MORE ON WELFARE EFFECTS OF DISTORTIONS VIA ENVIRONMENTAL AND TRADE POLICY

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MORE ON WELFARE EFFECTS OF DISTORTIONS VIA ENVIRONMENTAL AND TRADE POLICY

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ABSTRACT

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Günter Schamel and Harry de Gorter

This paper analyzes the effects of trade on the environment and welfare as well as terms of trade effects in response to alternative environmental and trade policies. We model abatement activity as an alternative but cleaner production method to distinguish different means of pollution reduction and to show how large countries may exploit terms of trade effects via environmental policies. When tariffs are below 'optimal' levels, terms of trade induced welfare losses due to tariff reductions may in part be offset with lower output taxes and higher abatement subsidies. Large importers can compensate tariff reductions through lenient output restrictions or even production subsidies plus generous subsidies for environmentally benign production. Optimal “green” tariffs may be zero or negative and thus welfare improving but also trade distorting.

Key Words: trade, environment, terms of trade, abatement

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Issues relating to the interaction of trade and the environment are a major international policy concern. They are likely to be a focal point during the next round of trade negotiations within the WTO. Free trade advocates contend that trade liberalization makes countries richer and as a result they adopt tougher environmental standards. Many environmentalists, by contrast fear that freer trade leads to lower environmental standards and thus more pollution. Polluting producers in high-income, high-standards countries fear competitors from abroad facing lower environmental standards. Yet, the WTO calls for environmental policies that have a minimal trade-distorting impact.

In this paper, we look at pollution problems related to the production of goods. Pollution is contained within countries but affected by policies and trade. We link the literature on optimal environmental policies and terms of trade shifts in response to domestic and trade policies. We distinguish output reductions from abatement and pollution prevention activities as separate but interrelated components of pollution reduction. In contrast to output reduction, which results in a profit loss, abatement and/or pollution prevention activities are cleaner production methods that involve input substitution at a direct cost to producers. In addition to private curtailment costs, pollution incurs the social costs of environmental damages when released. Furthermore, we distinguish environmental policies that primarily reduce output from policies that primarily induce abatement and/or pollution prevention activity. This is crucial because a government may for political reasons favor cleaner production methods rather than output reduction for political reasons. This setup allows us to address three general issues related to trade and environment: What are the environmental and welfare impacts of opening trade? How will environmental policy distort trade? What constitutes an environmentally friendly green trade tax?

Opening trade induces relative price changes. The resulting welfare impact depends on the efficiency of existing environmental policies and the environmental impact of production. Input substitution effects between home production and abatement activity and the initial output mix determine the environmental impact. Small countries gain from opening trade to import polluting goods unless the environmental impact of home production is negative. Then, the net savings through lower import prices may not outweigh increased environmental damages. Small countries gain from opening trade to export polluting goods when net export earnings outweigh the environmental damage effect of increased production of exportables.

Large countries implementing trade-reducing environmental policies not only alter their resource allocations but also affect world market prices which may concurrently improve domestic welfare and harm other countries. This could be viewed as a trade-distorting abuse of market power. From a global welfare perspective, large countries should therefore minimize the terms of trade welfare effects of domestic environmental policy on world market prices. From a domestic welfare perspective however, large countries should maximize the terms of trade welfare effects of domestic environmental policy on world market prices.

Large exporters that do not restrict their own exports may be better off taxing polluting production above and subsidizing abatement below their respective marginal impacts. When tariffs are bound at low levels, large importers may be better off to tax...
polluting production below and to subsidize abatement above their respective marginal impacts. It is then possible that production subsidies for importers may improve domestic welfare when the welfare effect of higher world market prices exceeds the environmental impact of home production on social welfare. Consequently, large importers may partly offset the welfare losses of their domestic producers due to tariff reductions with production and abatement subsidies (especially when environmental damages are small). Large agricultural importers may do this through production subsidies and/or generous incentives for a cleaner production after committing to tariff reductions.

Without concurrent environmental regulations, trade taxes are green in the sense that they can reduce pollution. For importers, optimal green tariffs may be at low levels when marginal damages are large relative to their induced effect on world market prices. Then, lower tariffs would lead to a relatively large improvement for the domestic environment, with only minor effects on world markets. For WTO negotiations this implies that large importers lowering tariffs but have lax environmental policies in place may only improve their domestic welfare and still distort trade. What they really should do is to significantly raise environmental standards. Therefore, rules about enforcing environmental policy may be as important as rules about reducing tariffs in order to improve world welfare. However, environmental regulations are not part of the WTO mandate policy and questions about greening the WTO arise once again.
More on Welfare Effects of Distortions via Environmental and Trade Policy

1. Introduction

Interactions between trade and the environment are a major international policy issue (Anderson and Blackhurst 1992; Low 1992; OTA 1995; Bredahl et al. 1996; USDA 1994, 1996; OECD 1994, 1998; Anderson 1998, Antle et al. 1998). Environmental policies and their trade impacts will be a focal point during the next round of trade negotiations within the World Trade Organization (WTO). Environmentalists fear that freer trade leads to lower environmental standards and more pollution, and thus argue against it. Free trade advocates contend that trade makes countries richer and pollute less and that sound environmental policy, not trade barriers, is the best remedy against pollution. Domestic producers lobby for less environmental regulation or more restrictions on competing imports when the latter are produced abroad under lax environmental policies that give an unfair advantage to foreign producers. In this paper, we address three broad policy issues to better understand the links between trade and the domestic environment. First, we evaluate the effects of trade on pollution and welfare under alternative policy scenarios. Second, we identify when environmental policy interferes with trade and assess relative trade distortions. Third, we analyze how trade policy used for environmental purposes (also referred to as "green" trade policy) affect the terms of trade and welfare.

Government action to internalize an externality is needed if conditions for a market solution do not exist (e.g. ill defined property rights, prohibitively high transaction costs, missing insurance and risk markets and/or uneven organizational and political power of polluters and sufferers). Considering trade, the polity is to evaluate the costs of environmental damage against the benefits from trade, thereby making a tradeoff between income and environmental quality. The choice of a policy instrument (e.g. pollution tax, output tax, or abatement subsidy) determines the efficiency of environmental regulations. In general, firms have two options to reduce emissions. First, they may simply reduce production without input substitution, which is referred to as output reduction. For example, a coal-fired power station could lower SO\textsubscript{2} emissions, by reducing its operating time such that electricity output and SO\textsubscript{2} emissions decline. Second, firms may engage in pollution prevention and alter its production process such that it generates less waste gases per kWh of electricity. Pollution prevention involves input substitution or other changes to the production process to make it cleaner. For example, the power plants could switch to low sulfur coal (fuel switching) and
generate less waste gases per kWh of electricity. Alternatively, the power plant could install scrubbers, which remove SO$_2$ from the stream of waste gases. Such “end-of-pipe” technologies describe an abatement activity. However, both abatement and pollution prevention activities will raise private production costs as they compete for scarce resources and thus affect the input mix that goes into production and pollution reduction activities.

Agriculture is a good example to mention as it makes intensive use of the environment while many production activities are polluting. In the U.S, agricultural irrigation is responsible for saline waterways, aquifers, and drainage systems with annual losses exceeding $7 billion (Ribaudo 1986). The use of pesticides induces social and environmental costs (e.g. human health costs, losses due to pesticide resistance and/or reduced natural crop resistance) estimated at over $8 billion annually (Pimentel et al. 1993). Modern farming often leads to soil erosion, biodiversity losses, wetland degradation, and decreasing visual amenities associated with rural land. Fertilizers also induce social welfare losses. For example, nitrate residues from agricultural sources are found in water resources that supply drinking water. In order to reduce nitrate residues entering a water resource, farmers could simply reduce output by decreasing their crop acreage and all other inputs without changing their mix. Alternatively, farmers could prevent nitrate leaching (e.g. through more effective manure spreading technology). Many other abatement and pollution prevention technologies are available (for example in hog production, where special manure storage technologies reduce the odor burden in densely populated areas).

