined by

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

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

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

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

Making use of (2) and (3), we see that the maximized profit of the Home (resp. Foreign) firm equals $x^2 + x^{*2}$ (resp. $y^2 + y^{*2}$).

Regarding the specification of transboundary pollution, I suppose that $\theta \in [0,1]$ fraction of the Foreign emission arrives in Home, which implies that $Z = x + y + \theta(x^* + y^*)$. In the same way, pollution in Foreign is equal to $Z^* = \theta(x + y) + x^* + y^*$. By definition, $\theta = 0$ (resp. $\theta = 1$) corresponds to local (resp. global) pollution. From these assumptions and the Cournot-Nash equilibrium outputs in (2) and (3), Home's welfare is measured by a function of τ and τ^* as follows.

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

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$$+\tau \cdot \frac{[2(a-c-\tau)-t]}{3} - v\left(\frac{2(a-c-\tau)-t+\theta[2(a-c-\tau^*)-t]}{3}\right),$$

$$(4)$$

where the first term of the right-hand side is consumer surplus, the second and third terms are the Home firm's profit, the fourth term is the emission tax revenue, and the last term is the pollution damage. The assumption of symmetry between Home and Foreign enables me to express Foreign's welfare as $U(\tau^*, \tau, t)$.

2.3 An environmental policy game

2.4 The linear damage case

This subsection turns to the first stage in which the governments noncooperatively choose an emission tax. From (4) and under the specification of linear pollution damage sZ, the first-order conditions for welfare maximization are

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

Thus, the emission tax of each country is independent of the other country's tax in equilibrium. In other words, each country's reaction curve is orthogonal to each other in the $\tau - \tau^*$ plane. Not surprisingly, this extreme property comes from the assumption of linear damages from pollution.[9] The reason is that $U(\tau, \tau^*, t)$ becomes separable in τ and τ^*, i.e., strategic interactions vanish, under $v(Z) = sZ$.

Solving the above first-order conditions for τ and τ^*, I have

$$\tau^N = \tau^{*N} = \frac{2s-t}{2},$$

$$(5)$$

where superscript N represents the subgame perfect Nash equilibrium. Note here that the equilibrium emission tax is equal to marginal pollution damage if there is no transport cost.

2.5 The quadratic damage case

While linear pollution damage is a convenient specification and frequently assumed in the existing literature, it leads to an extreme outcome as shown above. In order to consider the validity of the result in the last subsection, I now replace the assumption of linear damage with that of quadratic damage.

Under the quadratic damage function $v(Z) = sZ^2/2$, the first-order conditions for welfare maximization are

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

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

These conditions characterize the reaction curve of each country, which is negatively correlated, namely, strategic substitutes hold unless pollution is local ($\theta = 0$). Solving this system of the first-order conditions yields the equilibrium emission tax:

$$\widetilde{\tau}^N = \widetilde{\tau}^{*N} = \frac{4\phi(a-c) - (2\phi+3)t}{2(2\phi+3)}, \quad \phi \equiv s(\theta+1), \tag{6}$$

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

At this stage, it is helpful to make clear several properties of the equilibrium emission taxes in two cases. For this purpose, decompose τ^N and $\widetilde{\tau}^N$ into two parts. The first part, which is given by the first term of the right-hand side in (5) and (6), is a pollution-related term and the second term is a trade-related term. The pollution-related term tells that higher taxes are chosen as the damage parameter s increases.

On the other hand, the trade-related term states that transport cost reductions induce higher emission taxes. The reason behind this finding is not so straightforward since transport cost reductions have the following impacts. First, lower transport costs promote competition and enhance consumer surplus by lowering prices. Second, market integration expands the foreign firm's

market share in the domestic market and hence a part of the domestic firm's profit shifts abroad, reducing domestic welfare. Third, transport cost reductions increase wasteful resources associated with costly exporting as Brander and Krugman (1983) point out. These three effects are present regardless of the presence of pollution. In addition to them, market integration unambiguously increases pollution in each country since consumption increases. While it is ambiguous whether emission tax revenue increases, it is fair to say that tax revenue increases if the initial trade cost is sufficiently large. The governments determine the emission tax so as to balance these effects. Eqs. (5) and (6) state that the negative welfare effects of market integration through profit-shifting, increasing waste, and pollution expansion dominate the positive effect of increasing competition, thereby yielding higher emission taxes.

