Trade Restrictions and Incentives to Tax Pollution Emissions
(Preliminary notes)

August 2010

Nori Tarui¹, Morihiro Yomogida², Ying Yao¹

Abstract
This paper studies the effect of a trade restriction on an incentive for a trade partner to tax the emission of greenhouse gases. We are motivated by the recent debate on border tax adjustments in climate change policies, i.e., whether or not developed economies such as EU and US could use trade measures to encourage developing economies such as China and India to reduce the emission of greenhouse gases. We consider a partial equilibrium model with two countries, in which production emits greenhouse gases that generate a cross-border externality. With this model, we examine how an import tariff affects an incentive for an exporting country's government to choose a tax on the emission of greenhouse gases. We show that, in a case of noncooperative optimal policies, an import tariff would induce the exporting country to choose a lower emission tax as compared to a case in which a tariff is banned for the importing country. This result suggests that import restrictions could not encourage other countries to adopt more stringent regulation on the environment.

¹Department of Economics, University of Hawaii.
²Department of Economics, Sophia University.
1 Introduction

Climate change and the discussion of mitigation policies in developing countries have renewed policymakers’ and researchers’ interests in the effects of border-tax adjustments (BTAs) on greenhouse gas (GHG) emissions and welfare among of trading countries. BTA, as discussed in US House and Senate bills, is proposed to encourage non-Annex-I countries such as China, India, and Brazil to adopt domestic GHG reduction policies, where GHG emissions are expected to increase as their economies grow into the future. Existing UN-based multilateral negotiations (through the Framework Convention) try to provide these growing countries with incentives to adopt GHG reduction measures. Some policymakers argue that BTAs may constitute a separate, bilateral measure to provide the same incentives: in the presence of BTAs, China and others may have stronger incentive to adopt GHG reduction policies in order to avoid being subject to BTA. This paper applies game theoretic approaches to international environmental agreements (IEA) in order to analyze whether BTA indeed provides such incentives.

The Kyoto Protocol is often criticized as “too little, too fast” in part because it provides ineffective incentives for participation; in particular, it lacks developing countries’ commitment to reduce GHG emissions. The Copenhagen summit fails to obligate any country to meet a specific emission-reduction target as well. The global effort to combat climate change is stuck in essentially the same place: who is going to pay for it? Big costs are hurdle to climate change mitigation.

Border tax adjustments (BTAs), is proposed to create incentives for non-Annex-B countries, where GHG emissions are keep on increasing correspond to their dramatically growing economies (e.g. China, India, Brazil), to reduce domestic GHG emissions. By applying partial equilibrium model, this paper attempts to examine how trade restriction affects an incentive for any exporting country to choose a tax on the emission of greenhouse gases.

Hufbauer, et al. (2009) summarizes three arguments for the use of BTAs:

1. Prevent “emission leakages” due to shifts in (emission-generating) production activities from countries with emissions regulation to countries with more lenient regulation.
2. Provide a level-playing field for firms under strict emissions regulation.
3. Work as a means to encourage more stringent emissions regulation in (developing) countries.

We apply a simple two-country/region trade model to address the last question, with some implications to the first two questions. Specifically, suppose a subset of countries restrict emissions. Do BTA by these countries encourage the other country...
(countries) to restrict emissions? This question is of high policy relevance because countries such as the United States and Japan may go ahead to control GHG emissions and adopt BTA. How would countries such as China react to these policies?

Numerous studies analyze the optimal environmental and trade policies for small and large countries. They tend to focus on a country's optimal decision and not the outcome of games where multiple countries act strategically. Krutilla (1991) derives the optimal tariff and tax for a large country using a partial equilibrium model. He finds that, when pollution is not transboundary, the optimal tax equals the Pigouvian level and the optimal tariff equals the standard optimal tariff in trade theory. Markusen (1975) analyzes the optimal tax structure from one country's point of view, and discusses second best policies when only one policy instrument (i.e. either import tariff or emissions tax) is available. Ludema and Wooton (1994) propose a partial equilibrium model with transboundary pollution where emissions in foreign country generate externalities in another country, but home country production creates no externalities.

Overall, these studies tend to analyze a country’s optimal tariff by taking the trade partners’ policies as given. Building on these previous studies, we address the consequence of strategic interactions among large countries, i.e. when the country imposing BTAs and the country facing BTAs by trade partners both act strategically.

The rest of this paper is organized as follows. Section 2 describes the assumptions of our model. Section 3 discusses the result of cooperative solution while section 4 compares three noncooperative cases and analyzes policy implications of the results. Section 5 concludes the paper with policy implications and comments on potential future extensions.

2 Model

2.1 Model environment
Suppose three countries trade one homogenous non-numeraire good, and a numeraire good. The non-numeraire good is produced and consumed in all three countries. We consider a situation where country 3 exports the good to countries 1 and 2. (We can imagine that countries 1, 2, and 3 represent US, Japan, and China.) The production of the good generates negative externalities (pollution that spills over across countries). The non-numeraire good is subject to tariffs while the numeraire good is freely traded. The government of each country is a player in the model. Assume that country $i$ chooses an environmental/pollution tax $e_i \geq 0$ per unit of production and an import tax $\tau_i \geq 0$. Trade tax is interpreted as import tariff if the country is an importer, and as export
subsidy if it is an exporter. The consumer and producer prices at country $i$ are

$$p_i = p_w + \tau_i,$$

$$q_i = p_i - e_i = p_w + \tau_i - e_i,$$

where $p_i$ is the consumer (buyers') price, $q_i$ the producer (sellers') price, and $p_w$ the world price. Let $\tau = (\tau_1, \tau_2, \tau_3)$ and $e = (e_1, e_2, e_3)$ be the strategy profile of the three countries.