A major difficulty in regulating pollution is that damage created often cannot be observed and policies must instead regulate outputs or inputs directly. Then, a distinction between output reduction and abatement as well as possible interaction effects is critical to evaluate the welfare and trade implications of alternative policies because government programs may want to target abatement or pollution prevention activities rather than regulate output or inputs. Production regulations such as acreage reduction schemes induce output reduction, but input substitution on the remaining acreage may limit effective pollution reductions. Pollution regulations such as per acre limits on pesticide use or pesticide taxes would also induce pollution abatement or prevention activities. However, a subsidy for abatement or pollution prevention
technology can also affect a country's comparative advantage because a polluter would not pay (OECD 1975).

Discord also exists between agricultural policy and environmental goals. Many price support receiving commodities are environmentally intensive (Reichelderfer 1990). Short-run effects of commodity policies such as deficiency payment schemes were higher output using more pollution-intensive inputs (e.g. water, fertilizers, and pesticides) per acre. Over time, price supports contributed to accelerated adoption of erosive and/or chemical-intensive technology. In addition, programs exist that promote environmentally benign production (e.g. soil conservation) while farm policy is supplemented by environmental programs to undo associated pollution problems (e.g. conservation reserve). However, recent developments suggest a reversal and indicate that future farm policy is more likely to accommodate environmental goals. For example, the Uruguay Round agreement on agriculture included commitments to reduce price supports, but excluded policies that have "minimal" trade impacts (so-called "green" box policies) from reduction commitments, specifically mentioning direct environmental programs (GATT 1994).

The debate about the role of environmental and trade policy leads to the three main issues posed at the beginning. What are the effects of trade on pollution and welfare levels, how will comparative advantage be affected by alternative trade and environmental policies, and how does a "green" trade policy affect the terms of trade and welfare? The paper is an attempt to analyze these issues systematically. The general model is applicable for a closed, small open and large economy and explicitly incorporates abatement and pollution prevention activity to distinguish the different components of pollution reduction costs and their interaction effects. The structure of the paper is as follows. In section 2, after a brief literature review, we introduce an analytical model to streamline the literature on regulatory policies and terms of trade (ToT) shifts in response to environmental and trade policy. We derive conditions for optimal social welfare under various scenarios, and examine stylized policies to reduce pollution. Section 3 analyzes the effects of trade on social welfare and pollution. The issue of trade distortion, comparative advantage, and "green" trade policy is examined in section 4, followed by some concluding remarks.
2. Modeling Trade and the Environment

Using partial-equilibrium graphical analysis, Anderson (1992) shows that importers as well as exporters of a polluting good may benefit from environmental policy and free trade and that even trade policy can be welfare improving. Markusen (1975) examines a large country that chooses trade and pollution taxes such that social welfare is maximized assuming that each unit of the polluting good generates a fixed quantity of pollution and no abatement technology.² In a partial-equilibrium model, Krutilla (1991) explores a very similar problem, showing that the optimal policy for large countries combines production and trade taxes together with a system of lump sum transfers. Siebert (1977) analyzes the optimal trade-off between environmental quality and gains from trade using a small country, two-sector model without abatement. Conrad (1993) constructs an international oligopoly model with a negative production externality and derives optimal policy responses to foreign emission taxes/abatement subsidies. In practice, direct market-based measures are not feasible, take time, require scarce institutional capacity to be implemented, and a ranking in terms of their welfare effects is difficult. Indirect measures tend to be less efficient than targeted market-based instruments. Copeland (1994) employs a duality approach to derive welfare improving conditions for incremental changes in trade and/or environmental policy for a small country. Mæstad (1998) derives conditions for second-best policies when the foreign country fails to implement appropriate environmental regulations.

Antle (1993) stresses the importance of the transformation frontier between production and the environment when analyzing the impacts of agricultural trade and growth on the environment. Such a transformation frontier is the core of the model developed in this paper. Few empirical studies analyze the effects of environmental policy on trade, but do not identify how trade is distorted (Leuck and Haley 1996; Tobey 1990). Other studies begin to analyze how agricultural policy affects the environment (Reichelderfer 1990; Anderson 1992; Anderson and Strutt 1996; Miranowski, Hrubovcak and Sutton 1991; OECD 1998).

Consider an economy endowed with a fixed resource base. The production possibility set \( H \) characterizes the technology and resources available:

\[
H = \{(x, y) : x \text{ can produce } y ; y \in \mathbb{R}_+^m ; x \in \mathbb{R}_+^n \}
\]
where $\mathbf{y}$ is the output vector and $\mathbf{x}$ is a vector of inputs. $\mathbf{H}$ is closed, convex, exhibits constant returns to scale, and is bounded above for fixed $\mathbf{x}$. All inputs are fully employed. All producers are price takers and profit maximizing. Thus, a dual producer revenue function is defined by

$$R(\mathbf{p}, \mathbf{x}) = \max \{ \mathbf{py} : (\mathbf{x}, \mathbf{y}) \in \mathbf{H} \}.$$  

$R(\mathbf{p}, \mathbf{x})$ is positively linearly homogenous, non-decreasing, convex and continuous in $\mathbf{p}$, and positively linearly homogenous, non-decreasing and concave in $\mathbf{x}$, and satisfies the Samuelson-McFadden lemma, i.e. the partial derivatives of $R(\mathbf{p}, \mathbf{x})$ with respect to output prices are revenue maximizing general-equilibrium supplies.

Consumer preferences are $U : \mathbb{R}^m \to \mathbb{R}$ with image $U(\mathbf{q})$ where $\mathbf{q} \in \mathbb{R}^n_+$ is the private consumption vector. $U(\mathbf{q})$ is strictly increasing and concave in $\mathbf{q}$. Dual to $U(\mathbf{q})$ is the expenditure function $e(\mathbf{p}, u)$. It is positively linearly homogenous, concave, continuous, and non-decreasing in $\mathbf{p}$, convex and strictly increasing in $u$, and satisfies Shepard's lemma.

$$e(\mathbf{p}, u) = \min \{ \mathbf{pq} : U(\mathbf{q}) \geq u \}.$$  

Neither producers nor consumers suffer a direct loss from pollution, but society at large bears the cost (e.g. in form of increased health cost). Thus, pollution is a public bad and pollution damages are a social liability. Aggregate producer revenue equals private income available for consumption: $R(\mathbf{p}, \mathbf{x}) = e(\mathbf{p}, u)$. Let the output vector be $\mathbf{y} = (Y, Q, A)$ with individual production functions for $Y$, $Q$, and $A$. $\mathbf{H}$ is a Ricardo-Viner type, fixed factor technology set in order to focus on outputs rather than inputs because a unique resource allocation defines every feasible output vector. $Y_{\text{max}}$, $Q_{\text{max}}$, and $A_{\text{max}}$ are defined by using the mobile factor exclusively for one good. The set $\mathbf{H}$ may be redefined by combining individual production functions with non-negativity and resource availability constraints:

$$\mathbf{H} \equiv \{(Y, Q, A) : Y = F(Q, A) \geq 0 ; 0 \leq Q \leq Q_{\text{max}} ; 0 \leq A \leq A_{\text{max}} \}.$$  