3 Welfare effects of market integration

Taking into account the foregoing arguments, this section examines welfare effects of transport cost reductions. I begin with the case of linear damage and proceed to the quadratic damage case. Interestingly, I can show that completely the same conclusion applies to both of these cases.

3.1 The linear damage case

Substituting (5) into (4) and specifying $v(Z) = sZ$, welfare in the subgame perfect Nash equilibrium is given by a function of the transport cost:

$$
\begin{aligned}
U\left(\tau^N, \tau^N, t\right) &= \frac{9t^2 - 6(a - c - s)t + 4(a - c - s)[2(a - c - s) - 3s\theta]}{18} \\
&\equiv W(t).
\end{aligned}
\tag{7}
$$

The rest of my task is to closely examine the properties of $W(t)$.

I begin by comparing welfare levels under free trade ($t = 0$) and autarky

$(t = \bar{t})$, where $\bar{t}$ is a prohibitive level of transport cost defined by

$$\bar{t} = \frac{2(a - c - s)}{3},$$

by setting $x^* = y = 0$ after substituting (5) into (2) and (3). If the transport costs are higher than $\bar{t}$, each duopolistic firm quits exporting and the resulting equilibrium reduces to autarky. In order to guarantee non-negativity of $\bar{t}$, I make:

Assumption: $a - c - s \geq 0$.

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

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

That is, welfare under free trade is equal to welfare under autarky. This is an intriguing contrast to the case of production-generated pollution in which I have either $W(0) > W(\bar{t})$ or $W(0) < W(\bar{t})$ depending on the magnitude of s.

I next examine the slope of $W(t)$. Differentiating (7) with respect to t once and twice yields

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

from which $W(t)$ is strictly convex and $W'(0) = -(a - c - s)/3 < 0$. On the other hand, the slope at the prohibitive trade cost becomes

$$W'(\bar{t}) = \frac{a - c - s}{3} > 0.$$

Moreover, it is easy to show that $W(t)$ reaches a bottom at $t = (a - c - s)/3 = \bar{t}/2$. Summarizing these results, I can establish:[10]

Proposition 1: *Market integration, i.e., a marginal decline in transport costs, can improve the Nash equilibrium welfare if their initial level is smaller than $\bar{t}/2$. However, trade with any non-prohibitive transport cost can not ensure strict welfare gains as compared to autarky, i.e., $W(t) \leq W(\bar{t})$ for any $t \in [0, \bar{t})$.*

Proof: Straightforward by noting that $W(t)$ is depicted as Figure 1. **Q.E.D.**

3.2 The quadratic damage case

Replacing the assumption of linear pollution damage with that of quadratic pollution damage, this subsection proves that Proposition 1 survives the assumption of quadratic damages from pollution. Substituting (6) into (4) and using $v(Z) = sZ^2/2$, the welfare level in the subgame perfect Nash equilibrium becomes

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

Following the argument in the previous subsection, I will make clear several properties of $\widetilde{W}(t)$.

The first step is to compare welfare levels under $t = 0$ and the prohibitive transport cost denoted by $\widetilde{t}$. In view of that imports in equilibrium are $x^* = y = [2(a-c) - (2\phi+3)t]/[2(2\phi+3)]$, the prohibitive trade cost is

$$
\widetilde{t} = \frac{2(a-c)}{2\phi+3} > 0.
$$

Substituting $t = 0$ and $t = \widetilde{t}$ into (8), we have

$$
\begin{aligned}
\widetilde{W}(0) &= \frac{2[\phi(1-\theta)+2](a-c)^2}{(2\phi+3)^2} \\
\widetilde{W}\left(\widetilde{t}\right) &= \frac{2[\phi(1-\theta)+2](a-c)^2}{(2\phi+3)^2},
\end{aligned}
$$

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namely, both free trade and autarky give rise to the same level of welfare.