Let $x_i(p_i)$ and $y_i(q_i)$ be the demand and supply given consumer and producer prices $p_i, q_i$ in country $i$. (We may assume that both are linear in prices.) Country $i$’s domestic excess demand is

$$M_i(p_w, \tau_i, e_i) = x_i(p_w + \tau_i) - y_i(p_w + \tau_i - e_i).$$

Under the world market clearing condition, we have

$$M_1(p_w, \tau_1, e_1) + M_2(p_w, \tau_2, e_2) + M_3(p_w, \tau_3, e_3) = 0.$$

We assume that a unit of production generates a unit of pollutant in each country. (See the next section about whether we want to keep this assumption.) Suppose a share $\lambda$ of pollution in countries $i$ and $j$ spills over to country $k$. Let $Y_{-i} = \sum_{j \neq i} y_j$ (the sum of outputs in countries other than $i$) and $Y_i = y_i + \lambda Y_{-i}$ (the amount of pollution in country $i$). Let $D_i(Y_i)$ be the damage due to pollution in country $i$. The parameter $\lambda$ represents the degree of transboundary pollution. The case $\lambda = 1$ would correspond to GHG emissions (complete spillover). With $\lambda = 0$, pollution is local.

As in Limão (2005), we introduce a political economy factor by assuming that each government may weigh consumer and producer surpluses (and pollution damages) differently. Country $i$’s government has the following welfare function:

$$W_i(\tau, e) = \int_{p_i}^{\infty} x_i(\omega)d\omega + \beta \int_{0}^{q_i} y_i(\omega)d\omega + \tau_i M_i + e_i y(q_i) - \gamma_i D_i(Y_i),$$

where the weights $\beta \geq 0$ and $\gamma_i$ represent the strength of the import-sector and environmental lobbies in country $i$, and may differ across countries. The first two terms represent the weighted consumer and producer surpluses, the next two the revenues from tariff and pollution tax, and the last term is the damages due to pollution.

### 2.2 How to introduce countries' heterogeneity (in a simple way)

We want to model a situation where a GHG emission-intensive good is exported from country 3 to countries 1 and 2 under both cooperative and noncooperative solutions. For this purpose, we assume that the countries are identical except that country 3’s marginal cost of the non-numeraire production is lower than countries 1 and 2's marginal costs.
3 Cooperative solution

With $\beta_i = \gamma_i = 1$ for all $i$, optimal tariffs and pollution taxes solve the following problem:

$$\max_{\tau, e} W_1(\tau, e) + W_2(\tau, e) + W_3(\tau, e)$$

s.t. $M_1(p_w, \tau_1, e_1) + M_2(p_w, \tau_2, e_2) + M_3(p_w, \tau_3, e_3) = 0$.

With $\beta_i = \gamma_i = 1$ for all $i$, the optimal solution is $\tau_i = 0$ for all $i$ and $e_i = D_i(Y_i) + \lambda \sum_{j \neq i}D_j'(Y_j)$ for all $i$. That is, the tariffs should be zero and the pollution tax is at the Pigouvian level, which equals to the sum of the marginal damages in all three countries.

4 Noncooperative outcomes

We considered an even simpler case with one importer (country 1) and one exporter (country 3). A goal is to consider the following question: would the exporter choose higher environmental tax rate when the importer can use tariff in addition to environmental tax compared to the case where tariff is not available for the importer? That is, does a tariff work to induce the exporter to set a stricter environmental regulation?

We consider three alternative sequences of moves.

1. Simultaneous move where the exporter and the importer move at the same time.
2. Sequential move where the exporter moves first (by choosing environmental tax) and then the importer moves (by choosing environmental tax and tariff);
3. Sequential move where the importer moves first (by choosing environmental tax and tariff) and then the exporter moves (by choosing environmental tax);

Each sequence of moves may be a plausible alternative. Case 2 may allow us to address the effectiveness of the importer's tariff as a threat against the exporter's policy choice. Case 3 would apply if we assume that the importer commits to a tariff level first, to which the exporter responds. Case 1 would be a benchmark.

In all cases, assume that country 1 chooses $e_1$ (and $\tau_1$ if tariff is available) and country 3 chooses $e_3$. We assume that tariff is not available or exogenously given for country 3. We imagine a situation where, through free trade negotiations, use of tariffs as a policy variable has been ruled out, and see what happens if the importer goes ahead and use tariff as a BTA measure.

4.1 Preliminaries
4.1.1 The equilibrium world price when \( \tau_i \) is not available

The market clearing condition is given by
\[
x_i(p_w) + x_i(p_w) = y_i(p_w - e_i) + y_i(p_w - e_3).
\]
Total differentiation of this condition yields the following derivatives:
\[
P_{e1} \equiv \frac{\partial P_w}{\partial e_1} = \frac{y'_1}{y'_1 + y'_3 - x'_1 - x_3} > 0,
\]
\[
P_{e3} \equiv \frac{\partial P_w}{\partial e_3} = \frac{y'_3}{y'_1 + y'_3 - x'_1 - x_3} > 0.
\]
Note that \( 0 < P_{e_i} < 1 \) for \( i = 1,3 \).

4.1.2 The equilibrium world price when \( \tau_i \) is available

The market clearing condition implies
\[
x_i(p_w + \tau_i) + x_i(p_w) = y_i(p_w + \tau_i - e_i) + y_i(p_w - e_3).
\]
Total differentiation of this condition yields the following derivatives:
\[
P_{e1} \equiv \frac{\partial P_w}{\partial e_1} = \frac{y'_1}{y'_1 + y'_3 - x'_1 - x_3} > 0,
\]
\[
P_{e3} \equiv \frac{\partial P_w}{\partial e_3} = \frac{y'_3}{y'_1 + y'_3 - x'_1 - x_3} > 0,
\]
\[
P_{\tau1} \equiv \frac{\partial P_w}{\partial \tau_1} = \frac{x'_1 - y'_1}{y'_1 + y'_3 - x'_1 - x_3} < 0.
\]
Note that \( 0 < P_{e_i} < 1,0 < P_{e_3} < 1 \) for all \( i = 1,2 \), and \( -1 < P_{\tau_1} < 0 \).

4.2 When two countries move simultaneously

Let \( \hat{\tau}_i \) and \( \hat{e}_i \) \( (i = 1,2) \) represent the best response functions. Let \( (e'_i, \tau'_i, e'_3) \) be the Nash equilibrium for the simultaneous-move case when \( \tau_i \) is available. Let \( (e'_i, e'_3) \) be the Nash equilibrium for the simultaneous-move case when \( \tau_i \) is not available.