Production of $Q$ generates gross pollution $E(Q)$ while production of good $Y$ is "clean." $E(Q)$ is a strictly convex function with $E(Q)(0) = 0$. Abatement $A$ lowers pollution and thus generates a positive externality. It can be produced with resources that may otherwise be used to produce private goods. Gross pollution is net pollution $S$ plus abatement $[E(Q) = S + A]$ and is either released into the
environment inducing external costs or abated entailing abatement costs. Pollution is contained within the
domestic economy and does not cross borders. Let \( D(S) \) define a strictly convex external cost function
with \( D_S(0) = 0 \). Social income \( I \) is producer revenue minus external costs \( D(S) \). Social welfare \( V(p, I) \) is
defined via the indirect utility function:

\[
V(p, I) = V \{ p, F(Q, A) + P\cdot Q - D[E(Q) - A] \} = \max \{ U(c) : pc \leq I \}
\]

where \( c \) is a social consumption vector internalizing pollution damages. \( U(c) \) is strictly increasing and
concave in \( c \). \( V(\bullet) \) is convex in prices and social income: \( V_p < 0; V_{pp} > 0; V_I > 0; V_{II} = 0 \).

Many authors do not distinguish between abatement and output reduction or assume that output
reduction is relatively cheaper (e.g. Baumol and Oates 1988; Krutilla 1991). For this to hold, one has to
assume that the marginal social opportunity costs (including external costs) of producing any feasible \( Q \)
without abatement are always less than the marginal opportunity costs of abatement. However, allowing for
an interior solution with abatement activity requires that

\[
-F_Q(Q, 0) + D_S(Q, 0) E(Q) \geq -F_A(Q, 0) - D_S(Q, 0) \quad \forall \ 0 \leq Q \leq Q_{max}.
\]

The RHS of condition [5] equals the marginal social opportunity costs (including external costs) of
producing any feasible \( Q \) without abatement while the LHS is the marginal opportunity costs of abating an
initial unit of pollution. Condition [5] indicates (i) no private incentive to engage in abatement activity,
because it would only save social costs and (ii) output reduction without abatement cannot achieve a
socially optimal pollution level. Without condition [5], abatement may still save social costs, but one cannot
exclude that output reduction only is sufficient to obtain a socially optimal pollution level.

Let \( Y \) be the numéraire good and \( P \) denote the price of good \( Q \) such that \( p = (1, P) \). The
aggregate production structure of the economy is given by \( R(p, x) = \max \{ Y + P\cdot Q : (x, y) \in H \} \). Assume
that any government revenue from an environmental policy \( Z \) may be redistributed at no cost. Without
environmental policy, domestic producers maximize revenues (i.e. gross domestic product), subject to
overall resource availability:

\[
R(P) = \max \{ F(Q, A) + P\cdot Q : s.t. \ 0 \leq Q \leq Q_{max}; \ 0 \leq A \leq A_{max} \}.
\]
Without private incentives to abate, domestic firms will produce \( y = [ F(Q, 0), Q, 0 ] \) and marginal private (opportunity) costs equal marginal private benefits: \( -F_Q = P \). Faced with an environmental policy \( Z(Q, A) \) where \( Z_Q > 0 \) and \( Z_A < 0 \), the objective of private producers is:

\[
[6b] \quad R(p) = \max \{ F(Q, A) + P \cdot Q - Z(Q, A) \quad \text{s.t.} \quad 0 \leq Q \leq Q_{\max}; \quad 0 \leq A \leq A_{\max} \}.
\]

Now, private incentives may exist, as marginal (opportunity) costs of producing \( Q \) may exceed the marginal (opportunity) costs of abatement activities. Condition [7] is the "private" equivalent of [5]. If satisfied, it indicates that at least some initial abatement is social cost saving.

\[
[7] \quad -F_Q(Q, 0) + Z_Q(*) \geq -F_A(Q, 0) - Z_A(*) \quad \forall \quad 0 \leq Q \leq Q_{\max}.
\]

Figure 1 shows transformation frontiers in \((Y, Q)\)-space. The solid outer frontier depicts a technology without abatement. Projecting output combinations with complete abatement of pollution [i.e. \( E(Q) = A \)] into \((Y, Q)\)-space defines a technology with complete abatement or an iso-pollution frontier with \( S = 0 \). The vertical distance between the two solid frontiers reflects total abatement costs (TAC) or the premium to producers of \( Q \) for the unregulated right to pollute. The dotted lines depict output combinations without abatement net of external costs (D). Depending on the pollution problem and abatement technology, external costs may or may not exceed total abatement costs (TAC). If \( D < TAC \), complete abatement is more costly than none. But condition [5] implies that initial abatement is social cost saving and less costly than simple output reduction. If \( D > TAC \), complete abatement of gross pollution would be less costly than none. However, complete abatement is never optimal, regardless of the relation between \( D \) and \( TAC \), because marginal opportunity costs of abatement are positive \([-F_A > 0 \quad \forall \ A > 0]\) and marginal external costs without pollution are zero \([D_S(0) = 0]\). Thus, the optimal pollution level is positive and society will tolerate at least some external costs.

2.1. Conditions for Optimal Social Welfare

In this section, we derive conditions for optimal social welfare in autarky, for a small country, and for a large country with ToT effects. Distinguish domestic prices \( p = (1, P) \) and world market prices \( \pi = (1, \pi) \). In autarky, maximizing producer revenue subject to technology and overall resource constraints yields the supply conditions. If \( U(\cdot) \) is strictly concave, a positive amount of the polluting good \( Q \) will be
produced and an endogenous autarky equilibrium price $P(Q, A)$ exists. Social welfare $V(\cdot)$ is given by a non-linear, continuous and twice continuously differentiable function $f: \mathbb{R}^2 \to \mathbb{R} : V \{ P(Q, A), F(Q, A) + P(Q, A) \cdot Q - D[E(Q) - A] \}$. 

Resource availability restricts the domain of $f$. Imposing a domestic market clearing condition does not restrict feasibility and social income obtainable from production. Thus, whether an economy is open or closed, the feasible set $H$ is compact. Since $f$ is continuous, maximizing social welfare in autarky has at least one solution. However, it cannot be determined whether $f$ is concave and a particular solution to the autarky problem [P.1] may not be unique:

$$[P.1] \quad V(P, I) = \max \{ V \{ P(Q, A), F(Q, A) + P(Q, A) \cdot Q - D[E(Q) - A] \} \quad \text{s.t.} \quad F(Q, A) \geq 0 ; 0 \leq Q \leq Q_{\text{max}} ; 0 \leq A \leq A_{\text{max}} \}. $$

First-order (necessary) conditions for a social welfare maximum are:

$$[9] \quad V_P P_Q + V_I (F_Q + P + P_Q Q - D_S E_Q) = 0 \quad \text{and} \quad V_P P_A + V_I (F_A + P_A Q + D_S) = 0 $$

Since $V(P, I)$ is an indirect utility and markets clear, Roy's Identity $[Q_d = -V_P/V_I]$ can be employed. By Walras' law, we may impose one market clearing condition via direct substitution of $Q = Q_d$ in [9] and obtain the following equilibrium conditions for a closed economy:

$$[10] \quad F_Q(Qa^*, Aa^*) + P(Qa^*, Aa^*) = D_S(Sa^*)E_Q(Qa^*) \quad \text{and} \quad F_A(Qa^*, Aa^*) = D_S(Sa^*) = 0 $$

where $Qa^*$, $Aa^*$, and $Sa^*$ are optimal output, abatement, and net pollution levels in autarky.