I next compute the slope of $\widetilde{W}(t)$. Straightforward calculations yield:

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

which enables me to know that $\widetilde{W}(t)$ is strictly convex and that $W'(0) = -(a - c)/(2\phi + 3) < 0$. On the other hand, the slope at the prohibitive transport cost is

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

Finally, I can check that $\widetilde{W}(t)$ reaches a bottom at $t = (a-c)/(2\phi+3) = \widetilde{t}/2$. Note that all of these results are in accordance with the result in the case of linear damage. Thus, I have arrived at:

Proposition 2: *The same conclusion as Proposition 1 on welfare effects of market integration holds in the case of quadratic damages from pollution.*

Proof: A diagram which is qualitatively identical to Figure 1 can be depicted in the present case. All I have to do is replace W and $\bar{t}$ with $\widetilde{W}$ and $\widetilde{t}$, respectively. Then, the proposition follows. **Q.E.D.**

3.3 Interpretations

Having formally proved the main results, I now consider the intuitions behind them. As shown in the last section, the impacts of transport cost reductions are decomposed into (i) the procompetitive effect, (ii) profit-shifting from the domestic firm to the foreign firm, (iii) expands wasteful resources associated with transport costs, (iv) pollution expansion through consumption expansion, and (v) the change in emission tax revenue. Declines in transport costs have the following direct effects: imports increase, domestic supply decreases, and consumption increases whereas waste with transportation increases. These changes in outputs increase the firm profit. On the other

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hand, market integration has indirect effects on welfare through the change in emission taxes and we know that market integration leads governments to raise emission taxes from Eqs. (5) and (6). As a result of higher emission taxes, imports decrease, domestic supply increases, and consumption decreases. The firm profit decreases from this rise in taxes. Moreover, they mitigate wasteful resources associated with costly imports, but it is ambiguous whether emission tax revenue increases.

What deserves attention is that the direct and indirect effects on consumption cancel each other out and thus consumer surplus and pollution damage remain unchanged through market integration.[11] Consequently, the effects of market integration reduce to three effects: changes in the firm profit, inefficiencies associated with wasteful trade, and emission tax revenue.

When the initial transport cost is high enough to satisfy $t \in [\bar{t}/2, \bar{t}]$, losses from wasteful trade dominate an increase in the firm profit. Moreover, the emission tax revenue is sufficiently small. Therefore, market integration involves welfare losses. The opposite reasoning applies to the case for $t \in [0, \bar{t}/2]$. If trade costs are sufficiently small, inefficiencies associated with wasteful trade are dominated by an increase in the firm profit. In addition, governments choose a very high pollution tax, thus obtaining large tax revenue. These positive effects outweigh the negative effects, resulting in welfare improvements.

However, I should stress that welfare under trade with any transport cost can not be higher than welfare under autarky. As Propositions 1 and 2 suggest, welfare under free trade (zero transport cost), which is a maximum of $W(t)$, is equal to welfare under autarky. This is because governments employ very strict environmental regulation, from which the resulting equilibrium coincides with autarky. This impossibility of Pareto superiority of free trade over autarky is not obtained in the production-generated pollution case. In this sense, our results highlight the importance of consumption-generated pollution as stressed by Copeland and Taylor (1995).

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4 Concluding remarks

This paper has studied the implications of consumption-generated pollution for welfare effects of market integration in the form of transport cost reductions. It is shown that trade with any transport cost including free trade (zero transport cost) can not render positive welfare gains. Consumption-generated pollution plays a key role behind this result.

I admittedly recognize that my analysis hinges on many simplifying assumptions although all of them are frequently made in the existing literature as well. In addition, while it is beyond the scope of this paper, it is meaningful to make a parallel analysis by allowing for coexistence of production- and consumption-generated pollution. Despite these restrictions, I believe that my simplest model can yield some important implications of consumption-generated pollution for welfare effects of market integration. It is my future research agenda to explore the validity of my results in more general settings.

Notes

1. Anderson and van Wincoop (2004) provide a comprehensive survey on empirical studies on trade costs including Baier and Bergstrand (2001).

2. Focusing on perfectly competitive product markets, Copeland and Taylor (2003) survey theoretical and empirical developments.

3. A parallel analysis in the case of production-generated pollution is found in Fujiwara (2010).

4. There is an empirical literature that addresses some implications of consumption-generated pollution for the Environmental Kuznetz Curve Hypothesis. See, for example, Rothman (1998) and Bagliani et al. (2008). The importance of consumption-generated pollution is highlighted in Copeland and Taylor (1995).

5. See, for example, Proposition 1 in Straume (2006, p. 544).

6. Fujiwara (2009) deals with tariff reductions, following the analysis of Burguet and Sempere (2003) and Baksi and Chaudhuri (2009).

