ESSAYS ON TRADE LIBERALIZATION, FOREIGN DIRECT INVESTMENT, AND THE ENVIRONMENT

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Chapter 2 studies the effect of a trade restriction on the incentive for a trade partner to tax the emission of greenhouse gases. We consider a game theory, partial equilibrium model to examine how an import tariff affects the incentive for an exporting country's government to choose a tax on the emission of greenhouse gases. We show that an increase in the exogenous tariff for the importer induces the exporter to adopt more lenient emissions regulations. When the tariff is endogenous, an import tariff induces the exporting country to choose a lower emission tax than it would have had the importing country been unable to impose the tariff. This result suggests that import restrictions do not encourage other countries to adopt more stringent environmental regulations.

Chapter 3 investigates how regional trade liberalization affects the environment by assessing the effects of regional trade agreements (RTAs) on pollutants. Toward this purpose, I constructed a dataset of 199 RTAs which includes all free trade agreements (FTAs) and Customs Unions (CUs) for goods. The dataset is unique because it includes each country’s intra-group trade volume across all RTA partners in a given year. Using the generalized method of moments, trade is treated as endogenous. Unlike the results found from broad liberalization, this study finds regional liberalization has a detrimental total direct effect as it increases sulfur dioxide concentrations, whereas it has a beneficial total direct effect in reducing carbon dioxide emissions. When considering the indirect effects due to the possible structural and volume change in Foreign Direct Investment, the indirect effects exacerbate the direct impacts. The result implies regional cooperation is effective in reducing greenhouse gases.
Chapter 4 analyzes the effects of natural disasters on Foreign Direct Investment (FDI) from three different perspectives using data from 214 countries over 1985-2014. The results indicate that when disasters are measured by their total number occurring and their number of affected people, they are negatively and statistically correlated with FDI in the long term, but there is no significant correlation when disasters are measured by their total monetary damage.
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CHAPTER 1

INTRODUCTION

The trend of globalization attracts more and more public attention nowadays, but the debate over the environmental consequences of globalization has never reached a consensus. My dissertation explores the relationship between globalization and the environment from different perspectives, intending to give some ramifications for future work and policy implications in this field. The second chapter examines how an import tariff affects the exporting country’s emission tax on greenhouse gases. The third chapter studies how regional trade agreements affect environmental quality. The fourth chapter addresses the effects of natural disasters on foreign direct investment.

Chapter 2 studies the effect of a trade restriction on the 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 developed economies such as the EU and US could use trade measures to encourage developing economies such as China and India to reduce their emissions of greenhouse gases. We consider a game theory, partial equilibrium model with two countries, in which production emits greenhouse gases that generate a cross-border externality. Using this model, we examine how an import tariff affects the incentive for an exporting country's government to choose a tax on the emission of greenhouse gases.

Studies on the environmental consequences of free trade, as well as on how regionalism affects trade liberalization toward nonmembers, have been largely inconclusive. Chapter 3 assesses the environmental consequences of regional trade agreements. Recent analysis at the country level and subnational level uses exogenous determinants of trade to identify the causal effect of a country’s trade on its environment, and finds that freer trade is good for the environment. The developments in theory and empirical evidence of trade creation and trade diversion suggest that it is ambiguous whether RTAs help or hinder the movement towards global free trade. This study provides the first comprehensive econometric study of the effect of RTAs on environmental quality by using exogenous geographic determinants of trade as instrumental variables. I include
two air quality indicators: sulfur dioxide and carbon dioxide, and use data on RTAs’ intra-group trade intensity and total trade intensity in 178 countries over the period 1960-2006. I examine to what extent environmental quality of countries with RTAs has been affected compared with countries without RTAs, and whether these effects differ by the share of RTAs to the overall trade volume, FDI inflows, GDP intensity (which indicates the importance of each RTA to the host country), income levels, geographical locations, and time periods. Lastly, I consider both the direct and indirect effects that RTAs bring about. I incorporate foreign direct investment (FDI) as a strategic interaction with RTAs to explain their effects on environmental degradation together.

Chapter 4 addresses how natural disasters affect FDI. Studies suggest it is still unclear whether natural disasters serve as creative destruction or have an adverse impact on the economy. Foreign direct investment, a key channel of international capital flow, has increased remarkably in the past several decades but is rarely investigated if it is affected by natural disasters. This paper investigates natural disasters—another type of risk foreign investors takes into account, that will influence potential physical capital, human capital, and infrastructure damages and reconstruction. Both recent and the historical natural disasters could be crucial for investors from a risk perspective. This paper examines the effects of natural disasters on foreign direct investment from three different perspectives using data from 214 countries over 1985-2014 in both short term and long term.
CHAPTER 2
TRADE RESTRICTIONS AND INCENTIVES TO TAX POLLUTION EMISSIONS

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 the welfare of the trading countries. As Hufbauer et al. (2009) summarize, three arguments for the use of BTAs exist. First, BTAs would prevent “emission leakages” due to shifts in (emission-generating) production activities from countries with emissions regulation to countries with more lenient regulation. Second, it could provide a level playing field for firms facing strict emissions regulations. Third, BTAs would work as a means to encourage more stringent emissions regulations in (developing) countries.

Bills that have been proposed in the US House and Senate related to BTA include the Waxman-Markey bill, the Kerry-Lieberman proposal, and the Cantwell Clear Act. BTAs, as discussed in these US House and Senate bills, are proposed to encourage non-Annex-I countries, such as China, India, and Brazil, to adopt domestic GHG reduction policies. GHG emissions are expected to increase in these countries as their economies grow into the future. Existing UN-based multilateral negotiations (through the Framework Convention) try to provide these developing countries with incentives to adopt GHG reduction measures. However, neither the Kyoto Protocol, nor the Copenhagen Summit succeeded as a global agreement on climate change mitigation. Given the limitations of such traditional international environmental agreements (IEA), some policymakers argue that BTAs may constitute a separate, bilateral, and more flexible measure to provide the same incentives: in the presence of BTAs, China and other countries may have stronger incentives to adopt GHG reduction policies to avoid being subject to a BTA.

We apply a simple two-country/region trade model to address the last question that Hufbauer et al. (2009) raised, with some implications for the first two questions as well. By applying a partial equilibrium model, this paper attempts to examine how trade

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1 This chapter draws from a joint research project with Nori Tarui and Morihiro Yomogida
restrictions affect the incentives for any exporting country to choose a tax on the emission of greenhouse gases. Specifically, suppose a subset of countries restrict emissions. Do BTAs by these countries encourage the other country (or countries) to restrict emissions? This question is of high policy relevance because countries such as the United States and Japan may decide to control GHG emissions and adopt BTAs. How would a country such as China react to these policies?

We show that regardless of the order of moves by the importer and the exporter, in cases of noncooperative optimal policies, an increase in the exogenous tariff for the importer induces the exporter to adopt more lenient emissions regulations. An exception the case when the exporter moves first: the result holds if the domestic marginal damage of the exporter is large enough. When the tariff is endogenous, an import tariff would induce the exporting country to choose a lower emission tax than it would have if the importing country were unable to impose a tariff. This result suggests that import restrictions would not encourage other countries to adopt more stringent environmental regulations.

Numerous studies have analyzed the optimal environmental and trade policies for both small and large countries. They tend to focus on a country's optimal decision, but 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 Pigovian 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 an import tariff or emissions tax) is available. Copeland (1996) analyzes the optimal unilateral policy for a home country and finds that if a foreign country introduces pollution regulation, the home country’s incentive to implement a pollution content tariff may increase because of the opportunity for rent-shifting.

Unlike these studies, several other studies have analyzed the outcomes of strategic trade and environmental policies with multiple countries. Ludema and Wooton (1994) propose a partial equilibrium model with transboundary pollution, where emissions in a foreign country generate externalities in another country, but production in the home country creates no externalities. Copeland (1990) analyzes a two-stage game that has countries choose tariffs cooperatively in the first stage, and choose pollution taxes noncooperatively in the second stage. Ferrara et al. (2009) examine the effects of three trading rules—discriminatory tariffs, MFN tariffs, and free trade on environmental standards. Each country sets abatement standards noncooperatively in the first stage, and simultaneously chooses tariffs given the tariff regime in the second stage.
Overall, building on these previous studies, we address the consequences of strategic interactions among large countries in a more generalized situation that corresponds to the debate on BTAs in the context of climate change policies. Our model analyzes a situation where both the country imposing BTAs and the country facing BTAs by trade partners act strategically. As in the case of climate change, both countries generate pollution that causes negative externalities, and the transboundary pollution affects all countries.

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

2 The Model

Although many studies have analyzed trade policy using a general equilibrium model, it is common to adopt partial equilibrium models in studies that analyze strategic interactions between countries (Ludema and Wooton, 1994; Barrett, 1994; Mæstad, 1998). As is demonstrated below, the analytics of strategic policy decisions are fairly complicated, even in a partial equilibrium framework. The partial equilibrium analysis in this paper allows us to illustrate the effects of a BTA on environmental policies in each country in a transparent manner; we have a discussion of the general equilibrium case in Section 5.

Suppose two countries trade two goods, one homogenous non-numeraire good and one numeraire. The non-numeraire good is produced and consumed in both countries. Its production generates negative externalities (pollution that affects both countries). The non-numeraire good is subject to tariffs, while the numeraire good is a clean good (i.e. its production does not generate externalities) and freely traded. In the following, we define the “exporter” to be the country that exports the non-numeraire good, and the “importer” to be the country that imports the non-numeraire good. 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 a trade tax $\tau_i \geq 0$. The trade tax is interpreted as an import tariff if the country is an importer and as an export subsidy if it is an exporter. The consumer and producer prices at country $i$ are

$$p_i = p_w + \tau_i,$$

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

$$w_{e_i} = \frac{p_i - e_i}{q_i}.$$

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where $p_i$ is the consumer (buyers’) price, $q_i$ is the producer (sellers’) price, and $p_w$ is the world price.