For a small country, the world market price is equal to the domestic price ($p = \pi$) such that $V(p, I) = \max I$ and optimal social welfare is defined by

$$[P.2] \quad V(p, I) = \max \{ F(Q, A) + P \cdot Q - D[E(Q) - A] \quad \text{s.t.} \quad 0 \leq Q \leq Q_{\text{max}} ; 0 \leq A \leq A_{\text{max}} \}. $$

A unique interior solution exists because social income is non-linear, twice continuously differentiable, and strictly concave. The first-order necessary conditions require that marginal benefits from polluting production (abatement) are equal to marginal social (abatement) cost:

$$[11] \quad P = -F_Q(Q, A) + D_S(S) E_Q(Q) \quad \text{and} \quad D_S(S) = -F_A(Q, A). $$

For a large country that does not engage in trade (border) policy, domestic and world market prices will not differ. Therefore, the endogenous price relation is $\pi(Q, A) = P(Q, A) = Pd(Qd, A)$, where
Pd(Qd, A) is the domestic demand price for the polluting good. \( \pi_Q < 0 \) is an excess supply relation and \( \pi_A < 0 \) indicates that Q and A are complements. Environmental policy affects trade indirectly through changes in domestic resource allocation and via resulting world price effects. Without trade policy, the problem maximizing domestic social welfare is given by:

\[
\text{(P.3)} \quad V(p, I) = \max \{ V[ Pd(Qd, A), F(Q, A) + \pi(Q, A)Q - D(E(Q)-A) ] \}
\text{ s.t. } 0 \leq Q \leq Q_{\text{max}} ; \ 0 \leq A \leq A_{\text{max}} ; \ \pi(Q, A) = P(Q, A) = Pd(Qd, A) \}
\]

which has at least one solution since \( V(p, I) \) is continuous and the feasible set \( H \) is compact. However, \( V(\bullet) \) may not be strictly concave and optima may be local. The first-order (necessary) conditions for a large country without trade policy are

\[
\text{(12)} \quad V_P + V_I( F_Q + P + P_Q Q - D_S E_Q ) = 0 \quad \text{and} \quad V_P + V_I( F_A + P_A Q + D_S ) = 0
\]

We substitute market clearing \([Q_x = Q-Qd]\) and Roy's Identity \([Qd = -V_P/V_I]\). Large countries face a downward sloping excess supply schedule defined by \( \pi^{-1}(Q, A) = Qx[\pi(Q, A)] \) where \( \partial Qx/\partial \pi < 0 \) and \( Qx[\pi(Q, A)] < \infty \ \forall \ \pi(Q, A) > 0 \). Consequently, the optimality conditions \(\text{(12)}\) can be expressed as:

\[
\text{(13)} \quad P = -F_Q + D_S E_Q - Qx\pi_Q \quad \text{and} \quad D_S = -F_A - Qx\pi_A .
\]

For a large country that does engage in trade (border) policy, domestic and world market prices will differ. If that country employs environmental policy to reduce pollution and improves its terms of trade through trade policy, it egoistically enhances domestic welfare at the expense of other countries. Trade policy affects social welfare via world market price effects and resulting adjustments in domestic production. Let trade taxes \( T \) create a wedge between domestic and world market prices such that the equilibrium price relation is given by

\[
\text{(14)} \quad \pi(Q, A, T) = P(Q, A, T) + T = Pd(Qd, A, T) + T
\]

where \( \pi_T = P_T + 1 > 0 \) and \( -1 < P_T \leq 0 \). Market clearing requires that \( Qx[\pi(Q, A, T)] = Q-Qd \). For trade taxes to augment social income, \( T \) is negative for importers and positive for exporters. With a trade tax policy, the problem maximizing domestic social welfare is:

\[
\text{(P.4)} \quad V(p, I, T) = \max \ V[ Pd(Qd, A, T), F(Q, A) + P(Q, A, T)Q - D(E(Q)-A) + T\cdot Qx[\pi(Q, A, T)] ]
\text{ s.t. } 0 \leq Q \leq Q_{\text{max}} ; \ 0 \leq A \leq A_{\text{max}} ; \ \pi(Q, A, T) = P(Q, A, T) + T = Pd(Qd, A, T) + T \}.
\]
Problem [P.4] has at least one solution since \( V(p, I, T) \) is a continuous function and the set \( H \) is compact.

After making necessary substitutions to the first-order conditions, we obtain:

\[
\begin{align*}
[15a] & \quad F_Q + P = D_x E_Q - T \cdot (\partial Q_x / \partial \pi) \pi Q - Q_x \cdot \pi Q \quad \text{and} \quad F_A = -D_S - T \cdot (\partial Q_x / \partial \pi) \pi A - Q_x \cdot \pi A \\
[15b] & \quad 0 = [T \cdot (\partial Q_x / \partial \pi) + Q_x] \quad \Rightarrow \quad T^* = -Q_x / (\partial Q_x / \partial \pi) = -\pi / \eta_X .
\end{align*}
\]

\( \eta_X = (\partial Q_x / \partial \pi)(Q_x / \pi) \) is the excess supply (demand) elasticity which is negative (positive) for large exporters (importers). \( T^* = -\pi / \eta_X \) is the regular optimal trade tax (Corden 1974), defined solely by [15b] because trade taxes affect output via price effects only. Conditions [15a/b] reflect indirect TOT effects \([Q_x \cdot \pi_i ; i = Q, A]\) plus added direct TOT effects \([T \cdot (\partial Q_x / \partial \pi) \cdot \pi_i ; i = Q, A]\).

**Definition:** \( Q_x \cdot \pi_i \) is the **indirect TOT effect** due to domestic policy. \( T \cdot (\partial Q_x / \partial \pi) \cdot \pi_i \) is the **direct TOT effect** due to trade policy. Adding both terms defines the combined **large country effect**:

\[
\pi_i [T \cdot (\partial Q_x / \partial \pi) + Q_x] \quad \text{where} \quad i = Q, A.
\]

Finally, consider a large country using trade policy as the **sole** instrument to improve its TOT and to reduce domestic pollution, that is a trade policy optimizing *domestic* welfare without an additional environmental policy. In this case, private firms produce the polluting good such that price equals marginal cost or \( P = F_Q \) and have no incentive to abate or prevent pollution. The problem maximizing domestic welfare is

\[
[P.5] \quad V(p, I, T) = \max \{ V[ Pd(Qd, T), F(Q) + P(Q, T) \cdot Q - D[E(Q)] + T \cdot Q_x[\pi(Q, T)] ] \\
\quad \text{s.t.} \quad 0 \leq Q \leq Q_{max} ; \quad \pi(Q, T) = P(Q, T) + T = Pd(Qd, T) + T \}.
\]

[P.5] has at least one solution since \( V(\bullet) \) is continuous and \( H \) is compact. Differentiating with respect to polluting output \( Q \) and trade tax \( T \) and making all the necessary substitutions yields the following optimality conditions when trade taxes are used:

\[
\begin{align*}
[16a] & \quad 0 = Q_x \cdot P_Q - D_x E_Q + T \cdot (\partial Q_x / \partial \pi) \pi_Q \\
[16b] & \quad 0 = Q_x \cdot T + T \cdot (\partial Q_x / \partial \pi) .
\end{align*}
\]