Let \( \overline{y}_i \) and \( \overline{x}_i \) be country \( i \)'s production and consumption with free trade and with no taxes on emissions (i.e. \( \tau_i = e_i = e_3 = 0 \)).
4.2.1 \( \tau_1 \) is available

First-order conditions and implicit expressions of the control variables

The exporter's first order condition for an interior solution is

\[-x_3 \cdot P_{e3} + y_3 \cdot (\beta_3 (P_{e3} - 1) + 1) + \tau_3 (y_3'(P_{e3} - 1) - x_3' \cdot P_{e3}) + e_3 y_3'(P_{e3} - 1) - \gamma_3 D_3'(y_3'(P_{e3} - 1) + \lambda y_3' P_{e3}) = 0.\]

So \( e_3 \) must satisfy

\[e_3 = \frac{-x_3 P_{e3} + y_3 (\beta_3 (P_{e3} - 1) - 1)}{y_3'(1 - P_{e3})} + \frac{\tau_3 (y_3'(P_{e3} - 1) - x_3' P_{e3})}{y_3'(1 - P_{e3})} + \gamma_3 D_3'(\cdot) - \frac{\gamma_3 D_3' \cdot \lambda y_3' P_{e3}}{y_3'(1 - P_{e3})}.\]

The first term corresponds to the terms of trade effect, which is positive for the exporter for \( \beta_3 \) small enough. The coefficient of the term involving \( \tau_3 \), which refers to the export-tax revenue effect, is negative. Given \( \tau_3 \leq 0 \) (i.e. country 3 imposes an export tax), the second term is positive. The third term is the domestic marginal damage while the last term represents the marginal spillover effect.

When \( \beta_3 = \gamma_3 = 1 \) and \( \tau_3 = 0 \), the condition reduces to:

\[e_3 = \frac{(y_3 - x_3) P_{e3}}{y_3'(1 - P_{e3})} + \delta_3 + \frac{-\delta_3 \lambda y_3' P_{e3}}{y_3'(1 - P_{e3})}.\]

The first term corresponds to the terms-of-trade effect, which is positive for the exporter. The second term equals the domestic marginal damages caused by the emission \( y_3 \), and the third term represents the marginal spillover effects, which is always negative. Because country 3 does not have tariff as a control variable, its emission tax \( e_3 \) must address all of these three effects in equilibrium. This has been found in many studies including Markusen (1975), Krutilla (1991), Rauscher (1997).

The importer's problem is to maximize

\[\Pi_i(\tau_1, e_1, e_3) = \int_{\tau_1}^\infty x_i(\omega)d\omega + \beta_1 \int_0^{\infty} y_i(\omega)d\omega + \tau_1 (y_i - x_i) + e_i y(q_i) - \gamma_1 D_1(y_i + \lambda y_3).\]

The first order condition for an interior solution is:

\[\frac{\partial \Pi_i}{\partial \tau_1} = P_{\tau_1} (y_i - x_i) - \tau_1 (1 + P_{\tau_1})(y_i - x_i) - \delta_1 \lambda y_3 P_{\tau_1} = 0,\]

\[\frac{\partial \Pi_i}{\partial e_1} = \ldots = 0.\]

These conditions imply

\[\hat{e}_1 = \hat{\delta}_1,\]
Note that $-1 < P_{\tau_1} < 0$, $(y_r - x_r)(1 + P_{\tau_1}) > 0$, and $y_i - x_i < 0$ because country 1 is an importer. So the first term (the terms-of-trade effect) is positive, and the second term (the marginal spillover effect) is positive as well.

Hence, the equilibrium environmental tax choice by the importer $e_i^*$ satisfies $e_i^* = \delta_1$ (i.e. the Pigouvian tax level) and is independent of the exporter's tax level. That is, when tariff is available as a policy variable, the optimal environmental tax should be set to equal the domestic marginal damage $\delta_1$ and the tariff should address all other distortions/strategic effects (i.e. the terms-of-trade effect and the emissions spillover effect). The same observation that a large country's optimal environmental tax rate should equal the marginal damage when tariff is available has been found in the prior literature (Markusen 1975, Krutilla 1991, Rauscher 1997).

Nature of the best response functions

We have $\frac{d\delta_1}{d\tau_1} < 0$ and $\frac{d\hat{\tau}_1}{de_3} < 0$: they are strategic substitutes. Note that $\frac{d\hat{\tau}_1}{de_3} = 0$ because $\hat{\tau}_1 = \delta_1$ and is independent of $e_3$ with linearity of damage functions.

More formally, suppose $x_i^* = y_i^* = 0$ for $i = 1,3$ and $D_i^* = 0$ for $i = 1,3$.

Suppose also that $\beta_i = 1$ for all $i$. Then $\frac{d\delta_1}{d\tau_1} < 0$ and $\frac{d\hat{\tau}_1}{de_3} < 0$.

Proof:

The first order condition for the importer is

$$P_{\tau_1} (y_i - x_i) - \tau_i (1 + P_{\tau_1}) (y_i' - x_i') - \delta_i \lambda y_i' P_{\tau_1} = 0.$$  

Totally differentiate with respect to $e_3$ and $\tau_1$

$$\Pi_{1rr} d\tau_1 + P_{\tau_1} (y_i' - x_i') P_{e_3} = 0,$$

where $\Pi_{1rr}$ is the second-order derivative of $\Pi_1$ with respect to $\tau_1$ and is negative. Therefore,

$$\frac{\partial \hat{\tau}_1}{\partial e_3} = \frac{(x_i' - y_i') P_{\tau_1} P_{e_3}}{\Pi_{1rr}} < 0,$$

where $x_i' < 0, y_i' > 0$, $P_{\tau_1} < 0$, and $P_{e_3} > 0$.

The first order condition for an interior solution is
\[-x_3p_{e_3} + y_3p_{e_3} + e_3y_3'(p_{e_3} - 1) - D'_3 \left[ y_3'(p_{e_3} - 1) + \lambda y_3'(p_{e_3}) \right] = 0.\]

Total differentiation with respect to \( e_i \) and \( e_j \), \( j \neq i \), yields
\[
[-x_3'p_{e_3} + y_3'p_{e_3}]d\tau_1 + (\Pi_{3ee})de_3 = 0,
\]
where \( \Pi_{3ee} \) is the second-order derivative of \( \Pi_3 \) with respect to \( e_3 \) and is negative. Therefore,
\[
\frac{\partial \hat{e}_3}{\partial \tau_1} = \frac{(x'_3 - y'_3)p_{\tau_1}p_{e_3}}{\Pi_{3ee}} < 0,
\]
where \( x'_i < 0, y'_i > 0, p_{\tau_1} < 0 \), and \( p_{e_3} > 0 \).