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 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

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

We assume that a unit of production generates a unit of pollution in each country. Hence no pollution abatement, which would reduce the amount of pollution per unit of output, is considered here (see Section 5 for a discussion of pollution abatement). Suppose a share $\lambda$ of the pollution in countries $i$ and $j$ spills over to country $k$. Let $Y_{i-k} = \sum_{j \neq i} y_j$ (the sum of outputs in countries other than $i$) and $Y_i = y_i + \lambda Y_{i-k}$ (the amount of pollution in country $i$). Let $D_i(Y_i)$ be the damage due to pollution in country $i$. We assume that the damage function is linear. This assumption is reasonable for a static analysis of climate change policies because the total stock of GHG is so large that the damage to the environment caused by an additional unit of pollution in a year is not substantial and is unlikely to change the marginal damage due to climate change in the future. The parameter $\lambda$ represents the degree of transboundary pollution. The case $\lambda = 1$ would correspond to GHG emissions (or complete spillover). With $\lambda = 0$, the 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

$$\Pi_i(\tau, e) = \int_{\omega_i}^\infty x_i(\omega)d\omega + \beta \int_0^{q_i} y_i(\omega)d\omega + \tau_i M_i + e_i y(q_i) - \gamma_i D_i(Y_i),$$

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

We model a situation where a GHG emission-intensive good is exported from country 2 to country 1, under both cooperative and noncooperative solutions. We consider a situation where country 2 exports the good to countries 1. (We can imagine

---

2 Limao (2005) states that the linear demand and supply functions are standard in similar analysis of strategic effects of trade policies and imply that the cross derivative of world prices with respect to tariffs and environmental taxes is zero.
that countries 1 and 2 represent the United States and China.) For this purpose, we assume that the countries are identical; except that country 2's marginal costs for non-numeraire production are lower than countries 1's marginal costs.

3 The Cooperative Solution

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

$$\max_{\tau, e} \Pi_i(\tau, e) + \Pi_2(\tau, e)$$

such that

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

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 Pigovian level, which equals to the sum of the marginal damages in both countries.

4 Noncooperative Outcomes

When countries choose policies noncooperatively, would the exporter choose a higher environmental tax rate when the importer can use a tariff in addition to an environmental tax or when a tariff is not available to the importer? That is, does a tariff work to induce the exporter to set stricter environmental regulations?

We consider three alternative sequences of moves.

1. Simultaneous moves, where the exporter and the importer move at the same time.
2. Sequential moves, where the exporter moves first (by choosing an environmental tax) and then the importer moves (by choosing an environmental tax and a tariff).
3. Sequential moves, where the importer moves first (by choosing an environmental tax and a tariff) and then the exporter moves (by choosing an 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 a tariff is available) and country 2 chooses $e_2$. We assume that a tariff is not available or is exogenously given for country 2. We imagine a situation where, through free trade negotiations, the use of tariffs as a policy variable has been ruled out and investigate what happens if the importer implements a 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

$$x_i(p_w) + x_2(p_w) = y_1(p_w - e_i) + y_2(p_w - e_2).$$

Total differentiation of this condition yields the following derivatives of the equilibrium world price:

$$P_{e1} = \frac{\partial P_w}{\partial e_1} = \frac{y_1'}{y_1' + y_2' - x_1' - x_2'} > 0,$$

$$P_{e2} = \frac{\partial P_w}{\partial e_2} = \frac{y_2'}{y_1' + y_2' - x_1' - x_2'} > 0.$$

Note that $0 < P_{e_i} < 1$ for $i = 1, 2$. Thus, the environmental taxes increase the equilibrium world price.

4.1.2 The Equilibrium World Price When $\tau_i$ is Available

The market clearing condition implies

$$x_i(p_w + \tau_i) + x_2(p_w) = y_1(p_w + \tau_i - e_i) + y_2(p_w - e_2).$$

Total differentiation of this condition yields the following derivatives of the equilibrium world price

$$P_{e1} = \frac{\partial P_w}{\partial e_1} = \frac{y_1'}{y_1' + y_2' - x_1' - x_2'} > 0,$$

$$P_{e2} = \frac{\partial P_w}{\partial e_2} = \frac{y_2'}{y_1' + y_2' - x_1' - x_2'} > 0,$$

$$P_{\tau1} = \frac{\partial P_w}{\partial \tau_1} = \frac{x_1' - y_1'}{y_1' + y_2' - x_1' - x_2'} < 0.$$

Note that $0 < P_{\tau_1} < 1, 0 < P_{e_2} < 1$, and $-1 < P_{\tau_1} < 0$. The tariff tends to reduce the equilibrium world price.

4.2 When Two Countries Move Simultaneously

Let $\hat{e}_i$ and $\hat{\tau}_i$ $(i = 1, 2)$ represent the best response functions, and $e_i^*$ $(i = 1, 2)$ represent the optimal taxes. Let $(e_1^*, \tau_1^*, e_2^*)$ be the Nash equilibrium for the simultaneous-move case when $\tau_i$ is available. Let $(e_1^*, e_2^*)$ be the Nash equilibrium for the simultaneous-move case when $\tau_i$ is not available.

Let $\bar{y}_i$ and $\bar{x}_i$ be country $i$’s production and consumption with free trade and

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4.2.1 \( \tau_1 \) is Available

First-order conditions and implicit expressions of the control variables

The exporter’s problem is to maximize

\[
\Pi_2(\tau_1, e_1, e_2) = \int_{p_i}^\infty x_2(\omega)d\omega + \beta \int_{0}^{\omega_1} y_2(\omega)d\omega + \tau_2(y_2 - x_2) + e_2(y_2(q_2) - \gamma y_2 D_2(y_2 + \lambda y_1)).
\]

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

\[
-x_2 \cdot P_e + y_2 \cdot (\beta_2(P_e - 1) + 1) + \tau_2(y_2'(P_e - 1) - x_2') + e_2 y_2'(P_e - 1) - \gamma y_2 D_2'(y_2'(P_e - 1) + \lambda y_2 P_e) = 0.
\]

So \( e_2 \) must satisfy

\[
e_2 = \frac{-x_2 P_e + y_2(\beta_2(P_e - 1) - 1)}{y_2'(1 - P_e)} + \frac{\tau_2(y_2'(P_e - 1) - x_2')}{y_2'(1 - P_e)} + \frac{\gamma y_2 D_2'(y_2'(P_e - 1) + \lambda y_2 P_e)}{y_2'(1 - P_e)}.
\]

The coefficient of the term involving \( \tau_2 \), which refers to the export tax revenue effect, is negative. Given \( \tau_2 \leq 0 \) (i.e., country 2 imposes an export tax), the second term is positive.

When \( \beta_2 = \gamma_2 = 1 \) and \( \tau_2 = 0 \), the condition reduces to:

\[
e_2 = \frac{(y_2 - x_2)P_e}{y_2'(1 - P_e)} + \delta + \frac{-\delta_2 \lambda y_2' P_e}{y_2'(1 - P_e)}.
\]

The first term corresponds to the terms-of-trade effect, which is positive for the exporter.

The second term equals the domestic marginal damage caused by the emission \( y_2 \), and the third term represents the marginal spillover effects, which is always negative.

Because country 2 does not have a tariff as a control variable, its emission tax \( e_2 \) must address all of these three effects in equilibrium. This result has been found in many studies, including Markusen (1975), Krutilla (1991), and Rauscher (1997).

The importer’s problem is to maximize

\[
\Pi_1(\tau_1, e_1, e_2) = \int_{\omega_1}^\infty x_1(\omega)d\omega + \beta_1 \int_{0}^{\omega_1} y_1(\omega)d\omega + \tau_1(x_1 - y_1) + e_1 y_1(q_1) - \gamma y_1 D_1(y_1 + \lambda y_2).
\]

The importer’s first order condition for an interior solution is

\[
\frac{\partial \Pi_1}{\partial \tau_1} = P_e I(y_1 - x_1) - \tau_1(1 + P_e)(y_1' - x_1') + e_1(1 + P_e)y_1' - \delta_q(y_1'(1 + P_e) + \lambda y_2 P_e) = 0,
\]

\[
\frac{\partial \Pi_1}{\partial e_1} = P_e I(y_1 - x_1) + \tau_1(x_1'P_e - y_1'(P_e - 1)) + e_1 y_1'(P_e - 1) - \delta_q(y_1'(P_e - 1) + \lambda y_2' P_e) = 0.
\]

These conditions imply

\[
\dot{e_1} = \delta_1,
\]
\[
\tau_1 = \frac{(y_1 - x_1)P_{y_1}}{(y_1' - x_1')(1 + P_{y_1})} + \frac{-\delta_1 y_1' P_{y_1}}{(y_1' - x_1')(1 + P_{y_1})}.
\]

Note that \( -1 < P_{y_1} < 0 \), \((y_1' - x_1')(1 + P_{y_1}) > 0 \), and \( y_1 - x_1 < 0 \) because country 1 is an importer. As for the tariff, then, 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 \( e_1^* \) satisfies \( e_1^* = \delta \) (i.e., the Pigovian tax level) and is independent of the exporter’s tax level. That is, when a 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 стратегических effects (i.e., the terms-of-trade effect and the emissions spillover effect). The observation that a large country’s optimal environmental tax rate should equal the marginal damage when a tariff is available has been found in the prior literature (Markusen, 1975; Krutilla, 1991; Rauscher, 1997; Mæstad, 1998).

The following lemma describes the nature of the best response functions.

**Lemma 1** In the simultaneous-move game, suppose \( x_i'' = y_i'' = 0 \) and \( D_i'' = 0 \) for \( i = 1,2 \).

Suppose also that \( \beta_i = \gamma_i = 1 \) for all \( i \). Then \( \frac{d\hat{e}_2}{d\tau_1} < 0 \) and \( \frac{d\hat{e}_1}{de_2} < 0 \).

See the appendix for the proof of Lemma 1 and all subsequent results. Lemma 1 states that the exporter’s emission tax and the importer’s tariff are strategic substitutes. Both address the positive terms-of-trade effect, so they move in opposite directions. The increasing tariff reduces the exporter’s positive terms-of-trade effect, and hence, the exporter has an incentive to lower its environmental tax to keep its export sector competitive. Note that \( \frac{d\hat{e}_1}{de_2} = 0 \) because \( \hat{e}_1 = \delta_1 \) and is independent of \( e_2 \), given linear damage functions.

### 4.2.2 \( \tau_1 \) is Not Available

First-order conditions and implicit expressions of the control variables

The implicit expression of the equilibrium \((e_1^f, e_2^f)\) is the same as in the case where \( \tau_1 \) is available.