### 2.2. Policies to Reduce Pollution

Pollution policy may target polluting output \( Q \), abatement \( A \), net pollution \( S \), or excess supply \( Q_x \). If a net pollution tax \( t^S \) is to induce private firms to lower pollution, \( Z(\bullet) = t^S \cdot [E(Q) - A] \) will enter into problem [6b] and a private interior optimum is given by

\[
[17] \quad P = -F_Q(Q, A) + t^S E_Q(Q) \quad \text{and} \quad -F_A(Q, A) = t^S .
\]
If \( t^S \) is set such that conditions [17] and [11] coincide, a social optimum is reached and the Pigouvian tax \( t^S* = D_S(S*) \) with \( S* = E(Q*) - A* \) is the optimal policy instrument for a small country. If \( t^S < t^S* \), it yields a less than optimal pollution reduction. If \( t^S > t^S* \), pollution reductions exceed the optimum. Instead of a Pigouvian tax resulting in an efficient pollution level \( S* \), the environmental authority could issue permits in the aggregate equal to \( S* \) and allow firms to bid for them. With all firms being price takers, the market clearing price will be \( t^{S*} \) and satisfy conditions [17]. If the total permits issued are not equal to \( S* \), their market clearing price will not equal \( t^{S*} \).

Figure 2 shows the effects of environmental policy in a small country. The outer frontier depicts a technology without abatement, the inner frontier a technology with complete abatement \([E(Q)=A]\). A dashed iso-pollution-frontier projects all output combinations resulting in pollution level \( S* \) into \((Y, Q)\)-space. When the slope of the outer frontier at \((Y_0, Q_0)\) equals \( P \), a private optimum is attained without environmental policy. When the slope of the iso-pollution-frontier for \( S* \) at \((Y*, Q*)\) equals \( P \), a social optimum is achieved with environmental policy. Point \((Y*, Q*)\) describes optimal production with a pollution tax \( t^{S*} = D_S(S*) \). The locus starting at \((Y_0, Q_0)\) and ending on the inner frontier defines optimal production points with aggregate permit levels decreasing from \( S_0 \) to zero. Revenues without policy and optimal policy induced revenues are shown by price lines tangent at \((Y_0, Q_0)\) and \((Y*, Q*)\), respectively. The vertical distance between these price lines reflects socially optimal regulatory costs. The socially optimal premium for the right to pollute is the vertical distance between the point \((Y*, Q*)\) and the inner frontier.

Pollution can be reduced by abatement and/or shifting production capacity to the non-polluting sector. If pollution is reduced through abatement, scarce resources are directly taken away from the production of private goods. If pollution is lowered via output reduction only, allowing for more production of the non-polluting good, scarce resources are transferred to a less efficient private use. Thus, while lowering external costs and enhancing social welfare, any policy induced reduction in pollution will affect producer revenue and thus private income available for consumption. When comparing environmental policy alternatives the following issues arise: What is the tradeoff between income foregone and pollution damages saved when reducing pollution and what differences result from sub-optimal environmental policy?
How will the welfare gains from trade differ? What is the tradeoff between social welfare improvement and pollution levels?

3. The Effects of Trade on Social Welfare and Pollution

This section examines the social welfare and net pollution effects when a small country opens to free trade. If \( P(Q_a^*, A_a^*) \) is only infinitesimally different from the world market price \( \pi \), opening trade results in an incremental price change \( dP = \pi - P(Q_a^*, A_a^*) \). If \( dP > 0 \) (\( dP < 0 \)), a small country becomes an exporter (importer) of the polluting good and an importer (exporter) of the non-polluting good. For an exporter, output increases (\( dQ > 0 \)) and more abatement is needed (\( dA > 0 \)). For an importer, output declines (\( dQ < 0 \)) and less abatement is necessary (\( dA < 0 \)).

The net pollution effect of trade is determined by interaction effects between polluting good production and abatement (depending on the initial output mix and the shape of \( H \)) in response to a trade induced relative price change. In general, the change in net pollution is \( dS = E_Q dQ - dA \) such that pollution will decrease (increase) when a small country becomes an importer (exporter) of a polluting good. However, depending on the relative effect of \( E_Q dQ \) vs. \( dA \), net pollution may actually increase (decrease) for small importers (exporters) of the polluting good. For importers, net pollution will increase if trade induced relative price changes generate output interaction effects between the polluting good and abatement such that \( E_Q dQ > dA \). For exporters, pollution will decrease if trade induced relative price changes generate output interaction effects such that \( E_Q dQ < dA \). Price, output mix, and net pollution effects in response of trade are summarized in Table 1.

<table>
<thead>
<tr>
<th>Effect on</th>
<th>Importer of Q</th>
<th>Exporter of Q</th>
</tr>
</thead>
<tbody>
<tr>
<td>Price</td>
<td>( dP &lt; 0 )</td>
<td>( dP &gt; 0 )</td>
</tr>
<tr>
<td>Production</td>
<td>( dQ &lt; 0, dA \leq 0, dY &gt; 0 )</td>
<td>( dQ &gt; 0, dA \geq 0, dY &lt; 0 )</td>
</tr>
</tbody>
</table>
| Net Pollution  | \( dS \leq 0 \) if \( E_Q dQ \leq dA \)  
\( dS > 0 \) if \( E_Q dQ > dA \) | \( dS \geq 0 \) if \( E_Q dQ \geq dA \)  
\( dS < 0 \) if \( E_Q dQ < dA \) |

We now examine how social welfare is affected by trade. What are the necessary and sufficient condition(s) for social welfare gains in response to trade? The link between domestic price response and
resulting output effects of trade is defined as 
\[ dP = P_Q dQ + P_A dA, \]
separating a partial price effect 
\[ P_Q dQ \]
due to the polluting good and a partial price effect 
\[ P_A dA \]
due to abatement. Social income is 
\[ I(Q,A) = F(Q, A) + P(Q, A)\cdot Q - D(E(Q)\cdot A). \]
Due to trade, the change in social income (dI) for a small country is given by taking the total differential:

\[ dI = I_Q dQ + I_A dA = \left[ F_Q + P + P_Q Q - D_S E_Q \right] dQ + \left[ F_A + P_A Q + D_S \right] dA. \]

Because 
\[ dS = E_Q dQ - dA \]
and 
\[ P = \pi, \]
rearranging terms in expression [18] yields

\[ dI = \left[ F_Q + P \right] dQ + F_A dA - D_S dS + Q \cdot dP. \]

Totally differentiating \( V(p, I) \) yields the change in social welfare 
\[ dV = V_P dP + V_I dI \]
where \( V_P < 0 \) and \( V_I > 0 \). Using Roy’s Identity, the change in social welfare is positive (dI > 0) only if

\[ V_I dI > -V_P dP \text{ or } dI > Qd\cdot dP \]

Thus, non-decreasing social income (dI ≥ 0) is a sufficient condition for gains from trade for small importers of a polluting good. Increasing social income (dI > 0) is a necessary condition for gains from trade for small exporters of a polluting good.