Analytical expression of the equilibrium solution

\[
e_i' = \hat{\delta}_i,
\]
where
\[
B_i \equiv d_i - (b_i + d_i)p_{\epsilon_i}^2 \quad (i = 1, 3),
\]
\[
G \equiv \frac{(\bar{y}_3 - \bar{x}_3)p_{e_3} - \delta_3[d_3(p_{e_3} - 1) + \lambda d_3p_{e_3}]}{B_3},
\]
\[
A_i \equiv 1 - \frac{(b_3 + d_3)p_{\epsilon_3}^2}{B_i(1 - p_{\epsilon_3}^2)},
\]
\[
A_f \equiv 1 - \frac{(b_3 + d_3)(b_3 + d_3)p_{\epsilon_3}^2}{B_iB_3}.
\]

Note that \( B_i > 0 \) for \( i = 1, 3 \), \( G > 0 \), \( A_i > 0 \), and \( A_f > 0 \). \( G > 0 \) follows from
\[ \bar{y}_3 - \bar{x}_3 > 0 \quad \text{and} \quad d_3(P_{e_3} - 1) + \lambda d_1 P_{e_3} < 0. \]

4.2.2 \( \tau_1 \) is not available

First-order conditions and implicit expressions of the control variables

The implicit expression of \( e_3 \) is the same as in the case where \( \tau_1 \) is available.

The first order conditions are
\[
(y_3 - x_3)P_{e_3} + e_3y'_3(P_{e_3} - 1) - \delta_3(y_3(P_{e_3} - 1) + \lambda y'_3 P_{e_3}) = 0,
\]
\[
(y_1 - x_1)P_{e_1} + e_1y'_1(P_{e_1} - 1) - \delta_1(y_1(P_{e_1} - 1) + \lambda y'_1 P_{e_1}) = 0.
\]

So
\[
e'_i = \frac{(y_i - x_i)P_{e_i}}{y'_i(1 - P_{e_i})} + \delta_i + \frac{- \delta_i \lambda y'_i P_{e_i}}{y'_i(1 - P_{e_i})}, \quad i = 1, 2, j \neq i.
\]

Observe that the first term corresponds to the terms-of-trade effect, which is negative for country 1 (Importer) and positive for country 3 (Exporter) while the third term is negative for both countries. Therefore, the importer's equilibrium emission is lower when tariff is not available:
\[ e'_1 = \delta_1 > e'_i. \]

Nature of the best response functions

Note that \( \frac{d \hat{e}_3}{de_1} > 0 \) and \( \frac{d \hat{e}_1}{de_3} > 0 \) : they are strategic complements.

More precisely, suppose \( x'_i = y'_i = 0 \) for \( i = 1, 3 \) and \( D'_i = 0 \) for \( i = 1, 3 \).

Suppose also that \( \beta_i = 1 \) for all \( i \). Then \( \frac{d \hat{e}_i}{de_j} > 0. \)

Proof:

Country \( i \)'s payoff is
\[
\Pi_i(e_i; e_{-i}) = \int_{p_w}^\infty x_i(\omega)d\omega + \beta \int_{p_w^{-e_i}} y_i(\omega)d\omega + e_i y'_i(p - e_i) \gamma_i D_i \left( y_i(p - e_i) + \lambda \sum_{j \neq i} y'_j(p_j) \right).
\]

The first order condition for an interior solution is
\[
-x_i P_{e_i} + y_i(\beta(P_{e_i} - 1) + 1) + e_i y'_i(P_{e_i} - 1) - \gamma_i D'_i \left[ y'_i(P_{e_i} - 1) + \lambda \sum_{j \neq i} y'_j(p_{e_j}) \right] = 0.
\]

With \( \beta_i = 1 \), total differentiation with respect to \( e_i \) and \( e_j, j \neq i \), yields
\[-x'_{i} P_{e_j} P_{e_i} + y'_{i} P_{e_j} P_{e_i}] de_i + (\Pi') de_j = 0,
\]

where \( \Pi'_{i} \) is the second-order derivative of \( \Pi_{i} \) with respect to \( e_{i} \) and is negative at \( e_{i} \) provided that \( \Pi_{i} \) is a concave function. Therefore,
\[
\frac{de_i}{de_j} = \frac{(x'_{i} - y'_{i}) P_{e_j} P_{e_i}}{D_{i}^{2} \Pi_{i}} > 0,
\]

where \( x'_{i} < 0, y'_{i} > 0, P_{e_j} > 0, \) and \( P_{e_i} > 0 \).

Analytical expression of the equilibrium solution
\[
e_{j}^{f} = \frac{(b_{3} + d_{3}) P_{e_j} P_{e_i}}{B_{i} B_{3}} \left[ (\bar{y}_{i} - \bar{x}_{i}) P_{e_i} - \delta_{i} [d_{i} (P_{e_i} - 1) + \lambda d_{j} P_{e_j}] \right] \frac{G + \frac{B_{i} B_{3}}{B_{3}}}{A_{f}},
\]

\[e_{i}^{f} = xxx.\]

**4.2.3 Comparing \( e_{i}^{f} \) and \( e_{i}^{e} \)**

Now we present one of the main results so far.

**Proposition 1** Suppose \( x''_{i} = y''_{i} = 0 \) for \( i = 1,3 \) and \( D''_{i} = 0 \) for \( i = 1,3 \) (i.e. linear demand and supply with linear damages). Suppose also that \( \beta_i = \gamma_i = 1 \) for all \( i \) (i.e. no political-economy factors). Then the exporter's equilibrium emission tax rate is lower when the importer imposes tariff on its import, i.e.
\[e_{i}^{f} < e_{i}^{e}.\]

See the appendix for the proof. The figure on the last page is based on a numerical example that contrasts \( e_{i}^{f} \) and \( e_{i}^{e} \). An implication of the proposition is that the availability of tariff for the importer does not induce the exporter to adopt more stringent environmental regulation.

As we will see below, the conclusion of Proposition 1 holds regardless of the order of moves by the exporter and the importer.

In order to provide an intuition behind the result of proposition 1, we now consider a game where importer’s tariff is given exogenously. How do the Nash equilibrium environmental taxes change when tariff rate increases? Proposition 2 describes the result that as the tariff increases, the environmental tax of importer...
increases, while the environmental tax of exporter decreases. This result corresponds to proposition 1 and our simulation result.