The first order conditions are

\[
(y_2 - x_2)P_{e_2} + e_2y_2'(P_{e_2} - 1) - \delta_2(y_2'(P_{e_2} - 1) + \lambda y_2'P_{e_2}) = 0,
\]
\[(y_i - x_i)P_{e_i} + e_i'y_i'(P_{e_i} - 1) - \delta_i(y_i'(P_{e_i} - 1) + \lambda y_i'P_{e_i}) = 0.\]

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 (the importer) and positive for country 2 (the exporter), while the third term is negative for both countries. Therefore, the importer’s equilibrium emissions are lower when a tariff is not available:
\[e_i^0 = \delta_i > e_i'.\]

The following lemma describes the nature of the best response functions.

**Lemma 2** In the simultaneous-move game, suppose \[x_i'' = y_i'' = 0\] and \[D_i'' = 0\] for \[i = 1, 2.\]

Suppose also that \[\beta_i = \gamma_i = 1\] for all \[i\]. Then \[\frac{de_1}{de_i} > 0\] and \[\frac{de_2}{de_i} > 0.\]

Lemma 2 states that the exporter’s emission tax and the importer’s emission tax are strategic complements. The importer addresses the negative terms-of-trade effect, while the exporter addresses the positive terms–of-trade effect, so they move in same direction. Increasing the importer’s environmental taxes enhances the exporter’s positive terms-of-trade effect; hence, the exporter has an incentive to increase its environmental tax, and vice versa.

**4.2.3 Comparing \(e_1'\) and \(e_2'\)**

To provide the intuition behind the case where the tariff is endogenous, we now consider a game where the importer’s tariff is given exogenously first. How do the Nash equilibrium environmental taxes change when the tariff rate increases exogenously? Even though we have shown that the best response function of \(e_2\) decreases as the tariff increases, how the equilibrium value of \(e_2\) changes according to the change of the tariff still depends on the relative impacts of a tariff increase on \(e_1\) and \(e_2\). This is because \(e_1\) and \(e_2\) are strategic complements to each other (see Figure 1). On the basis of the best response functions we obtained above, we use comparative statics to show the changes in equilibrium environmental taxes \(e_1\) and \(e_2\) when the tariff changes exogenously.

Now we present one of the main results so far.

**Proposition 1** Let \((e_1^*, e_2^*)\) be the Nash Equilibrium of the simultaneous-move game with
exogenous tariffs. When two countries move simultaneously, suppose \( x^*_i = y^*_i = 0 \) and \( D^*_i = 0 \) for \( i = 1,2 \) (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 \( \frac{de^*_2}{d\tau_1} < 0 \) and \( \frac{de^*_1}{d\tau_1} > 0 \).

An implication of the proposition is that the availability of the exogenous tariff for the importer induces the exporter to adopt more lenient emissions regulations but encourages the importer to adopt more stringent environmental regulations.

This is because when a tariff is available as a policy tool, it could address all strategic effects other than the domestic externality concerns due to domestic pollution, i.e., the terms–of–trade and spillover effects. The importer’s environmental tax would be equal to the Pigovian tax rate when the importer chooses its tariff optimally. When a tariff is not available, the importer’s environmental tax has to decrease to address strategic effects, which were the responsibilities of the tariff. The incentive for the exporter works in the following way: the increasing tariff reduces the exporter’s positive terms–of–trade effect; hence, the exporter has an incentive to lower its environmental tax to keep its export sector competitive. Therefore, if we consider the exporter’s strategic reactions, the use of a tariff by importers will not induce exporters to tighten their externality regulations.\(^3\)

\(^3\) Unless \( y'_2 \) is too large, the exporter’s emission tax acts only as a partial substitute for the import tariff. Therefore, in terms of the emission tax and trade tax substitution, trade tax is better than nothing because the exporter’s emission tax rate is higher than trade tax. However, we do not know if that is the case for welfare.
Figure 1. Shifts in best responses when import tariff increases exogenously

Figure 1 shows the result described in Proposition 1: as the tariff increases exogenously, the equilibrium environmental tax for the importer increases, while the equilibrium environmental tax of the exporter decreases. Lemma 2 indicates that $e_1$ and $e_2$ are strategic complements, so both of their slopes are positive. Because the best response function of $e_1$ shifts up and the best response function of $e_2$ shifts down as the tariff increases exogenously, the equilibrium taxes move from the point denoted by the triangle to that denoted by the circle. This result allows us to compare the equilibrium environmental tax for the exporter in a game when a tariff is available for the importer and in a game when it is not available (Proposition 2).

**Proposition 2** Let $e_{2}^{l}$ and $e_{2}^{f}$ be the exporter’s Nash Equilibrium environmental taxes when a tariff is available and not available, respectively. When two countries move simultaneously, suppose $x_{i}^{e} = y_{i}^{e} = 0$ and $D_{i}^{e} = 0$ for $i = 1,2$ (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 a tariff on its import, i.e.,

$$e_{2}^{l} < e_{2}^{f}$$

Proposition 2 indicates that the equilibrium environmental tax rate for the exporter is smaller when the importer uses an import tariff than when the importer does not. An implication of this proposition is that the availability of a tariff for the importer does not induce the exporter to adopt more stringent environmental regulations.
As we will see below, the conclusions of Proposition 1 and Proposition 2 hold regardless of the order of moves by the exporter and the importer.

4.3 When the Importer Moves First

4.3.1 $\tau_1$ is Available

First-order conditions and implicit expressions of the control variables

The exporter’s problem is the same as in the simultaneous-move case

$$\Pi_2(\tau_1, e_1, e_2) = \int_{p_2}^{q_2} x_2(\omega)d\omega + \beta_2 \int_{y_2}^{y_1} y_2(\omega)d\omega + e_2 y_2(q_2) - \gamma_2 D_2(y_2 + \lambda y_1).$$

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

$$-x_2 \cdot P_{e_2} + y_2 \cdot (\beta_2(P_{e_2} - 1) + 1) + \tau_2 (y_2'(P_{e_2} - 1) - x_2' \cdot P_{e_2}) + e_2 y_2'(P_{e_2} - 1) - \gamma_2 D_2(y_2(P_{e_2} - 1) + \lambda y_1' P_{e_2}) = 0,$$

when $\beta_2 = \gamma_2 = 1$ and $\tau_2 = 0$, $e_2$ must satisfy

$$e_2 = \frac{y_2'(1 - P_{e_2})}{y_2'(1 - P_{e_2})} + \delta_2 + \frac{-\delta_2 \lambda y_1' P_{e_2}}{y_2'(1 - P_{e_2})}.$$

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 $y_2$ and is positive. The third term represents the marginal spillover effects, which is always negative.

The importer’s problem is to maximize

$$\Pi_1(\tau_1, e_1, e_2) = \int_{p_1}^{q_1} x_1(\omega)d\omega + \beta_1 \int_{y_1}^{y_1} y_1(\omega)d\omega + e_1 y_1(q_1) - \gamma_1 D_1(y_1 + \lambda y_2).$$

The importer’s first order condition for an interior solution is

$$-x_1 \cdot P_{e_1} + y_1 \cdot (\beta_1(P_{e_1} - 1) + 1) + \tau_1 (y_1'(P_{e_1} - 1) - x_1' \cdot P_{e_1}) + e_1 y_1'(P_{e_1} + P_{e_2} \frac{\partial e_2}{\partial \tau_1}) y_1'$$

$$- \delta_1 [y_1'(1 + P_{e_1} + P_{e_2} \frac{\partial e_2}{\partial \tau_1}) + \lambda y_2'(P_{e_1} + P_{e_2} \frac{\partial e_2}{\partial \tau_1}) - \frac{\partial e_2}{\partial \tau_1}] = 0, $$

$$\frac{\partial \Pi_1}{\partial e_1} = (P_{e_1} + P_{e_2} \frac{\partial e_2}{\partial e_1})(y_1 - x_1) + \tau_1 (y_1'(P_{e_1} + P_{e_2} \frac{\partial e_2}{\partial e_1}) - y_1'(P_{e_1} + P_{e_2} \frac{\partial e_2}{\partial \tau_1} - 1)) + e_1 y_1'(P_{e_1} + P_{e_2} \frac{\partial e_2}{\partial e_1} - 1)$$

$$- \delta_1 [y_1'(P_{e_1} + P_{e_2} \frac{\partial e_2}{\partial e_1} - 1) + \lambda y_2'(P_{e_1} + P_{e_2} \frac{\partial e_2}{\partial e_1} - \frac{\partial e_2}{\partial e_1})] = 0.$$
\[
\frac{dP_w}{d\tau_1} = \frac{\partial p_w}{\partial \tau_1} + \frac{\partial p_w}{\partial e_2} \frac{\partial e_2}{\partial \tau_1}, \quad \text{and} \quad \frac{dP_w}{de_1} = \frac{\partial p_w}{\partial e_1} + \frac{\partial p_w}{\partial e_2} \frac{\partial e_2}{\partial e_1}.
\]

These conditions imply

\[
\hat{\epsilon}_1 = \delta_1,
\]

\[
\tau_1 = \frac{(y_1 - x_1)(P_{\tau_1} + P_{\tau_2} \frac{\partial e_2}{\partial \tau_1}) - \delta_1 \lambda y_2'(P_{\tau_1} + P_{\tau_2} \frac{\partial e_2}{\partial \tau_1}) - \frac{\partial e_2}{\partial \tau_1}}{(y'_1 - x'_1)(1 + P_{\tau_1} + P_{\tau_2} \frac{\partial e_2}{\partial \tau_1})}.
\]

Note that \(-1 < P_{\tau_1} < 0\), \(\frac{\partial e_2}{\partial \tau_1} < 0\), \(P_{\tau_1} + P_{\tau_2} \frac{\partial e_2}{\partial \tau_1} < 0\), and \(y_1 - x_1 < 0\) because country 1 is an importer. As for the tariff, the expression is similar to the case of simultaneous moves. The difference is that \(\frac{\partial p_w}{\partial \tau_1}\) is replaced by \(\frac{dP_w}{d\tau_1}\). The first term (the terms-of-trade effect) is positive, and the second term (the marginal spillover effect) is positive as well.

As in the simultaneous-move game, the equilibrium environmental tax choice by the importer \(e_1^*\) satisfies \(e_1^* = \delta\) (i.e., the Pigovian tax level) and is independent of the exporter's tax level. That is, when a 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 observation that a large country's optimal environmental tax rate should equal the marginal damage when a tariff is available has been found in the prior literature (Markusen, 1975; Krutilus, 1991; Rauscher, 1997).