If no environmental policy is in effect when trade is opened, no private incentive to engage in abatement activity exists (i.e. 
\[ F_Q + P = 0, \]
dA = 0, 
\[ dS = E_Q dQ \]) such that expression [19] reduces to 
\[ dI = Q \cdot dP - D_S E_Q dQ. \]
Small importers gain from trade because 
\[ dI = Q \cdot dP - D_S E_Q dQ > Qd\cdot dP \text{ or } Qx\cdot dP - D_S E_Q dQ > 0. \]
For small exporters to gain from trade, increased export earnings must exceed increased external costs: 
\[ Qx\cdot dP > D_S E_Q dQ. \]
If an optimal environmental policy is in effect when trade is opened (i.e. 
\[ F_Q + P - D_S E_Q = 0 \text{ and } F_A + D_S = 0 \]) and condition [18] reduces to 
\[ dI = Q \cdot dP , \]
both importers and exporters gain from trade because 
\[ dI = Q \cdot dP > Qd\cdot dP \text{ or } Qx\cdot dP > 0. \]
An optimal environmental policy results in unambiguous gains from trade since any net opportunity costs of output mix effects will void external cost effects.

If sub-optimal environmental policies are in effect when trade is opened, we must distinguish if pollution is increasing or decreasing due to trade and if the country will become a (small) importer or exporter of the polluting good. From conditions [17], we conclude that 
\[ F_Q + P \leq 0 \text{ and } F_A < 0. \]
If net pollution decreases (dS < 0) for small importers, we obtain welfare gains from trade because the change
in social income will exceed the change in consumption spending due to a trade induced relative price change:  \(dI = [F_Q + P]dQ + F_A dA - D_S dS + Qd \cdot dP > Qd \cdot dP\) or 
\([F_Q + P]dQ + F_A dA - D_S dS + Qx \cdot dP > 0\). If net pollution increases (\(dS > 0\)) for a small exporter, we obtain welfare gains from trade only if increased export earnings exceed the net opportunity costs of trade induced output mix effects plus the increase in external costs: 
\(Qx \cdot dP > -\{ [F_Q + P]dQ + F_A dA \} + D_S dS\).

Should net pollution increase for a small importer, it may not gain from trade if due to trade induced relative price changes, an abatement inducing policy yields interaction effects between the polluting good and abatement activity such that \(E_Q dQ > dA\). Using conditions [19] and [20], \(dV < 0\) only if 
\(Qx \cdot dP + [F_Q + P]dQ + F_A dA < D_S [E_Q dQ - dA]\). Thus, a small importer of a polluting good may lose from trade if increasing import savings plus any net opportunity costs of trade induced output mix effects do not exceed increasing external costs.

If net pollution decreases for a small exporter, it may gain from trade if (due to trade induced relative price changes) an abatement inducing policy yields interaction effects such that \(E_Q dQ < dA\). Using conditions [19] and [20], \(dV > 0\) only if 
\(Qx \cdot dP - D_S [E_Q dQ - dA] > -[F_Q + P]dQ - F_A dA\). Hence, small exporters of a polluting good may gain from trade if increased export earnings plus decreased external costs exceed the net opportunity costs of trade induced output mix effects. Table 2 summarizes the conditions for small country welfare gains from trade under alternative environmental policy assumptions.

Please notice that the results depend crucially on the shape of the production set (i.e. the partial derivatives of \(F(\cdot)\)), the impact of pollution on social welfare (\(D_S\)) and how polluting the technology is (\(E_Q\)). For example, a country may not gain from importing a polluting good when trade in turn leads to a sharp decline in abatement activity which increases pollution damage by more than the gains from commodity trade.

### Table 2: Environmental Policy and Gains from Trade (Small Country)

<table>
<thead>
<tr>
<th>Environmental Policy</th>
<th>Importer of Q</th>
<th>Exporter of Q</th>
</tr>
</thead>
<tbody>
<tr>
<td>none</td>
<td>always gain</td>
<td>Qx \cdot dP &gt; D_S E_Q dQ</td>
</tr>
<tr>
<td>optimal</td>
<td>always gain</td>
<td>always gain</td>
</tr>
<tr>
<td>sub-optimal &amp; dS &lt; 0</td>
<td>always gain</td>
<td>Qx \cdot dP - D_S dS &gt; -[F_Q + P]dQ - F_A dA</td>
</tr>
<tr>
<td>sub-optimal &amp; dS &gt; 0</td>
<td>Qx \cdot dP + [F_Q + P]dQ + F_A dA &gt; D_S dS</td>
<td>Qx \cdot dP &gt; -[F_Q + P]dQ - F_A dA + D_S dS</td>
</tr>
</tbody>
</table>
Proposition 1: Small importers accrue gains from trade unless increased import savings plus any net opportunity costs of trade induced output interaction effects do not exceed increased external costs and thus raise pollution. Small exporters accrue gains from trade if increased export earnings exceed the net opportunity costs of trade induced output interaction effects plus the external cost effects.

This generalizes Anderson’s (1992) results for small countries which does not consider that pollution may actually increase (decrease) for small importers (exporters) through trade induced output interaction effects. Thus, importers may actually lose from trade and exporters may gain even without environmental policy in place when trade is opened. Moreover, we derive specific conditions for welfare gains due to trade with sub-optimal environmental policy.  

4. Trade Distortion

A criterion on which to pin down the notion of trade is attainable social welfare $V(p, I)$. In theory, social welfare is appealing since it is comprehensive and includes gross domestic product and external costs. By not allowing for across border pollution, global social welfare is maximized when all countries simultaneously choose policies as trade conditions change so as to keep marginal social costs equal to marginal social benefits within their respective borders. Empirically, social welfare is difficult to assess accurate pollution data may not be observed. To operationalize the concept of trade distortion, we let the maximum domestic (global) social welfare attainable with a particular policy set define a domestically (globally) optimal policy choice. Since a global welfare optimum depends on environmental policies in all countries, any reference to a non-trade distorting global welfare optimum assumes that policies in other countries are optimal and support a global welfare optimum. Thus, it is not intended that a single country worrying about the effect its policy actions on international terms of trade is capable of ensuring a global optimum. A large country that implements environmental policy will alter its resource allocation, which affects supply and demand structures and in turn international trade patterns. Thus, one can infer that particular environmental policies may involve a welfare improving exploitation of market power and unnecessarily distort trade.

One can analyze policies from a domestic and a global perspective. From a domestic vantage point, a large country should adopt policies that maximize ToT effects and thus domestic social welfare. Solving problem [P.4] implies that an environmental tax combined with a trade tax optimizes domestic social wel-
fare. With a trade tax \( T^* \) no further ToT improvement is possible. If \( V^T \) is strictly concave, a unique domestic social welfare optimum is attainable with a Pigouvian pollution tax \( t^* = D_S \) and a simultaneous optimal trade tax \( T^* = -\pi/\eta_X \).

From a global perspective, large countries should adopt policies that minimize ToT effects. However, the maximum social welfare attainable without trade policy (\( T = 0 \)) may not be optimal from a global perspective. Large countries still exert market power when domestic policy moves the ToT in excess of what is optimal for environmental reasons which would inevitably affect world markets due to the indirect ToT effect. Environmental policy designed to induce less pollution may concurrently be a second-best improvement of domestic welfare and impinge global welfare. Analytically, domestic welfare without trade policy is optimized when the polluting sector behaves according to conditions [13] including the indirect ToT effect. A global welfare optimum is supported when the domestic economy behaves according to conditions [13], excluding the indirect ToT effect.

**Proposition 2:** When \( T = 0 \), optimal domestic welfare for a large country is achieved by taxing output at \( t^Q = D_S E_Q - Qx \cdot \pi_Q \) and a simultaneous abatement subsidy at \( s^A = D_S + Qx \cdot \pi_A \).