**Proposition 2** Suppose $x_i^* = y_i^* = 0$ for $i = 1,3$ and $D_i^* = 0$ for $i = 1,3$ (i.e. linear demand and supply with linear damages). Suppose also that $\beta_i = \gamma_i = 1$ for all $i$ (i.e. no political-economy factors). Then $\frac{de_s}{d\tau} < 0$, $\frac{de_k}{d\tau} > 0$.

See the appendix for the proof. An implication of the proposition is that the availability of the tariff for the importer induces the exporter to adopt more lenient emissions regulation but encourages importer to adopt more stringent environmental regulation. That is because when tariff is available as a policy tool, it could address all other strategic effects, such as terms of trade effects, so the environmental tax would equals to the Pigovian tax rate. When tariff is not available, the environmental tax of importer has to decrease to address strategic effects which were the responsibility of tariff. Incentive for the exporter is same. The conclusion of Proposition 2 holds regardless of the order of moves by the exporter and the importer.

### 4.3 When the exporter moves first

#### 4.3.1 $\tau_1$ is available

First-order conditions and implicit expressions of the control variables

The importer's problem is the same as in the simultaneous-move case.

$$\Pi_1(\tau_1, e_1, e_3) = \int_{p_1}^{x_1} x_1(\omega) d\omega + \beta_1 \int_{q_1}^{y_1} y_1(\omega) d\omega + \tau_1(y_1 - x_1) + e_1 y(q_i) - \gamma_i D_i(y_i).$$

The first order condition’s for Importer's payoff maximization:

$$P_{\tau_1}(y_1 - x_1) - \tau_1(1 + P_{\tau_1})(y_1' - x_1') - \delta_1 A y^1 P_{\tau_1} = 0.$$

These conditions imply

$$\hat{e}_1 = \hat{\delta}_1,$$

$$\tau_1 = \frac{(y_1 - x_1)P_{\tau_1}}{(y_1' - x_1')(1 + P_{\tau_1})} + \frac{-\delta_1 A y^1 P_{\tau_1}}{(y_1' - x_1')(1 + P_{\tau_1})}.$$

Note that $-1 < P_{\tau_1} < 0$, $(y_1' - x_1')(1 + P_{\tau_1}) > 0$, and $y_1 - x_1 < 0$ because country 1 is an importer. So the first term (ToT effect) is positive, and the second term (the marginal
spillover effect) is positive.

The exporter's payoff is given by

$$\Pi_{e}(e_3) = \int_{p_w}^{\infty} x_3(x) dx + \int_{0}^{p_w} e_3 x_3(p_w-x_3) - D_3(y_3(p_w-e_3) + \lambda y_3(p_w + \tau_1(e_3) - e_1(e_3)), $$

and the first-order condition for an interior solution is

$$\frac{d\Pi_{e}}{de_3} = -x_3 \cdot \frac{dp_w}{de_3} + y_3 \cdot \left( \frac{dp_w}{de_3} - 1 \right) + e_3 y'_3 \cdot \left( \frac{dp_w}{de_3} - 1 \right) + y_3 - \delta_3 \cdot \lambda y'_3 \left( \frac{dp_w}{de_3} + \frac{d\tau_1}{de_3} \right) + y_3' \left( \frac{dp_w}{de_3} - 1 \right) = 0,$$

where $\frac{dp_w}{de_3}$ is the total derivative of the world price with respect to $e_3$:

$$\frac{dp_w}{de_3} \equiv \frac{\partial p_w}{\partial e_3} + \frac{\partial p_w}{\partial \tau_1} \frac{\partial \tau_1}{\partial e_3} + \frac{\partial p_w}{\partial e_1} \frac{\partial e_1}{\partial e_3} = \frac{\partial p_w}{\partial e_3} + \frac{\partial p_w}{\partial \tau_1} \frac{\partial \tau_1}{\partial e_3}.$$

Note that $\frac{\partial e_1}{\partial e_3} = 0$ when tariff is available---the importer's best response implies $e_1 = \delta_1$, the marginal damage of emissions, regardless of the exporter's decision. The condition reduces to:

$$e_3 = \frac{(y_3 - x_3) \frac{dp_w}{de_3} + \delta_3 \lambda y'_3 \left( \frac{dp_w}{de_3} + \frac{d\tau_1}{de_3} \right) + y_3' \left( 1 - \frac{dp_w}{de_3} \right) }{y_3' \left( 1 - \frac{dp_w}{de_3} \right) + \delta_3 + y_3' \left( 1 - \frac{dp_w}{de_3} \right)}.$$

The expression is similar to the case of simultaneous move. A difference is that the partial derivative of $p_w$, $\frac{\partial p_w}{\partial e_3}$, is now replaced by the total derivative $\frac{dp_w}{de_3}$. In the expression above, the first term corresponds to the terms-of-trade effect, which is positive for the exporter. The second term equals the domestic marginal damages caused by the emission $y_3$, and the third term represents the marginal spillover effects, which is always negative.

As in the simultaneous-move game, the subgame-perfect equilibrium environmental tax choice by the importer $e^*_i$ satisfies $e^*_i = \delta$ (i.e. the Pigouvian tax level) and is independent of the exporter's tax level. That is, when tariff is available as a policy variable, the optimal environmental tax should be set to equal the domestic marginal damage $\delta_i$ and the tariff should address all other distortions/strategic effects (i.e. the terms-of-trade effect and the emissions spillover effect). The same observation
that a large country's optimal environmental tax rate should equal the marginal damage when tariff is available has been found in the prior literature (Markusen 1975, Krutilla 1991, Rauscher 1997).

Nature of the best response functions

As in the case of simultaneous move, we have \( \frac{d\hat{\tau}_1}{de_3} < 0 \), and \( \frac{d\hat{e}_1}{de_3} = 0 \) because \( \hat{e}_1 = \delta_1 \)

and is independent of \( e_3 \) with the linearity of damage functions.

More formally, suppose \( x_i^* = y_i^* = 0 \) for \( i = 1,3 \) and \( D_i^* = 0 \) for \( i = 1,3 \).

Suppose also that \( \beta_i = 1 \) for all \( i \). Then \( \frac{d\hat{e}_1}{de_3} < 0 \).