The following lemma describes the nature of the best response functions.

**Lemma 3** In the game where the importer moves first, suppose \(x_i^* = y_i^* = 0\) and \(D_i^* = 0\) for \(i = 1, 2\). Suppose also that \(\beta_i = \gamma_i = 1\) for all \(i\), then \(\frac{\partial \hat{e}_2}{\partial \tau_1} < 0\) holds.

Lemma 3 states that the exporter’s emission tax decreases when the importer’s tariff increases. Note that \(\frac{d\hat{e}_1}{de_2} = 0\) because \(\hat{e}_1 = \delta_1\) and is independent of \(e_2\) given linear damage functions.

4.3.2 \(\tau_1\) is not Available
First-order conditions and implicit expressions of the control variables

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

The implicit expression of \( e_2 \) is the same as in the case where \( \tau_i \) is available.

The first order conditions are

\[
(y_2 - x_2)\pi_e + e_2 y'_2 (\pi_e - 1) - \delta_2 (y'_2 (\pi_e - 1) + \lambda y'_1 \pi_e) = 0,
\]

so

\[
e_2 = \frac{(y_2 - x_2)\pi_e}{y'_2 (1 - \pi_e)} + \delta_2 + \frac{\delta_2 \lambda y'_1 \pi_e}{y'_2 (1 - \pi_e)}.
\]

Observe that the first term corresponds to the terms-of-trade effect, which is positive for country 2 (the exporter), while the third term is negative for both countries.

The importer’s first order condition for an interior solution is

\[
(P_{e1} + P_{e2} \frac{\partial e_2}{\partial e_1}) (y_1 - x_1) + e_1 y'_1 (P_{e1} + P_{e2} \frac{\partial e_2}{\partial e_1} - 1)
\]

\[
- \delta_1 [y'_1 (P_{e1} + P_{e2} \frac{\partial e_2}{\partial e_1} - 1) + \lambda y'_2 (P_{e1} + P_{e2} \frac{\partial e_2}{\partial e_1} - \frac{\partial e_1}{\partial e_1})] = 0.
\]

where \( \frac{dP_w}{de_1} \equiv \frac{\partial p_w}{\partial e_1} + \frac{\partial p_w}{\partial e_2} \frac{\partial e_2}{\partial e_1} \)

So

\[
e_1 = \frac{(y_2 - x_2)\frac{dP_w}{de_1}}{y'_1 \left(1 - \frac{dP_w}{de_1}\right)} + \delta_1 + \frac{\delta_2 \lambda y'_1 \left(\frac{dP_w}{de_1} - \frac{d e_2}{de_1}\right)}{y'_2 \left(1 - \frac{dP_w}{de_1}\right)}.
\]

The expression is similar to the case with simultaneous moves. The difference is that \( \frac{\partial p_w}{\partial e_1} \) is replaced by \( \frac{dP_w}{de_1} \). The first term (the terms-of-trade effect) is negative for country 1 (the importer), the second term (the marginal spillover effect) is positive, and the third term is always negative. Therefore, the importer's equilibrium emission is lower when a tariff is not available.

\[
e_i^f = \delta_i > e_i^f.
\]

The following lemma describes the nature of the best response functions.

**Lemma 4** In the game where the importer moves first, suppose \( x_i^* = y_i^* = 0 \) and \( D_i^* = 0 \).
for \( i = 1,2 \). Suppose also that \( \beta_i = \gamma_i = 1 \) for all \( i \), then \( \frac{de_2}{de_1} > 0 \).

Lemma 4 states that the exporter’s emission tax increases when the importer’s emission tax increases.

### 4.3.3 Comparing \( e_2' \) and \( e_2'' \)

The results for the simultaneous-move game hold in the game where importer moves first.

**Proposition 3** Let \((e_1^*, e_2^*)\) be the Nash equilibrium of the game where the importer moves first with exogenous tariffs. Suppose that \( x_i'' = y_i'' = 0 \) and \( D_i'' = 0 \) for \( i = 1,2 \) (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 \( \frac{de_2^*}{d\tau_1} < 0 \), \( \frac{de_1^*}{d\tau_1} > 0 \).

**Proposition 4** Let \( e_2', e_2'' \) be the exporter’s Nash Equilibrium environmental taxes when a tariff is available and not available, respectively. When the importer moves first, suppose \( x_i'' = y_i'' = 0 \) and \( D_i'' = 0 \) for \( i = 1,2 \) (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). The exporter’s equilibrium emission tax rate is lower when the importer imposes a tariff on its import, i.e.,

\[
e_2' < e_2''.
\]

An implication of the proposition is that the availability of a tariff for the importer does not induce the exporter to adopt more stringent environmental regulations.

### 4.4 When the exporter moves first

#### 4.4.1 \( \tau_1 \) 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

\[
\Pi_i(\tau_1, e_1, e_2) = \int_{\beta_1}^{\beta_2} x_i(\omega) d\omega + \beta_1 \int_{0}^{\gamma_1} y_i(\omega) d\omega + \tau_1 (y_i - x_i) + e_i y(q_i) - \gamma_i D_i(Y_i).
\]
The first order condition's for the Importer's payoff maximization
\[ P_{r_1}(y_1 - x_i) - \tau_1(1 + P_{r_1})(y_i' - x_i') - \delta_y y_i' P_{r_1} = 0. \]

These conditions imply
\[ \hat{e}_1 = \hat{\delta}_1, \]
\[ \tau_1 = \frac{(y_1 - x_i)P_{r_1}}{(y_i' - x_i')(1 + P_{r_1})} + \frac{-\delta_y y_i' P_{r_1}}{(y_i' - x_i')(1 + P_{r_1})}. \]

Note that \(-1 < P_{r_1} < 0, (y_i' - x_i')(1 + P_{r_1}) > 0\), and \(y_i - x_i < 0\) because country 1 is an importer. Therefore, the first term (the terms-of-trade effect) is positive, and the second term (the marginal spillover effect) is positive as well.

The exporter's payoff is given by
\[ \Pi_2(e_2) \equiv \int_{p_w}^{P_{r_2}} x_2(\omega)d\omega + \int_{0}^{p_w - e_2} y_2(\omega)d\omega + e_2y_2(p_w - e_2) - D_2(y_2(p_w - e_2) + \lambda y_2(p_w + \tau_1(e_2) - e_1(e_2))), \]

and the first-order condition for an interior solution is
\[ \frac{d\Pi_2}{de_2} = -x_2 \cdot \frac{dP_w}{de_2} + y_2 \left( \frac{dP_w}{de_2} - 1 \right) + e_2y_2 \left( \frac{dP_w}{de_2} - 1 \right) + y_2 \]
\[ - \hat{\delta}_2 \left[ \lambda y_2 \left( \frac{dP_w}{de_2} + \frac{d\tau_1}{de_2} \right) + y_2 \left( \frac{dP_w}{de_2} - 1 \right) \right] = 0, \]

where \( \frac{dP_w}{de_2} \) is the total derivative of the world price with respect to \( e_2 \)
\[ \frac{dP_w}{de_2} = \frac{\partial p_w}{\partial e_2} + \frac{\partial p_w}{\partial \tau_1} \frac{\partial \tau_1}{\partial e_2} + \frac{\partial p_w}{\partial e_1} \frac{\partial e_1}{\partial e_2} = \frac{\partial p_w}{\partial e_2} + \frac{\partial p_w}{\partial \tau_1} \frac{\partial \tau_1}{\partial e_2}. \]

Note that \( \frac{\partial e_1}{\partial e_2} = 0 \) 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
\[ e_2 = \frac{(y_2 - x_i) \frac{dP_w}{de_2}}{y_2' \left( 1 - \frac{dP_w}{de_2} \right)} + \frac{-\hat{\delta}_2 y_2' \left( \frac{dP_w}{de_2} + \frac{d\tau_1}{de_2} \right)}{y_2' \left( 1 - \frac{dP_w}{de_2} \right)}.
\]

The expression is similar to the case with simultaneous moves. A difference is that the partial derivative of \( p_w, \frac{\partial p_w}{\partial e_2} \), is now replaced by the total derivative \( \frac{dP_w}{de_2} \). 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 $y_2$, 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 Pigovian tax level) and is independent of the exporter's tax level. That is, when a 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 observation that a large country's optimal environmental tax rate should equal the marginal damage when a tariff is available has been found in the prior literature (Markusen, 1975; Krutilla, 1991; Rauscher, 1997; Mæstad, 1998).

The following lemma describes the nature of the best response functions.

**Lemma 5** In the game where the exporter moves first, suppose $x_i^* = y_i^* = 0$ and $D_i^* = 0$ for $i = 1, 2$. Suppose also that $\beta_i = \gamma_i = 1$ for all $i$, then $\frac{d\bar{\tau}_1}{de_2} < 0$ holds.

Lemma 5 states that the importer’s tariff decreases when the exporter’s emission tax increases. Note that $\frac{d\bar{\tau}_1}{de_2} = 0$ because $\bar{\tau}_1 = \delta_1$ and is independent of $e_2$, given linear damage functions.