**Proof:** \( F_Q + P = t^Q \) and \( F_A + s^A = 0 \) are necessary conditions for the private problem \( R(P) = \max \{ F(Q, A) + P \cdot Q - t^Q \cdot Q + s^A \cdot A \ \text{s.t.} \ 0 \leq Q \leq Q_{max} ; 0 \leq A \leq A_{max} \} \) \( t^Q = D_S E_Q - Qx \cdot \pi_Q \) and \( s^A = D_S + Qx \cdot \pi_A \) satisfy conditions [13] for [P.3]. q.e.d.

**Corollary:** When \( T = 0 \), it is optimal for a large exporter (importer) of a polluting good to tax production above (below) marginal external cost \( (D_S E_Q) \) and to simultaneously subsidize abatement below (above) marginal social damage avoided \( (D_S) \).

**Proof:**

**Importer:** \( Qx < 0 \) → \( t^Q = D_S E_Q - Qx \cdot \pi_Q < D_S E_Q \) b/c \( \pi_Q < 0 \)

→ \( s^A = D_S + Qx \cdot \pi_A > D_S \) b/c \( \pi_A < 0 \)

**Exporter:** \( Qx > 0 \) → \( t^Q = D_S E_Q - Qx \cdot \pi_Q > D_S E_Q \)

→ \( s^A = D_S + Qx \cdot \pi_A < D_S \) q.e.d.

Comparing the private and social optimality conditions shows that we should distinguish policies that induce pollution reductions via output reduction and abatement activity. From a domestic perspective, differences between taxing output at \( t^Q \) and marginal damages created by polluting production and between subsidizing abatement at \( s^A \) and marginal damages avoided by abating pollution yield market power via domestic policy that harms global welfare. Large countries are non-trade-distorting and support a global welfare optimum if they only tax/subsidize marginal damages created/avoided.
We examine environmental policy in conjunction with sub-optimal trade policy \( T \neq T^* \) or a sole trade policy by a large country. These more likely to be of practical relevance in trade negotiations since optimal Pigouvian taxes are difficult to implement (Baumol and Oates 1988), export taxes are infeasible, and tariffs may be bound by international trade agreements. First, consider which environmental policy would optimize domestic welfare when trade taxes are unequal to \( T^* \). When \( 0 \neq T \neq T^* \), condition \( 15b \) is not satisfied, but \( 15a \) which includes a direct ToT effect, remains valid for a constrained domestic optimum.

**Proposition 3:** With sub-optimal trade taxes \( T \neq T^* \), domestic social welfare for a large country is optimized with a polluting output tax \( t^q = D_S E_Q - \pi_Q [T \cdot (\partial Qx/\partial \pi) + Qx] \) plus a simultaneous abatement subsidy \( s^A = D_S + \pi_A [T \cdot (\partial Qx/\partial \pi) + Qx] \).

**Proof:** If \( 0 \neq T \neq T^* \), substitution into the first-order conditions that proved Proposition 2 will satisfy optimality conditions \( 15 \) associated with \( P.4 \).

**Corollary a:** If \( |T| < |T^*| \), large importers (exporters) raise their welfare by taxing polluting output below (above) \( D_S E_Q \) while simultaneously subsidizing abatement above (below) \( D_S \).

**Proof:** Importer: \( Qx < 0 \) and \( 0 \geq T > T^* \) \( \Rightarrow [T \cdot (\partial Qx/\partial \pi) + Qx] < 0 \)
\[ t^q = D_S E_Q - \pi_Q [T \cdot (\partial Qx/\partial \pi) + Qx] < D_S E_Q \]
\[ s^A = D_S + \pi_A [T \cdot (\partial Qx/\partial \pi) + Qx] > D_S \]

Exporter: \( Qx > 0 \) and \( 0 \leq T < T^* \) \( \Rightarrow [T \cdot (\partial Qx/\partial \pi) + Qx] > 0 \)
\[ t^q = D_S E_Q - \pi_Q [T \cdot (\partial Qx/\partial \pi) + Qx] > D_S E_Q \]
\[ s^A = D_S + \pi_A [T \cdot (\partial Qx/\partial \pi) + Qx] < D_S \]

**Corollary b:** If \( |T| > |T^*| \), large importers (exporters) raise their welfare by taxing polluting output above (below) \( D_S E_Q \) while simultaneously subsidizing abatement below (above) \( D_S \).

**Proof:** Importer: \( Qx < 0 \) and \( 0 \geq T^* > T \) \( \Rightarrow [T \cdot (\partial Qx/\partial \pi) + Qx] > 0 \)
\[ t^q = D_S E_Q - \pi_Q [T \cdot (\partial Qx/\partial \pi) + Qx] > D_S E_Q \]
\[ s^A = D_S + \pi_A [T \cdot (\partial Qx/\partial \pi) + Qx] < D_S \]

Exporter: \( Qx > 0 \) and \( 0 \leq T^* < T \) \( \Rightarrow [T \cdot (\partial Qx/\partial \pi) + Qx] < 0 \)
\[ t^q = D_S E_Q - \pi_Q [T \cdot (\partial Qx/\partial \pi) + Qx] < D_S E_Q \]
\[ s^A = D_S + \pi_A [T \cdot (\partial Qx/\partial \pi) + Qx] > D_S \]

The intuition for **Corollary b** is that lower trade taxes improve the ToT for importers (exporters) such that a polluting output tax above (below) \( D_S E_Q \) plus a simultaneous abatement subsidy below (above) \( D_S \) is a second-best supplement to a higher than optimal trade tax.\(^{11} \) Thus, if the large country effect exceeds the external effect, it follows that a production subsidy for exporters and an abatement tax for importers may supplement larger than optimal trade taxes. The intuition for **Corollary a** is that higher trade taxes improve
the ToT for importers (exporters) such that a polluting output tax below (above) $D_S E_Q$ together with an abatement subsidy above (below) $D_S$ is a second-best supplement to a lower than optimal trade tax. Thus, a production subsidy for importers and an abatement tax for exporters may in fact supplement lower than optimal trade taxes if the large country effect exceeds the external effect. Corollary a is a significant result for international trade negotiations and the WTO: When tariffs are bound below $T^*$ large importers improve their ToT with output taxes below marginal external costs created plus abatement subsidies above marginal external costs avoided. ToT induced welfare losses due to tariff reductions below $T^*$ may in part be compensated by lowering output taxes below (possibly subsidizing production when marginal external costs are small) and raising abatement subsidies above Pigouvian levels. For example, large agricultural importers may in fact use such a strategy and in part compensate low tariffs through lenient output restrictions (or even production subsidies) and generous incentives for environmentally benign production (i.e. abatement activity). For the WTO to require first-best environmental policies to be put in place is too simple of a suggestion because many agricultural pollution problems are non-point source problems and thus not directly observable.

Second, consider trade policy as the sole instrument to improve the ToT and to deal with negative externalities, that is a “green” trade policy that will optimize domestic welfare without environmental policy. Thus, private firms have no incentive to abate pollution and will produce where $P = \text{marginal costs}$. From conditions [16a/b], we obtain an explicit expression for the optimal green trade tax $T = -\pi/\eta_X + D_S E_Q /((\partial Qx/\partial \pi)\cdot[\pi Q - \pi T])$. For large importers (exporters) the optimal green trade tax is below (above) the regular optimal trade tax $T^* = -\pi/\eta_X$. The green term $D_S E_Q /((\partial Qx/\partial \pi)\cdot[\pi Q - \pi T])$ is positive since $\pi Q < 0$ and $\pi T > 0$ and corrects the regular optimal trade tax for the externality impact. We can conclude that increasing the external effect $D_S E_Q$ or decreasing the ToT impact $(\partial Qx/\partial \pi)\cdot[\pi Q - \pi T]$ yields a larger green term. A green export tax has a second-best environmental benefit for large exporters. For large importers, it follows that optimal green tariffs may be close to zero, if the green term is roughly equal to the regular optimal trade tax $[\pi/\eta_X = D_S E_Q /((\partial Qx/\partial \pi)\cdot[\pi Q - \pi T])]$. This result is significant for international trade negotiations: for large importers without stringent environmental policy enforcement, low tariff rates may be welfare improving, but also still trade distorting. Thus, a no
tariff policy may in fact be "green." This would imply that rules about enforcing environmental policy may be just as important as rules about reducing tariffs and it would call for a "greening" of the WTO. Table 3 summarizes important (optimal) policy parameters for large countries.