Proof: (Same as in the simultaneous-move case.)

Analytical expression of the equilibrium solution

When tariff is available, the equilibrium tax rate by the exporter is given by

\[
\begin{align*}
e'_3 \ &= \frac{\hat{P}_3 \{c_3 - d_3 \hat{P}_w - (a_3 - b_3 \hat{P}_w)\} - \delta_3 \left\{ \lambda d_3 \left( \frac{\hat{P}_3}{d_3} + \frac{d\hat{\tau}_1}{de_3} \right) + d_3 (\hat{P}_3 - 1) \right\}}{d_3 - \hat{P}_3 (b_3 + e_3)^2},
\end{align*}
\]

where \( \hat{P}_e \equiv \frac{dP}{de_3} \) and \( \hat{P}_w \) satisfies

\[
P_w = \hat{P}_w + \hat{P}_e e_3.
\]

4.3.2 \( \tau_1 \) is not available

First-order conditions and implicit expressions of the control variables

The importer's FOC is the same as in the simultaneous-move case:

\[
(y_i - x_i)P_{e_1} + e_1 y_{i}'(P_{e_1} - 1) - \delta_1(y_i(P_{e_1} - 1) + \lambda y_{i}'P_{e_1}) = 0.
\]

So

\[
e_1 = \frac{(y_i - x_i)P_{e_1}}{y_{i}'(1 - P_{e_1})} + \delta_1 + \frac{-\delta_1 \lambda y_{i}'P_{e_1}}{y_{i}'(1 - P_{e_1})}.
\]

Observe that the first term (ToT effect) is negative for country 1 (Importer) and positive for country 3 (Exporter) while the third term is negative for both countries. Therefore, the importer's equilibrium emission is lower when tariff is not available:

\[
e'_1 = \delta_1 > e'_f.
\]

The exporter's payoff is
\[ \Pi_3(e_3) \equiv \int_{p_w}^{\infty} x_3(\omega) d\omega + \int_{0}^{p_w-e_3} y_3(\omega) d\omega + e_3 y_3(p_w-e_3) - D_3 \left(y_3(p_w-e_3) + \lambda y_3(p_w-e_1(e_3))\right) \]

The first order condition for an interior solution is

\[ \frac{d\Pi_3}{de_3} = -x_3 \cdot \frac{dp_w}{de_3} + y_3 \cdot \left( \frac{dp_w}{de_3} - 1 \right) + e_3 y'_3 \cdot \left( \frac{dp_w}{de_3} - 1 \right) + y_3 - \delta_3 \cdot \left( \lambda y_3 \left( \frac{dp_w}{de_3} - \frac{de_1}{de_3} \right) + y'_3 \left( \frac{dp_w}{de_3} - 1 \right) \right) = 0, \]

where

\[ \frac{dp_w}{de_3} \equiv \frac{\partial p_w}{\partial e_3} + \frac{\partial p_w}{\partial e_1} \frac{de_1}{de_3}, \]

and \( \delta_3 \equiv D'_3 \). The condition reduces to:

\[ e_3 = \frac{y_3 - x_3}{y'_3 \cdot \left( 1 - \frac{dp_w}{de_3} \right)} + \delta_3 + \frac{-\delta_3 \lambda y_3 \left( \frac{dp_w}{de_3} - \frac{de_1}{de_3} \right)}{y'_3 \cdot \left( 1 - \frac{dp_w}{de_3} \right)}. \]

The expression is similar to the case of simultaneous move. A difference is that the partial derivative of \( p_w, \frac{\partial p_w}{\partial e_3} \), is now replaced by the total derivative \( \frac{dp_w}{de_3} \). In the above expression, the first term corresponds to the terms-of-trade effect, which is positive for the exporter. The second term equals the domestic marginal damages caused by the emission \( y_3 \), and the third term represents the marginal spillover effects, which is always negative.

**Nature of the best response functions**

Note that \( \frac{de_1}{de_3} > 0 \) as in the case of simultaneous move.

A couple of remarks are in order.

1. Given the linearity assumptions on \( x_i, y_i \) and \( D_i \), the subgame-perfect equilibrium environmental tax choice by the importer \( e_1^* \) satisfies

\[ e_1^*(e_3) = h + ke_3 \] where \( k > 0 \). That is, the higher (lower) the environmental tax by the exporter, the higher (lower) the environmental tax by the importer.

2. We also find that \( h > 0 \) if \( \delta_1 \) (the marginal damage from global emissions) is large; \( h < 0 \) if \( \delta_1 \) is small. Why? When the importer is restricted to choose only an environmental tax (and tariff is not available as a policy variable), the importer's equilibrium tax should address not only the production externality from domestic production but also (i) the terms-of-trade effect and (ii) spillover effects
from foreign production. When $\delta_i$ is small, the damage from emissions is not as important as the terms-of-trade effect.

3. The above two results likely depend on the assumptions of the model, particularly partial equilibrium and linear damage functions.

Analytical expression of the equilibrium solution

When the import tariff is not available, the equilibrium tax rate by the exporter is given by

$$e_3^I = \frac{\hat{P}_{e_3} \left( c_3 - d_3 \hat{P}_w - (a_3 - b_3 \hat{P}_w) \right) - \lambda d_3 \left( \hat{P}_{e_3} - \frac{de_3}{de_3} \right) + d_3 (\hat{P}_{e_3} - 1)}{d_3 - \hat{P}_{e_3} (b_3 + e_3)^2}.$$ 

4.3.3 Comparing $e_3^I$ and $e_3^f$

Proposition 3 Suppose $x_i'' = y_i'' = 0$ for $i = 1, 3$ and $D_i'' = 0$ for $i = 1, 3$. Suppose also that $\beta_i = \gamma_i = 1$ for all $i$. Then the exporter's equilibrium emission tax rate is lower when the importer imposes tariff on its import:

$$e_3^I < e_3^f.$$ 

See the appendix for the (incomplete) proof.