### 4.4.2 $\tau_1$ 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:

$$(y_1 - x_1)P_{e_1} + e_1 y'_1(P_{e_1} - 1) - \delta_1(y_1(P_{e_1} - 1) + \lambda y_2' P_{e_1}) = 0.$$ 

So

$$e_1 = \frac{(y_1 - x_1)P_{e_1}}{y'_1(1 - P_{e_1})} + \delta_1 + \frac{-\delta_1 \lambda y_2' P_{e_1}}{y'_1(1 - P_{e_1})}. $$

Observe that the first term (ToT effect) is negative for country 1 (the importer) and positive for country 2 (the exporter), while the third term is negative for both countries. Therefore, the importer's equilibrium emission is lower when a tariff is not available

$$e_1^* = \delta_1 > e_1^f.$$ 

The exporter's payoff is
\[ \Pi_2(e_2) \equiv \int_{p_w}^{e_2} x_2(\omega) d\omega + \int_0^{e_2} y_2(\omega) d\omega + e_2 y_2(p_w - e_2) - D_2(y_2(p_w - e_2) + \lambda y_2(p_w - e_1(e_2)) \]

The first order condition for an interior solution is

\[ \frac{d\Pi_2}{de_2} = -x_2 \frac{dP_w}{de_2} + y_2 \left( \frac{dP_w}{de_2} - 1 \right) + e_2 y'_2 \left( \frac{dP_w}{de_2} - 1 \right) + y_2 - \delta_2 \left[ \lambda y_2 \left( \frac{dP_w}{de_2} - \frac{de_1}{de_2} \right) + y'_2 \left( \frac{dP_w}{de_2} - 1 \right) \right] = 0, \]

where

\[ \frac{dP_w}{de_2} \equiv \frac{\partial P_w}{\partial e_2} + \frac{\partial P_w}{\partial e_1} \frac{\partial e_1}{\partial e_2}, \]

and \( \delta_2 \equiv D'_2 \). The condition reduces to

\[ e_2 = \frac{(y_2 - x_2) \frac{dP_w}{de_2}}{y'_2 \left( 1 - \frac{dP_w}{de_2} \right)} + \delta_2 + \frac{-\delta_2 \lambda y'_2 \left( \frac{dP_w}{de_2} - \frac{de_1}{de_2} \right)}{y'_2 \left( 1 - \frac{dP_w}{de_2} \right)}. \]

The expression is similar to the case with simultaneous moves. A difference is that the partial derivative of \( p_w \), \( \frac{\partial P_w}{\partial e_2} \), is now replaced by the total derivative \( \frac{dP_w}{de_2} \). 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 \( y_2 \), and the third term represents the marginal spillover effects, which is always negative.

The following lemma describes the nature of the best response functions.

**Lemma 6** In the game where the exporter moves first, suppose \( x''_i = y''_i = 0 \) and \( D''_i = 0 \) for \( i = 1,2 \). Suppose also that \( \beta_i = \gamma_i = 1 \) for all \( i \). How the exporter’s environmental tax rate affects the importer’s environmental tax rate (i.e. the sign of \( \frac{de_1}{de_2} \)) is ambiguous.

Lemma 6 states that a higher environmental tax imposed by the exporter the change of environmental tax from the importer is ambiguous.

**4.4.3 Comparing \( e'_2 \) and \( e''_2 \)**

**Proposition 5** Let \( e'_2 \) and \( e''_2 \) be the exporter’s Nash Equilibrium environmental taxes when a tariff is available and is not available, respectively. When the exporter moves first, suppose \( x''_i = y''_i = 0 \) and \( D''_i = 0 \) for \( i = 1,2 \) (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). The exporter’s equilibrium emission tax rate is lower when the importer imposes a tariff on its imports, if \( \delta_2 \) is large enough, i.e.,

\[
e'_2 < e'^f.
\]

With this order of moves, the assumption that \( \delta_2 \) is large enough is needed for this proposition to hold.

5 Discussion

Free riding is the greatest barrier to reaching an agreement to mitigate climate change. 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 (an import tariff) affects the incentive for an exporting country to levy a tax on the emission of greenhouse gases. Instead of simply focusing on a country’s optimal decision, we address the consequences 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 than it would if a tariff were not available to the importing country. The result suggests that the emission tax of an exporting country is a strategic substitute for the tariff of an importing country, while it is a strategic complement with the emission tax of an importing country. This result supports our main conclusion that trade restrictions would not encourage other countries to adopt more stringent environmental regulations.

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

To illustrate the consequences of strategic interactions among countries and their consequences on environmental regulations 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 bilateral trade is observed among China, the US, and Japan. Moreover, Japan is a net exporter of Iron/Steel to China, while the US is a net importer from China. In the cement sector, even though Japan and the US are both net importers from China, China consumes most of its
cement products domestically (UN Comtrade 2007, 2008). 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 be to incorporate more countries into the model. If there are more developing countries (exporters) or developed countries (importers), how would it affect other countries’ incentives to carry out environmental regulation and BTA adoptions? Additionally, we do not distinguish BTAs from simple import tariffs. If we precisely define a BTA as the difference between the environmental taxes of two countries, would the results still hold? Another research direction would be to incorporate pollution abatement. When abatement is available, the damage of pollution to developed countries (importers) is smaller than the damage to developing countries (exporters) because developed countries have access to more advanced technology to produce lower pollution per unit of production. How will the abatement affect the result? Would the exporter still have an incentive to adopt more lenient environmental regulations when facing a BTA? 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 Lemma 1

With \( \hat{\delta}_1 \equiv \delta \), the first order condition for the importer is

\[ P_{\tau_1} (y_1 - x_1) - \tau_1 (1 + P_{\tau_1}) (y'_1 - x'_1) - \delta_1 y'_2 P_{\tau_1} = 0. \]

Totally differentiate with respect to \( e_2 \) and \( \tau_1 \)

\[ [-x'_1 P_{e_2}^{\tau_1} P_{\tau_1} + y'_1 P_{e_2}^{\tau_1} P_{\tau_1}] d e_2 + (\Pi_{1rr} d \tau_1) = 0, \]

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

\[ \frac{\partial \hat{\tau}_1}{\partial e_2} = \frac{(x'_1 - y'_1) P_{\tau_1}^{\tau_2} P_{\tau_1}}{\Pi_{1rr}} < 0, \]

where \( x'_1 < 0, y'_1 > 0, P_{\tau_1} < 0, \) and \( P_{\tau_2} > 0. \)
The first order condition for the exporter for an interior solution is

\[-x_2^iP_{\varepsilon_2} + y_2^iP_{\varepsilon_2} + e_2 y_2'(P_{\varepsilon_2} - 1) - D'_2 \cdot [y_2'(P_{\varepsilon_2} - 1) + \lambda y'_1(P_{\varepsilon_2})] = 0.\]

Totally differentiate with respect to $e_2$ and $\tau_1$, yields

\[-x'_2^iP_{\varepsilon_2} + y'_2^iP_{\varepsilon_2} \right) d\tau_1 + (\Pi_{2ee}) de_2 = 0,

where $\Pi_{2ee}$ is the second-order derivative of $\Pi_2$ with respect to $e_2$ and is negative.

Therefore,

\[\frac{\partial \hat{e}_2}{\partial \tau_1} = \frac{(x'_2 - y'_2)^iP_{\varepsilon_2} P_{\varepsilon_2}}{\Pi_{2ee}} < 0,

where $x'_2 < 0, y'_2 > 0, P_{\varepsilon_1} < 0$, and $P_{\varepsilon_2} > 0$.

Analytical expression of the equilibrium solution

\[e'_2 = \frac{\delta_2 \left( \frac{b_i + d_i}{P_{\varepsilon_2}} P_{\varepsilon_2} \right) + F \left[ \delta_1 \{ (b_i + d_i)P_{\varepsilon_2} + d_i \} + (\bar{y}_2 - \bar{x}_2)P_{\varepsilon_2} + \delta_2 \{ d_2 (P_{\varepsilon_2} - 1) + \lambda d_1 P_{\varepsilon_2} \} \right]}{B_2},

\[e'_1 = \delta_1,

where

\[B_i \equiv d_i - (b_i + d_i)P_{\varepsilon_1}^2 (i = 1,2),

\[F \equiv \frac{(b_2 + d_2)P_{\varepsilon_1} P_{\varepsilon_2}}{(b_i + d_i)(1 - P_{\varepsilon_1}^2)},

\[G \equiv \frac{(\bar{y}_2 - \bar{x}_2)P_{\varepsilon_2} - \delta_2 \{ d_2 (P_{\varepsilon_2} - 1) + \lambda d_1 P_{\varepsilon_2} \}}{B_2},

\[A_i \equiv 1 - \frac{(b_2 + d_2)P_{\varepsilon_1} P_{\varepsilon_2}^2}{B_2 (1 - P_{\varepsilon_1}^2)},

\[A_f \equiv 1 - \frac{(b_1 + d_1)(b_2 + d_2)P_{\varepsilon_1}^2 P_{\varepsilon_2}^2}{B_1 B_2}.

Note that $B_i > 0$ for $i = 1,2, G > 0, A_i > 0$, and $A_f > 0$. $G > 0$ follows from

\[
\bar{y}_2 - \bar{x}_2 > 0 \text{ and } d_2 (P_{\varepsilon_2} - 1) + \lambda d_1 P_{\varepsilon_2} < 0.
\]

\[\frac{\partial \hat{e}_2}{\partial \tau_1} = \frac{(x'_2 - y'_2)^iP_{\varepsilon_2} P_{\varepsilon_2}}{\Pi_{2ee}} = \frac{x'_1 x'_2 - x'_2 y'_2 - x'_2 y'_1 + y'_1 y'_2}{-(x'_1 x'_2 - x'_2 y'_2 - x'_2 y'_1 + y'_1 y'_2) + y'_2 y'_2 - y'_1 y'_1 - x'_1 x'_2 - x'_2 x'_2 + x'_2 y'_1 + 2 x'_1 y'_1}.
\]
where \( \frac{\partial e_2}{\partial x_1} \rightarrow -1 \) holds unless \( y_2^2 \) is too large. Therefore, when the importing tariff exists, the decrease of the exporter’s emission tax is smaller than the importing tariff, which means it acts as a partial substitute for the importing tariff.

**Proof of Lemma 2**

Country \( i \)'s payoff is

\[
\Pi_i(e_1; e_{-1}) = \int_{p_w}^{x_i} x_i(\omega) d\omega + \beta \int_0^{\nu_i} y_i(\omega) d\omega + e_i y_i(p_w - e_i) - \gamma_i D_i \left( y_i(p_w - e_i) + \lambda y_j(q_j) \right)
\]

The first order condition for an interior solution is

\[-x_i P_{e_i} + y_i (\beta_i (P_{e_i} - 1) + 1) + e_i y_i (P_{e_i} - 1) - \gamma_i D_i \left[ y_i (P_{e_i} - 1) + \lambda y_j (p_{q_j}) \right] = 0.
\]

With \( \beta_i = 1 \), total differentiation with respect to \( e_i \) and \( e_j \), \( j \neq i \), yields

\[-x_i^i P_{e_j} + y_i^i P_{e_i} + y_i^j P_{e_j} \] \( de_j \) \(+ \left( \Pi_i^* \right) de_i = 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,

\[
\frac{d\hat{e}_i}{de_j} = \frac{(x_i' - y_i') P_{e_i} P_{e_j}}{D_i \Pi_i} > 0,
\]

where \( x_i' < 0, y_i' > 0, P_{e_j} > 0 \), and \( P_{e_j} > 0 \).