**Table 3: Optimal Trade and Environmental Policy for a Large Country**

<table>
<thead>
<tr>
<th>Trade Policy</th>
<th>Environmental Policy</th>
</tr>
</thead>
<tbody>
<tr>
<td>not exploit ToT</td>
<td>$T = 0$</td>
</tr>
<tr>
<td>exploit ToT without trade policy</td>
<td>$T = 0$</td>
</tr>
<tr>
<td>exploit ToT with trade policy</td>
<td>$T^* = -\frac{\pi}{\eta_X}$</td>
</tr>
<tr>
<td></td>
<td>$0 \neq T \neq T^*$</td>
</tr>
<tr>
<td></td>
<td>$T = -\frac{\pi}{\eta_X} + \left[ \frac{D_S \cdot E_Q}{[\partial Q_x / \partial \pi] (\pi_Q - \pi_T)} \right]$</td>
</tr>
</tbody>
</table>

**5. Summary and Extensions**

We looked at ToT shifts in response to trade policy and environmental regulations dealing with production externalities using a general-equilibrium model. The theory allows us to analyze the effects of trade on pollution and welfare, how trade and competitive advantage is affected by environmental and trade policy, and how a "green" trade policy affect the environment.

Large countries may use domestic environmental policy (e.g. taxing pollution above marginal external costs) to move the ToT in their favor. Then, there is not only a welfare effect due to less pollution, but also an indirect ToT effect which acts like a trade barrier. Thus, only if large countries tax/subsidize at the rate of marginal damage created/avoided, their policies are non-trade-distorting and support a global welfare optimum. We derive a number of significant results for international trade negotiations. When existing tariffs are bound below $T^*$, ToT induced welfare losses due to tariff reductions may in part be compensated by lowering output taxes below (possibly subsidizing output when marginal external costs are small) and raising abatement subsidies above Pigouvian levels. For example, large importers may in part compensate bound tariffs through lenient output restrictions (or even production subsidies) plus generous subsi-
dies for cleaner production methods (i.e. abatement activity). For large importers the optimal "green" tariff is less than the regular optimal tariff and may in fact be zero. Thus, large importers with lax environmental policies may have an incentive to lower tariff rates which would be welfare improving for them, but trade distorting. For international trade negotiations this implies that "green" rules about enforcing environmental policy may be as important as rules about reducing tariffs.

In our model, we have analyzed production externalities only. Nevertheless, we may hint at or assert conclusions with respect to consumption externalities and public policies to exploit ToT effects. Without trade taxes, it would be optimal for a large exporter (importer) of a polluting good to tax consumption below (above) marginal external cost and to simultaneously subsidize abatement activity above (below) marginal social damage avoided. When trade taxes are lower than optimal, large importers (exporters) may raise their welfare by taxing polluting consumption above (below) marginal external costs while simultaneously subsidizing abatement below (above) marginal social damage avoided. This would be significant for international trade negotiations because when tariffs are bound, large importers may forego potential welfare gains due to higher tariffs but could in part compensate this by raising consumption taxes above and lowering abatement subsidies below Pigouvian levels. The optimal green trade tax for large importers (exporters) would be above (below) the standard optimal trade tax serving as a second-best alternative for environmental policy which would be significant for international trade negotiations because large exporters may have an incentive to subsidize exports and thus import pollution.

We have not looked at the complexities added when pollution spills over national borders or problems of global commons. Asserting conclusions with respect to cross-border pollution is more difficult as pollution would be a function of both domestic and foreign production or consumption. Following Markusen (1975), environmental and/or trade policies would have to be modified to represent the impact of foreign pollution.

Clearly, all theoretical conclusions in this paper would require empirical validation to prove their actual significance for international trade negotiations. However, we argue that it would be premature to dismiss them as not particularly important. We simply do not know enough about the significance of environmental impacts (e.g. the green term) on trade. Consequently, it is important to empirically evaluate the
conceptual model developed in this paper. For example, with data on environmental impacts and abatement technology, the model can be applied to assess the effects of a "green" agricultural policy for a typical field crop.
References:


Figure 1: External Costs (D) vs. Total Abatement Costs (TAC)

- Technology set without abatement
- Technology set with complete abatement

D > TAC
D < TAC
Figure 2: Pollution Tax / Tradeable Permits (Small Country)
Endnotes:

1 Throughout the paper, the term abatement will refer to both pollution abatement and prevention activity. Likewise, abated pollution will refer to both abated and prevented pollution.

2 Markusen also allows for transborder pollution (with Cournot-Nash behavior between governments).

3 With a variable factor model, where factors are mobile between sectors, cross-substitution between production factors affects optimal resource allocation and a multi-output cost minimization problem must be solved first.

4 In chapter 4, Baumol and Oates (1988) describe a basic general equilibrium externality model. Output levels and input usage of firms determine emissions, but emissions reduction is not defined. In chapter 5, emissions reduction is defined, but they make no clear distinction between abatement and output reduction. In chapter 14, they assume abatement technology is available, but only implicitly, defining abatement outlays as a function of output and total emissions.

5 $Z(\cdot)$ may target net pollution $S$, production $Q$, abatement $A$, specific production factors, or some combination thereof.

6 If demand is derived from a Cobb-Douglas utility function $U(\cdot) = (Yd)^\alpha/(Qd)^{1-\alpha}$, the market clearing condition $Q = Qd = (1-\alpha)M/P(Q, A)$ defines the endogenous equilibrium price ratio $P(Q, A)$. After substituting for $M$, we solve for the equilibrium price $P(Q, A) = k F(Q, A)/Q$ where $k = (1-\alpha)/\alpha$. Demand is strictly positive, because $U(\cdot)$ is strictly concave. Thus, a positive amount of good $Q$ is produced and $P(Q, A)$ exists.

7 With an optimal trade tax, condition [15a] simplify to the small country conditions [11]. Note that the large country case embodies the small country case with $\pi_i = 0 (i = Q, A)$ and $\eta_X = \pm \infty$ such that the large country effect is zero.

8 Regulatory costs are total policy induced losses in producer revenue (gross domestic product) from a baseline without policy intervention and are equal to the cost of output reduction and abatement.

9 We do not analyze how existing gains from trade are affected by an exogenous price change induced through policy shifts abroad, i.e. when international prices rise (fall) for importers (exporters). However, the results of Table 2 are valid in general for any sufficiently small price change and the resulting output interaction effects.

10 Propositions 2 and 3 and their Corollaries generalize Krutilla (1991) with a general-equilibrium model that also explicitly models pollution abatement technology.

11 Tariff rates above $T^*$ deteriorate the ToT and may in part be compensated by raising output taxes above and lowering abatement subsidies below Pigouvian levels.

12 An example for an abatement activity with consumption externalities would be recycling.
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