5 Discussion

The greenhouse gas control is a global public good which makes free riding the biggest barrier to achieve a climate change mitigation agreement. This paper studies whether trade-based measures such as BTA could enhance international negotiation and cooperation on climate-change mitigation. We applied a two-country partial equilibrium model with a cross-border externality to examine how a trade restriction (import tariff) affects an incentive for an exporting country to choose a tax on the emission of greenhouse gases. Instead of simply focusing on a country’s optimal decision, we address the consequence of games where multiple large countries act strategically. We showed that regardless of the order of moves by the importer and the exporter, in the cases of noncooperative optimal policies, an import tariff would induce the exporting country to choose a lower emission tax compared to the case where tariff is not available for the importing country. The result suggests that the emission tax of an exporting country is
strategic substitutes with the tariff of the importing country, while it is strategic complements with the emission tax of the importing country. This result supports our main conclusion that trade restrictions could not encourage other countries to adopt more stringent regulation on the environment.

Economists and international-law scholars have raised concerns about the use of BTAs for various reasons such as its effectiveness on addressing carbon leakage and its compatibility with WTO rules. The above theoretical result has another policy implication on the effect of BTAs on trading partners’ incentive to regulate transboundary pollution: in terms of emissions tax rates, the effect is found to be negative.

In order to illustrate the consequence of strategic interactions among countries and their consequence on environmental regulation in each country, we used a simple model of international trade. A number of extensions might be useful. Trade statistics on carbon-intensive goods (Iron/Steel, Pulp/Paper, cement etc.) indicate that a bilateral trade is observed among China, US and Japan. Moreover, Japan is a net exporter of Iron/Steel to China, while US is a net importer from China. In the cement sector, even though Japan and US are both net importers from China, China consumes most of cement products domestically. The effects of these trade facts on BTAs are obviously not negligible. A further extension would be to consider an appropriate modeling strategy to analyze BTAs that reflect these trade facts.

Another natural extension of our model would incorporate more countries into the model. If there are more than one developing countries (exporters) or developed countries (importers), how would it affect other countries’ incentives to carry out environmental regulation and BTA adoptions? One could also investigate whether the results in this paper would carry over to general equilibrium models. Exploring these issues is left for future research.

appendix

proof of proposition 1

(So far we've proved that the inequality holds if $\delta_3$ is large enough. We are trying to see if the inequality holds for all parameter values such that the trade direction remains unaltered.)
Suppose \( y_i \) and \( x_i \) are given by

\[
x_i(p) = a_i - b_i p, \quad y_i(p) = c_i + d_i p,
\]

where \( a_i, b_i, c_i, d_i \) are positive scalars. Let \( B \equiv b_1 + b_3 \) and \( D \equiv d_1 + d_3 \). With these specifications, the world price with no tariff and taxes equals \( \bar{p}_w = \frac{A-C}{B+D} \), and hence

\[
\bar{x}_i = a_i - b_i \bar{p}_w \quad \text{and} \quad \bar{y}_i = c_i + d_i \bar{p}_w.
\]

Then the difference between \( e_i^f \) and \( e_i' \) is given by

\[
e_i^f - e_i' = \frac{(A_i - A_j)G}{A_i A_j} + \frac{F}{B_i B_j^2 (b_i + d_i)(1 - P_i^2) A_i A_j},
\]

where

\[
F \equiv B_3 (b_3 + d_3) P_3 \left( \frac{-b_i d_i (b_i + d_i)}{(B + D)^2} \right) (\bar{y}_i - \bar{x}_i)
\]

\[
+ (b_3 + d_3) P_3 \left( d_i P_i^2 - (b_i + d_i) P_i \right) \left( \frac{\delta_i d_i d_3}{(B + D)^2} (b_3 + d_3)(b_i + b_3 + d_i) + B_3 \delta_i \lambda d_3 \right).
\]

We have \( A_i - A_j < 0 \), \( A_i > 0 \), \( A_j > 0 \), \( G > 0 \), \( d_i P_i^2 - (b_i + d_i) P_i > 0 \), and \( F > 0 \). Therefore, \( e_i^f - e_i' > 0 \) if \( G \) is sufficiently small. Because \( G \) is increasing in \( \delta_3 \), we have \( e_i^f - e_i' > 0 \) if \( \delta_3 \) is sufficiently small.

Note that, with \( \delta_3 \) sufficiently large, we have \( y_3 - x_3 > 0 \) in equilibrium: that is, country 3 which would be the exporter under natural trade (without any tax or tariff) becomes a net importer. If we assume that the extent of externalities is not too large to reverse the direction of trade, it may be the case that \( \delta_3 \) is small enough for \( e_i^f > e_i' \) to hold. (We haven't proved this last claim.)

The expression of \( y_i^f - x_i^f \) (the exporter's equilibrium export when the importer's tariff is not available) is the following.

\[
y_i^f - x_i^f = \frac{d_i d_i H}{(B + D) A_i B_i B_3},
\]

where

\[
H \equiv \{(b_1 + b_3)(B + D) + d_i d_i \}(\bar{y}_3 + \bar{x}_3) + \left( \frac{(b_3 + d_i)(b_i + d_i + b_3)}{B + D} \right) \{-\delta_i (d_i (P_i^2 - 1) + \lambda d_i P_i^2) \}
\]

\[
+ \left( \frac{(b_3 + d_i)(b_i + b_3 + d_i)}{B + D} \right) \delta_3 (d_3 (P_3^2 - 1) + \lambda d_3 P_3^2).
\]
Note that $d_i(P_{e1} - 1) + \lambda d_3 P_{e1} < 0$ and $d_3(P_{e3} - 1) + \lambda d_i P_{e3} < 0$. So we can verify that $y'_3 - x'_3$ can be negative if $\delta_3$ is sufficiently large.