**Analytical expression of the equilibrium solution**

\[
G + \frac{(b_2 + d_2) P_{e_1} P_{e_2}}{B_1 B_2} \left[ (\bar{y}_1 - \bar{y}_1) P_{e_1} - \delta_1 \{ d_1 (P_{e_1} - 1) + \lambda d_2 P_{e_1} \} \right] = \frac{B_2}{A_2},
\]

\[
e_2^f = \frac{(b_1 + d_1) P_{e_1} P_{e_2}}{B_1 B_2} \left[ (\bar{y}_1 - \bar{y}_1) P_{e_1} - \delta_1 \{ d_1 (P_{e_1} - 1) + \lambda d_2 P_{e_1} \} \right]
\]

**Proof of Proposition 1**

When two countries move simultaneously, the first order condition with respect to \( e_1 \) for an interior solution for the importer is

\[
\frac{d\Pi_1}{de_2} = e_1 \left[ b_1 P_{e_1} P_{e_2} + d_1 (P_{e_1} - 1) (\beta_1 (P_{e_1} - 1) + 1) + d_1 (P_{e_1} - 1) \right] + \tau_1 \left[ b_1 (P_{e_1} + 1) P_{e_1} + d_1 (P_{e_1} + 1) (\beta_1 (P_{e_1} - 1) + 1) + \left( -b_1 P_{e_1} - \delta_1 \{ d_1 (P_{e_1} - 1) + \lambda d_2 P_{e_1} \} \right) - \left( a_1 - b_1 P_{e_1} \right) P_{e_1} + (c_1 + d_1 P_{e_1}) (\beta_1 (P_{e_1} - 1) + 1) - \gamma_1 \delta_1 (d_1 (P_{e_1} - 1) + \lambda d_2 P_{e_1}) = 0.
\]
The first order condition with respect to $e_2$ for an interior solution for the exporter is
\[
\frac{d\tau_2}{de_2} = e_2 \left[ b_2 P_1 P_2 e_2 + d_2 (P_2 e_2 - 1) (\beta_2 (P_2 e_2 - 1) + 1) + e_2 \left[ b_2 P_1 P_2 e_2 + d_2 P_1 e_2 (\beta_2 (P_2 e_2 - 1) + 1) \right] + \tau_1 \left[ b_2 P_1 P_2 e_2 + d_2 P_1 e_2 (\beta_2 (P_2 e_2 - 1) + 1) \right] - (a_2 - b_2 (P_2^w + \tau_2)) P_1 e_2 + (c_2 + d_2 (P_2^w + \tau_2)) (\beta_2 (P_2 e_2 - 1) + 1) + \tau_2 (d_2 (P_2 e_2 - 1) + b_2 P_2 e_2) - \gamma_3 \delta_1 (d_2 (P_2 e_2 - 1) + \lambda d_1 P_2 e_2) = 0.
\]

Totally differentiate the two equations with respect to $e_1$, $e_2$ and $\tau_1$, and obtain
\[
[b_1 P_1 P_1 e_1 + d_1 (P_1 e_1 - 1) (\beta_1 (P_1 e_1 - 1) + 1) + d_1 (P_1 e_1 - 1)] d\tau_1 = [b_2 P_2 e_2 + d_2 (P_2 e_2 - 1) (\beta_2 (P_2 e_2 - 1) + 1) + d_1 (P_2 e_2 - 1)] d\tau_1.
\]

Therefore,
\[
\begin{pmatrix}
(b_1 P_1 P_1 e_1 + d_1 (P_1 e_1 - 1) (\beta_1 (P_1 e_1 - 1) + 1) + d_1 (P_1 e_1 - 1)) & (b_2 P_2 e_2 + d_2 (P_2 e_2 - 1) (\beta_2 (P_2 e_2 - 1) + 1) + d_2 (P_2 e_2 - 1))
\end{pmatrix}
\begin{pmatrix}
de_1 
d_2
\end{pmatrix} = \begin{pmatrix}
(b_1 P_1 P_1 e_1 + d_1 (P_1 e_1 - 1) (\beta_1 (P_1 e_1 - 1) + 1) + d_1 (P_1 e_1 - 1))
\end{pmatrix}
\begin{pmatrix}
d\tau_1 
d\tau_1
\end{pmatrix}.
\]

By using Cramer’s rule, we have
\[
\frac{de_1}{d\tau_1} = \frac{-b_1 d_2 P_2 P_1 e_1 (\beta_2 (P_2 e_2 - 1) + 1) - b_2 d_1 P_1 P_2 e_1 (\beta_1 (P_1 e_1 - 1) + 1) - d_1 d_2 (P_2 e_2 - 1) (\beta_2 (P_2 e_2 - 1) + 1)}{b_1 d_2 P_2 P_1 e_1 (\beta_2 (P_2 e_2 - 1) + 1) + b_2 d_1 P_1 P_2 e_1 (\beta_1 (P_1 e_1 - 1) + 1) + d_1 d_2 (P_2 e_2 - 1) (\beta_2 (P_2 e_2 - 1) + 1)}
\]
\[
\frac{de_2}{d\tau_1} = \frac{d_1 (P_1 e_1 + P_1) (\beta_1 (P_1 e_1 - 1) + 1) - d_2 (P_2 e_2 - 1) (\beta_2 (P_2 e_2 - 1) + 1)}{d_1 d_2 (P_2 e_2 - 1) (\beta_2 (P_2 e_2 - 1) + 1) + b_2 P_2 e_2}.
\]

With $\beta_i = 1$, for all $i$, the equations reduce to
\[
\frac{\partial e_1}{\partial \tau_1} = \frac{d_1 d_2 - d_2 P_2 P_1 e_1 (b_2 + d_2)}{d_1 d_2 - d_2 P_1 P_2 e_2 (b_1 + d_2) - d_1 P_2 P_2 e_2 (b_2 + d_2)} > 0,
\]
\[
\frac{\partial e_2}{\partial \tau_1} = \frac{d_1 P_1 e_1 + P_1 e_1 (b_2 + d_2)}{d_1 d_2 - d_2 P_1 P_2 e_1 (b_1 + d_2) - d_1 P_2 P_2 e_2 (b_2 + d_2)} < 0,
\]

where $P_1 > 0$, $P_2 > 0$, $P_1 < 0$, $P_1 + P_1 < 0$ and the denominator is positive. This result is consistent with our previous analysis and simulation result. Q.E.D.

**Proof of Proposition 2**

The first order necessary conditions with respect to $e_1$ and $e_2$ when the tariff is
endogenous are identical to the first order conditions with an exogenous tariff. With the assumptions that demand and supply functions are linear, with linear damages, the first order necessary conditions are sufficient. In addition, the analytical expression of $\tau_1$ from the first order condition indicates that $\tau_1 \geq 0$. $\tau_1$ equals zero under free trade, and $\tau_1$ is positive when it is optimal. According to Proposition 1, $\frac{de_2}{d\tau_1} < 0$, therefore, if the exogenously given tariff level increases from zero to a certain positive level that is equal to the optimal tariff level in the endogenous tariff condition, the exporter’s environmental taxes will decrease. Hence, under the endogenous tariff condition, $e_2^e < e_2^f$.

Q.E.D.

Proof of Lemma 3

The first order condition for the exporter is

$$P_{e_2}(y_2 - x_2) + e_2 y_2'(P_{e_2} - 1) - D_2'(y_2'(P_{e_2} - 1) + \lambda y_2'P_{e_2}) = 0.$$  

With $\hat{e}_1 \equiv \delta$ fixed, totally differentiate with respect to $e_2$ and $\tau_1$

$$[-x_2'P_{e_2} + y_2'P_{e_2}]d\tau_1 + (D_2\Pi_2 de_2) = 0,$$

where $D_2\Pi_2$ is the second-order derivative of $\Pi_2$ with respect to $e_2$ and is negative. Therefore,

$$\frac{\partial \hat{e}_2}{\partial \tau_1} = \frac{(x_2' - y_2')P_{e_2}P_{e_2}}{D_2\Pi_2} < 0,$$

where $x_2' < 0, y_2' > 0$, $P_{e_1} < 0$, and $P_{e_2} > 0$.

Proof of Lemma 4

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

$$(y_2 - x_2)P_{e_2} + e_2 y_2'(P_{e_2} - 1) - \delta_2(y_2'(P_{e_2} - 1) + \lambda y_2'P_{e_2}) = 0,$$

Totally differentiate with respect to $e_2$ and $e_1$

$$[-x_2'P_{e_2} + y_2'P_{e_2}]de_1 + (D_2\Pi_2 de_2) = 0,$$

where $D_2\Pi_2$ is the second-order derivative of $\Pi_2$ with respect to $e_2$ and is negative. Therefore,
\[
\frac{d\hat{e}_2}{de_1} = \frac{(x'_2 - y'_2)P_{e_1}P_{e_2}}{D_2\Pi_2} > 0,
\]
where \(x'_2 < 0, y'_2 > 0\), \(P_{e_1} > 0\), and \(P_{e_2} > 0\).

**Proof of Proposition 3**

When importer moves first given exogenous tariff, \(\tau_1\) has effects on \(e_2\) in two ways: first, it changes \(e_2\) directly; second, it affects \(e_1\) and consequently influences \(e_2\):

\[
\frac{de_2}{d\tau_1} = \frac{\partial e_2}{\partial e_1} \frac{de_1}{d\tau_1} = \frac{\partial e_2}{\partial e_1} \frac{de_2}{d\tau_1}.
\]

So far we have proven that the best response functions of \(e_2\) with respect to \(e_1\) is

\[
\frac{\partial e_2}{\partial e_1} = \frac{(x'_2 - y'_2)P_{e_1}P_{e_2}}{D_2\Pi_2} = \frac{(x'_2 - y'_2)P_{e_1}P_{e_2}}{(y'_2 - x'_2)^2 - y'_2^2} > 0.
\]

where \(x'_2 < 0\), \(y'_2 > 0\), \(P_{e_1} = \frac{y'_1}{y_2' + y'_1 - x'_2 - x'_1} > 0\), \(P_{e_2} = \frac{y'_2}{y_2' + y'_1 - x'_2 - x'_1} > 0\) and the denominator \(D_2\Pi_2\) is negative

and that the best response functions of \(e_2\) with respect to \(\tau_1\) is

\[
\frac{\partial e_2}{\partial \tau_1} = \frac{(x'_2 - y'_2)P_{e_1}P_{e_2}}{D_2\Pi_2} = \frac{(x'_2 - y'_2)P_{e_1}P_{e_2}}{(y'_2 - x'_2)^2 - y'_2^2} < 0.
\]

Therefore, with \(e_2 = f + \frac{\partial e_2}{\partial e_1} e_1 + \frac{\partial e_2}{\partial \tau_1} \tau_1\), totally differentiate the first order condition for the importer with respect to \(e_1\) and \(\tau_1\)

\[
\frac{de_1}{d\tau_1} = \frac{(x'_1 - y'_1)(P_{e_1} + P_{e_2} \frac{\partial e_2}{\partial e_1})(P_{e_1} + P_{e_2} \frac{\partial e_2}{\partial \tau_1}) - y'_1}{\Pi_{1ee}} = \frac{(x'_1 - y'_1)(P_{e_1} + P_{e_2} \frac{\partial e_2}{\partial e_1})(P_{e_1} + P_{e_2} \frac{\partial e_2}{\partial \tau_1}) - y'_1}{(y'_1 - x'_1)(P_{e_1} + P_{e_2} \frac{\partial e_2}{\partial e_1})P_{e_1} - y'_1} > 0.
\]

where both numerator and denominator are negative.