7. My model is basically the same as Straume's (2006) except for that I assume pollution from consumption and that he allows for product differentiation.

8. See Brander (1981), Brander and Krugman (1983) and Helpman and Krugman (1985, pp. 104-111).

9. In the case of production-generated pollution, reaction curves are non-orthogonal even under linear damages.

10. The intuitions behind the result are postponed until Proposition 2 is proved since the same interpretations apply both to Proposition 1 and to Proposition 2.

11. From (2) and (3), the total supply in Home is $x + y = [2(a - c - \tau) - t]/3$. Thus, the effect of transport cost reductions becomes

$$\frac{d(x + y)}{dt} = \frac{\partial(x + y)}{\partial \tau} \cdot \frac{d\tau}{dt} + \frac{\partial(x + y)}{\partial t} = \frac{-2}{3} \cdot \frac{-1}{2} + \frac{-1}{3} = 0,$$

by considering (5) and (6).

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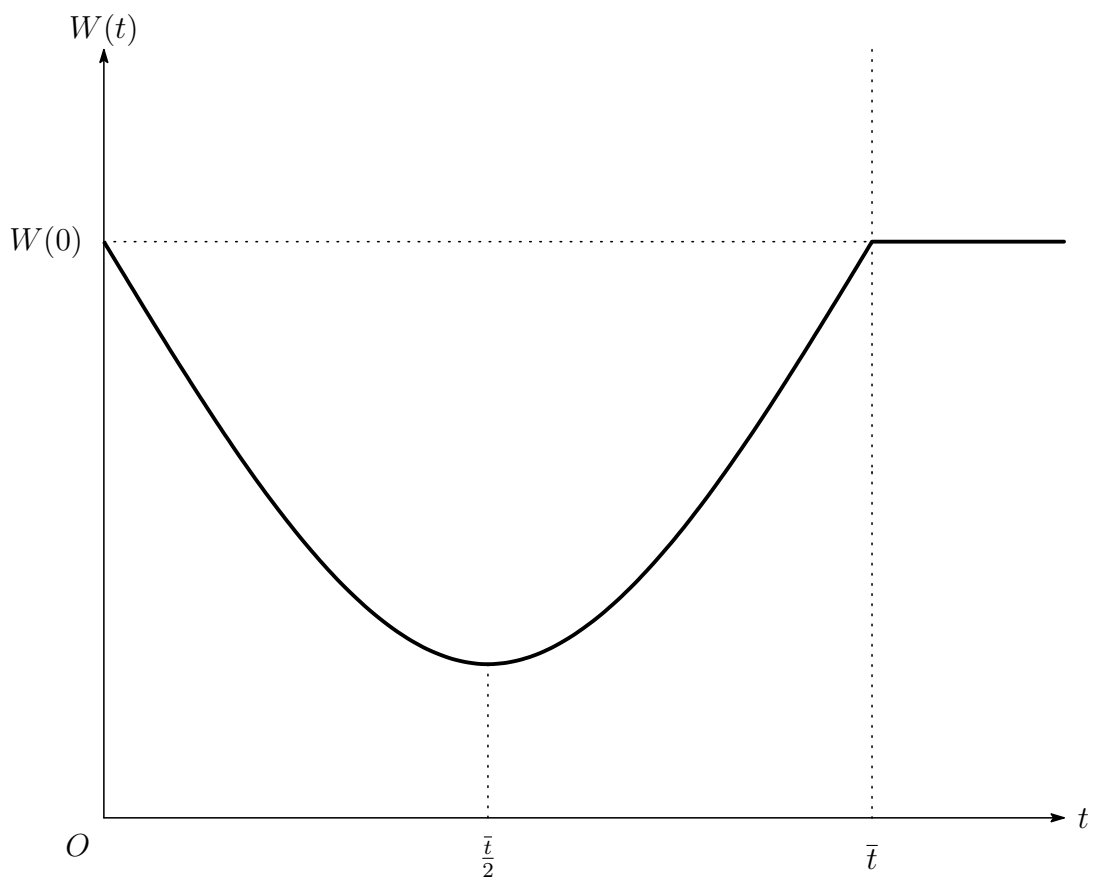[24] Walz, U. and D. Wellisch. 1997. Is free trade in the interest of exporting countries when there is ecological dumping? *Journal of Public Economics* Vol. 66: 275-291.

Figure 1: The Nash equilibrium welfare