**Proof of Proposition 2**

We’ve proved when two countries move simultaneously, the first order condition with respect to $e_1$ for an interior solution for the importer is

$$\frac{dn_1}{de_1} = e_1[b_1 P_{e1} + d_1(P_{e1} - 1)(\beta_1(P_{e1} - 1) + 1) + d_1(P_{e1} - 1)] + \tau_1[b_1(P_{e1} + 1)P_{e1} + d_1(P_{e1} + 1)(\beta_1(P_{e1} - 1) + 1) + (b_1 P_{e1} - d_1(P_{e1} - 1))] + e_2[b_1 P_{e2} + d_1 P_{e3}(\beta_1(P_{e1} - 1) + 1) - (a_1 - b_1 P_{e1})P_{e2} + (c_1 + d_1 P_{e1}) (\beta_1(P_{e1} - 1) + 1) - y_1 \delta_1(d_1(P_{e1} - 1) + \lambda d_3 P_{e3}) = 0.$$ 

The first order condition with respect to $e_3$ for an interior solution for the exporter is

$$\frac{dn_3}{de_3} = e_3[b_1 P_{e1} + d_3(P_{e3} - 1)(\beta_3(P_{e3} - 1) + 1) + d_3(P_{e3} - 1)] + e_1[b_3 P_{e1} + d_3 P_{e3}(\beta_3(P_{e3} - 1) + 1) + d_3(P_{e3} - 1)] + \tau_1[b_3 P_{e1} + d_3 P_{e3}(\beta_3(P_{e3} - 1) + 1) - (a_3 - b_3 P_{e1})P_{e1} + (c_3 + d_3 P_{e1})(\beta_3(P_{e3} - 1) + 1)] + \tau_3(d_3(P_{e3} - 1) + b_3 P_{e3}) - y_3 \delta_3(d_3(P_{e3} - 1) + \lambda d_3 P_{e3}) = 0.$$ 

Totally differentiate the two equations with respect to $e_1$, $e_3$ and $\tau_1$, and obtain

$$\frac{dn_1}{de_1} + \frac{dn_3}{de_3} = -\left[b_1(P_{e1} + 1)P_{e1} + d_1(P_{e1} - 1)(\beta_1(P_{e1} - 1) + 1) + (b_1 P_{e1} - d_1(P_{e1} - 1))\right]d\tau_1.$$

Therefore,

$$\begin{pmatrix} b_1 P_{e1} + d_1(P_{e1} - 1)(\beta_1(P_{e1} - 1) + 1) & b_1 P_{e1} + d_1 P_{e3}(\beta_1(P_{e1} - 1) + 1) \\ b_3 P_{e1} + d_3 P_{e3}(\beta_3(P_{e3} - 1) + 1) & b_3 P_{e1} + d_3 P_{e3}(\beta_3(P_{e3} - 1) + 1) + \frac{dn_3}{de_3} \end{pmatrix} = \begin{pmatrix} de_1 \\ de_3 \end{pmatrix}$$

By using Cramer’s rule, we have

$$\frac{de_1}{d\tau_1} = \frac{-b_1 d_3 P_{e1} P_{e3}((\beta_3(P_{e3} - 1) + 1) - (P_{e3} - 1)) - b_3 d_1 P_{e1} P_{e3}((\beta_1(P_{e1} - 1) + 1) - (P_{e1} - 1)) + d_3 d_1 (P_{e1} - 1)(P_{e3} - 1)(\beta_3(P_{e3} - 1) + 1) - d_3 P_{e3}((\beta_3(P_{e3} - 1) + 1) - (P_{e3} - 1))}{b_1 d_3 P_{e1} P_{e3}((\beta_3(P_{e3} - 1) + 1) - (P_{e3} - 1)) + b_3 d_1 P_{e1} P_{e3}((\beta_1(P_{e1} - 1) + 1) - (P_{e1} - 1)) + d_1 d_3 (1 - P_{e1} - P_{e3})(\beta_1(P_{e1} - 1) + 1)(\beta_3(P_{e3} - 1) + 1)}.$$ 

$$\frac{de_3}{d\tau_1} = \frac{d_1(P_{e1} + 1)(\beta_1(P_{e1} - 1) + 1) - (P_{e1} - 1)) + d_3 d_1 (P_{e1} - 1)(P_{e3} - 1)(\beta_1(P_{e1} - 1) + 1) + \beta_3(P_{e3} - 1) + 1}{b_1 d_3 P_{e1} P_{e3}((\beta_3(P_{e3} - 1) + 1) - (P_{e3} - 1)) + b_3 d_1 P_{e1} P_{e3}((\beta_1(P_{e1} - 1) + 1) - (P_{e1} - 1)) + d_1 d_3 (1 - P_{e1} - P_{e3})(\beta_1(P_{e1} - 1) + 1)(\beta_3(P_{e3} - 1) + 1)}.$$
With $\beta_i = 1$, for all $i$, the equations reduce to

$$\frac{\partial e_1}{\partial \tau_1} = \frac{d_1 d_3 - d_1 p_{e1} p_{e2} (b_3 + d_3)}{d_1 d_3 - d_1 p_{e1} p_{e2} (b_1 + d_1) - d_1 p_{e1} p_{e2} (b_3 + d_3)} > 0,$$

$$\frac{\partial e_3}{\partial \tau_1} = \frac{d_1 (p_{e1} + P_{\tau_1}) p_{e2} (b_3 + d_3)}{d_1 d_3 - d_1 p_{e1} p_{e2} (b_1 + d_1) - d_1 p_{e1} p_{e2} (b_3 + d_3)} < 0,$$

where $P_{\tau_1} > 0$, $P_{e3} > 0$, $P_{\tau_1} < 0$, $P_{e1} + P_{\tau_1} < 0$ and the denominator is positive. This result is consistent with our previous analysis and simulation result.

**Proof of Proposition 3**

So far we’ve proved that the inequality holds if $\delta_3$ is large enough.

It follows that $e_3^i < e_3^f$ IF the following conditions hold:

1. $\hat{p}_w^i < \hat{p}_w^f$ ;
2. $\hat{p}_{e3}^i > \hat{p}_{e3}^f$ ;
3. $\frac{\partial e_3^*}{\partial P_{w}} > 0$;
4. $\frac{\partial e_3^*}{\partial P_{e3}} < 0$;
5. $\hat{p}_{e3}^i + \frac{d \tau_1}{d e_3} > \hat{p}_{e3}^f - \frac{de_1}{d e_3}$.

At this point, we have shown that 1,2,3, and 5 hold. Condition 4 holds if $\delta_3$ is large enough. Numerical simulations imply that $e_3^i < e_3^f$ holds even if $\delta_3$ is small (and condition 4 does not hold), so the above conditions are sufficient but not necessary for $e_3^i < e_3^f$.

**References**


Solid lines represent the best responses (country 1’s tariff and country 3’s emission tax) when tariff is available for country 1 (the importer), and the broken lines represent the best responses (country 1 and 3’s emission taxes) when tariff is not available. The vertical axis measures country 1’s strategy: the tariff rate for the first case, and the emission tax rate for the second case. The horizontal axis measures country 3’s emission tax rate.