Therefore, we have
\[
\frac{de_2}{d\tau_1} = \frac{\partial e_2}{\partial \epsilon_1} \frac{d\epsilon_1}{d\tau_1} + \frac{\partial e_2}{\partial \epsilon} \frac{d\epsilon}{d\tau_1} = \frac{(y_2' - x_2')(P_{e2})}{D_2\Pi_2} \left[ -P_{e1} \frac{(x_1' - y_1')(P_{\tau_1} + P_{e2} \frac{\partial e_2}{\partial \tau_1})(P_{e1} + P_{e2} \frac{\partial e_2}{\partial \epsilon}) - y_1'}{\Pi_{ee}} - P_{e1} \right] = \\
\frac{(y_2' - x_2')(P_{e2})}{D_2\Pi_2} \left[ \frac{P_{e1}[(y_1' - x_1')(P_{\tau_1} + P_{e2} \frac{\partial e_2}{\partial \epsilon})(P_{e1} + P_{e2} \frac{\partial e_2}{\partial \epsilon}) + y_1'] - P_{\tau_1}[(y_1' - x_1')(P_{e1} + P_{e2} \frac{\partial e_2}{\partial \epsilon})^2 - y_1']}{\Pi_{ee}} \right] = \\
\frac{(y_2' - x_2')(P_{e2})}{D_2\Pi_2} \left[ \frac{(x_1' - y_1')(P_{e1} + P_{e2} \frac{\partial e_2}{\partial \epsilon})}{D_2\Pi_2} \frac{P_{e1}(x_1' - y_1'P_{\tau_1}P_{e2}) - P_{\tau_1}(x_1' - y_1')(P_{e1}P_{e2}) + y_1'(P_{e1} + P_{\tau_1})}{D_2\Pi_2} \right] = \\
\frac{(y_2' - x_2')(P_{e2})}{D_2\Pi_2} \left[ y_1'(P_{e1} + P_{\tau_1}) \right] < 0.
\]

where \( P_{e1} + P_{\tau_1} < 0 \). This result is consistent with our previous analysis and simulation result. Q.E.D.

**Proof of Proposition 4**

Same as in the simultaneous-move case (Proof of Proposition 2). \( \tau_1 \) influences \( e_2(e_1, \epsilon_1, \tau_1) \) through the same mechanism, regardless of whether \( \tau_1 \) is endogenous or exogenous: \( \frac{de_2}{d\tau_1} = \frac{\partial e_2}{\partial \epsilon_1} \frac{d\epsilon_1}{d\tau_1} + \frac{\partial e_2}{\partial \epsilon} \frac{d\epsilon}{d\tau_1} < 0 \). The first order necessary conditions are identical to the first order conditions with an exogenous tariff, and they are sufficient: \( \tau_1 \) is positive. Therefore, no matter if \( \tau_1 \) is endogenous or exogenous, when \( \tau_1 \) increases, it affects \( e_1 \) in the same way, subsequently its effect to \( e_2 \) is the same as well. Hence, under the endogenous tariff condition, \( e_2' \leq e_2' \). Q.E.D.

**Proof of Lemma 5**

Same as in the simultaneous-move case Lemma 1.

Analytical expression of the equilibrium solution When tariff is available, the equilibrium tax rate by the exporter is given by

\[
e_2' = \frac{\hat{P}_{e2} \{ e_2 - d_2 \hat{P}_w - (a_2 - b_2 \hat{P}_w) \} - \delta_2 \left\{ \lambda d_1 \left( \frac{\hat{P}_{e2} + d\tau_1}{de_2} + d_2 (\hat{P}_{e2} - 1) \right) \right\}}{d_2 \hat{P}_{e2} (b_2 + e_2)^2},
\]

where \( \hat{P}_{e2} \equiv \frac{dP_w}{de_2} \) and \( \hat{P}_w \) satisfies
Proof of Lemma 6

It follows from the first order conditions of importer’s best responses that
\[
\frac{de_1}{de_2} = \frac{(x_1' - y_1')P_{e2}P_{e1}}{-x_1'P_{e1}^2 + y_1'(P_{e1}^2 - 1)}.
\]

Therefore, whether \(\frac{de_1}{de_2}\) is greater or less than zero depends on the denominator, which is ambiguous.

Proof of Proposition 5

In what follows we show that the inequality holds if \(\delta_2\) is large enough.

The equilibrium environmental tax rate satisfy
\[
e'_{22} = \frac{\hat{P}_{e2} \{c_2 - d_2 \hat{P}_w - (a_2 - b_2 \hat{P}_w)\} - \delta_2 \left\{ \lambda d_1 \left( \hat{P}_{e2} + \frac{d \tau_1}{de_2} \right) + d_2 (\hat{P}_{e2} - 1) \right\}}{d_2 - \hat{P}_{e2} (b_2 + e_2)^2},
\]
\[
e''_{22} = \frac{\hat{P}_{e2} \{c_2 - d_2 \hat{P}_w - (a_2 - b_2 \hat{P}_w)\} - \delta_2 \left\{ \lambda d_1 \left( \hat{P}_{e2} - \frac{de_1}{de_2} \right) + d_2 (\hat{P}_{e2} - 1) \right\}}{d_2 - \hat{P}_{e2} (b_2 + e_2)^2}.
\]

It follows that \(e'_{22} < e''_{22}\) if the following conditions hold:

1. \(\hat{P}'_w < \hat{P}''_w\);
2. \(\hat{P}'_{e2} > \hat{P}''_{e2}\);
3. \(\frac{\partial e^*_{e2}}{\partial P_w} > 0\);
4. \(\frac{\partial e^*_{e2}}{\partial P_{e2}} < 0\);
5. \(\hat{P}'_{e2} + \frac{d \tau_1}{de_2} > \hat{P}''_{e2} - \frac{de_1}{de_2}\).

As for condition 1,
\[ \hat{P}_w^t = \hat{P}_w + \frac{1}{B + D} \left[ d_1 \delta_1 + P_{t1} \left[ -(a_1 - b_1(P_w + P_{e1} \delta_1) + c_1 + d_1(\bar{P}_w + d_1 \delta_1 - \delta_1) \right] \right] \]

\[ + \frac{1}{B + D} \left[ \frac{d_1 P_{e1} [- (a_1 - b_1(P_w + P_{e1} \delta_1)) + c_1 + d_1(\bar{P}_w + d_1 \delta_1 - \delta_1) \delta_1 d_1^2 (P_{e1} - 1)]}{- (b_1 + d_1) P_{e1}^2 + d_1} \right] \]

\[ \hat{P}_w^f = \bar{P}_w + \frac{1}{B + D} \left[ \frac{d_1 P_{e1} [- (a_1 - b_1(P_w + P_{e1} \delta_1)) + c_1 + d_1(\bar{P}_w + d_1 \delta_1 - \delta_1) \delta_1 d_1^2 (P_{e1} - 1)]}{- (b_1 + d_1) P_{e1}^2 + d_1} \right] \]

Let \( A(P_{wt}) = d_1 \delta_1 + P_{t1} \left[ -(a_1 - b_1(P_w + P_{e1} \delta_1)) + c_1 + d_1(\bar{P}_w + d_1 \delta_1 - \delta_1) \right] - \delta_1 \lambda d_3 P_{t1} \)

\[ A(P_{wf}) = \frac{d_1 P_{e1} [- (a_1 - b_1(P_w + P_{e1} \delta_1)) + c_1 + d_1(\bar{P}_w + d_1 \delta_1 - \delta_1) \delta_1 d_1^2 (P_{e1} - 1)]}{- (b_1 + d_1) P_{e1}^2 + d_1} \]

Thus, \( A(P_{wt}) - A(P_{wf}) > 0 \)

And hence \( \hat{P}_w^t < \hat{P}_w^f \).

For condition 2,

\[ \frac{\partial A_{t1}}{\partial \delta_2} = P_{t1} \frac{\partial e_1}{\partial \delta_2} = \frac{(y_2^0 - y_1^0)^2}{[-(y_1^2 - x_1^2)^2 + (y_1^2 - x_1^2)]} \]

\[ \left[ y' - x' \right] \left[ (y_1^2 - x_1^2)^2 + (y_1^2 - x_1^2) \right] \]

Since \( A_{t1} > A \), and \( \hat{P}_w^t = P_{t1} \frac{\partial e_1}{\partial \delta_2} + \frac{\partial P_w}{\partial e_2} \), \( \hat{P}_w^f = P_{e1} \frac{\partial e_1}{\partial \delta_2} + \frac{\partial P_w}{\partial e_2} \), therefore \( \hat{P}_w^t > \hat{P}_w^f \).

For condition 3,

\[ \frac{\partial e_2^*}{\partial P_w} = \frac{1}{d_2 - \hat{P}_w^2} \left[ \hat{P}_w^2 (b_2 + d_2) \right] \]

\[ = \frac{1}{(B + D)^3} \left[ -(P_{t1}^2 - 1) \right] d_2 (b_1 + d_1) [(b_1 + d_1)(b_2 + d_2) + (b_1 + d_2)^2] \]

\[ > 0 \]

So \( \frac{\partial e_2^*}{\partial P_w} > 0 \).

For condition 4,

\[ \frac{\partial e_2^*}{\partial P_{e2}} = \frac{\left[ (a_2 - c_2 - (b_2 + d_2) P_w) + \delta_2 (P_{e2}^2 (b_2 + d_2) - d_2) \right]}{\left[ (a_2 - c_2 - (b_2 + d_2) P_w) - \delta_2 (P_{e2}^2 (b_2 + d_2) - d_2) \right]} \]

\[ - \frac{\left[ (a_2 - c_2 - (b_2 + d_2) P_w) + \delta_2 (P_{e2}^2 (b_2 + d_2) - d_2) \right]}{\left[ (a_2 - c_2 - (b_2 + d_2) P_w) - \delta_2 (P_{e2}^2 (b_2 + d_2) - d_2) \right]} \]

\[ < 0 \]

So \( \frac{\partial e_2^*}{\partial P_{e2}} < 0 \) if \( \delta_2 \) is large enough.

For condition 5,

\[ \hat{P}_e^t + \frac{d \tau_1}{d e_2} = \frac{(y_2^0 - x_2^0)(x_1^0 - y_1^0)y_2^0}{[y' - x'][-(y_1^2 - x_1^2)^2 + (y_1^2 - x_1^2)]} \]

\[ \hat{P}_e^f - \frac{d \tau_1}{d e_2} = \frac{(y_1^0 - y_1^0 + x_1^0)(x_1^0 - y_1^0)y_2^0}{[y' - x'][(y_1^2 - x_1^2) - (y_1^2 - x_1^2)]} \]

Where \( y' - x' = (y_1^0 - y_1^0) - (x_1^0 + x_2^0) \).

Since \( (y_2^0 - x_2^0)(x_1^0 - y_1^0)y_2^0 > (y_1^0 - y_1^0 + x_1^0)(x_1^0 - y_1^0)y_2^0 \),
\[ \hat{P}_e^2 + \frac{d\tau_1}{de_2} > \hat{P}_f - \frac{de_1}{de_2} \]

Therefore, conditions 1, 2, 3, and 5 hold. Condition 4 holds if \( \delta_2 \) is large enough. Q.E.D.

References


CHAPTER 3
ARE REGIONAL TRADE AGREEMENTS ENVIRONMENTALLY FRIENDLY?

I. Introduction

Protestors of economic integration often worry about the adverse impact of international trade on environmental quality. The question arises whether this worry is necessary. Environmental economists have begun to investigate this question recently. Several papers have shown that freer trade seems to be good for environment (Antweiler, Copeland, and Taylor 2001, Dean 2002), or at least that there is little evidence that trade openness increases air pollution (Frankel and Rose 2006). However, aside from global liberalization, these studies do not probe into the impact of regional liberalization, which is a trend in trade that cannot be replaced by broad free trade.

Along with the trend of globalization, regional economic integration attracts more public attention every year but especially in recent episodes. Accordingly, governments have established several regional economic cooperation organizations such as the European Union (EU), North American Free Trade Agreement (NAFTA), and Association of Southeast Asian Nations (ASEAN). As shown in Figure 2, Regional Trade Agreements (RTAs) have increased tremendously in recent twenty years. As of 2012, more than 310 RTAs that have been notified to the World Trade Organization (WTO) are currently in force.

Until recently, there was little evidence, both in terms of theoretical and empirical aspects, about how regionalism affects trade liberalization toward nonmembers. Given the prominence of policy ramifications of this conclusion to both economists and policy makers, further investigation is worthwhile but also raises a new concern—should we fear the adverse effects of regional trade liberalization on environmental quality?
This paper investigates how regional trade liberalization affects pollution as a means of assessing the environmental consequences of regional trade agreements. This is important for two reasons. First, it is a practical matter for policy makers. Suppose it is proved that compared to broad trade liberalization, regional liberalization has an adverse effect on environment. As a result, policy makers would be able to enforce corresponding policies to solve the problem, such as supplementing environmental provisions in RTAs.\textsuperscript{1} Second, the effects of trade on environment are still ambiguous. Several hypotheses are widely discussed. The pollution haven hypothesis suggests that international trade results in relatively low income countries producing more pollution-intensive goods because of relatively lax environmental regulation, while others export cleaner goods. Similarly, the race-to-the-bottom hypothesis indicates that open economies generally produce dirtier goods to maintain their international competitiveness. These two hypotheses suggest that trade is bad for the environment, especially for developing countries. In the meantime, gains from trade can outweigh such negative effects through the technique effect. As indicated in Frankel and Rose (2006), first, trade increases income and therefore promotes technological progress; second, multinational corporations will bring in clean technologies; third, openness that attracts public attention stimulates a domestic country to adopt more stringent regulation. Moreover, the indirect effects of RTAs on the environment have always been overlooked, but they are likely crucial--the possible FDI versus exports effect that FDI and exports generates different environmental consequences makes the impact more uncertain. One cannot simply conclude whether or not RTAs are environmentally friendly even though a few papers in the literature indicate that freer trade appears to be environmentally friendly.

In this paper, I provide the first comprehensive econometric study of the effect of RTAs on environmental quality. I use data on intra-group (RTAs)\textsuperscript{2} and total trade volume in 178 countries between 1960 and 2006. The data I retrieved includes each country’s intra-group trade volume across all RTA partners and years, making it highly unique. I examine to what extent environmental quality of countries with RTAs has been affected compared with countries without RTAs. I also examine whether these effects differ by the share of RTAs to the overall...
trade volume, FDI inflows, GDP intensity (which indicates the importance of each RTA to the host country), income levels, geographical locations, and time periods. Furthermore, different from previous works, I consider both the direct and indirect effects that RTAs bring about. Specifically, I revisit the Frankel and Rose (2006) framework, which focuses on the impact of broad trade liberalization. Frankel and Rose (2006) address the potential simultaneity issue between pollution and trade by using instrumental variables derived from widely used gravity and neoclassical economic growth models. Besides, the availability of environmental data is always a serious issue in trade and environment research. Due to data limitations, even though the linkage between trade and environment is controversial and politically important, only limited empirical analysis has been done. The environmental dataset I utilize here is one of the most comprehensive panel air quality datasets so far, both in terms of country coverage and time period. I differ in this study from other work based on cross-section data by relying on panel data with various pollutants at the country level spanning as long as 46 years. I include two air quality indicators: sulfur dioxide concentrations and carbon dioxide emissions. The air quality data is valid as late as 2006. In addition, I include as many and as varied countries as possible globally, including both industrialized and developing countries.

I find that, opposite to broad trade liberalization, the total direct effects of regional liberalization increase sulfur dioxide concentrations while decreasing carbon dioxide emissions. In addition, when considering the indirect effects caused by regional liberalization due to the possible structural and volume change in FDI, the indirect effects increase sulfur dioxide concentrations and decrease carbon dioxide concentrations. In the meantime, the results show that the more important the RTA member countries are, the higher sulfur dioxide concentrations the RTAs result in, though they reduce carbon dioxide emissions. Compared with the ineffectiveness of reducing greenhouse gases (GHG) under global liberalization (Frankle and Rose 2006), regional cooperation seems more effective. It may be because the agreement of GHG reduction is easier to achieve among a relatively smaller number of members with similar regional interests rather than a large group of diverse members that often have competing interests. Results can be

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3 The availability of data is a serious issue in trade and environment research, hence it is normal to see papers use 10 years old or much older data to analyze questions.
4 The importance of RTA member countries depend on the intra-group GDP to overall GDP, which will be illustrated in details later.
attributed to the fundamentally different characteristics of the two pollutants—carbon dioxide emissions reduction is more attractive to RTA member countries as a global public good that does not affect member countries’ interests; however, sulfur dioxide is only a local pollutant and matters only to the domestic government in question.

Previous literature shows that the effects of trade liberalization on the environment are complicated. Antweiler, Copeland, and Taylor (2001) show that broad trade liberalization promotes income growth, and the effect of income growth on pollution emissions is decomposed into three channels: scale, composition, and technique effects. They state that trade liberalization shifts dirty goods production from lax-regulation countries to more stringent-regulation countries. The global composition effect of trade lowers world pollution. Freer trade appears to be good for the environment for the average country. The question yet remains whether this applies to regional trade liberalization as well. We might need first to consider, as a background mechanism, how RTAs affect trade patterns. The key factor that distinguishes the effects of RTAs from broad free trade is the scale effect. That is, RTAs do not necessarily promote the scale effect. When governments establish RTAs, they eliminate barriers to trade between members, which is assumed to provide a considerable incentive to increase trade between members and to reduce trade from outside the RTA. Trade creation and trade diversion may occur when an RTA is established. Trade creation is through the elimination of tariffs between members causing further decreases in price of the goods, consumers increase their demand for these goods while domestic production itself decreases, creating new trade. In the meantime, trade diversion occurs when an RTA shifts imports from a more efficient supplier to a less efficient supplier. Moreover, trade diversion and trade creation can happen at the same time. Suppose we consider a country produces two goods: a dirty good and a clean good. If the home country forms an RTA with a country from which it imports the clean good, the price of the good decreases. Then, the domestic production of the clean good decreases, and the resources reallocate to produce the dirty good for the home country. The scale effect is thereby ambiguous because there is no way to compare the amount of the decrease in the clean good production with the increase in the dirty good production. The composition and technique effects are negative in this case. On the other hand, if the home country forms an RTA with a country from which it imports the dirty good, the domestic production of the dirty good decreases and the resources
will reallocate to produce the clean good. The scale effect is also ambiguous while the composition and technique effects remain positive. The overall effects are unclear in both cases.

This paper advances the literature on how trade determinants affect the environment. It makes three main contributions. First, I organize a comprehensive RTA data set that includes all 319 RTAs currently in force under the WTO framework as a means of analyzing the impact of RTAs on the environment. Most trade papers treat RTAs as a binary dummy variable in the sense that they treat all RTAs equivalent, regardless of the number and the importance of signatories for each RTA (Tinbergen 1962, Bergstrand 1985, Frankel, Stein, and Wei 1995, Rose 2004). In order to capture the heterogeneity across RTAs, I include the interactive term GDP intensity with RTA dummies instead of the simple RTA dummy variables. Moreover, the RTAs in those papers are always selective. Most of them only cover certain major RTAs, resulting in omitting RTAs that include a considerable amount of small countries. These small countries are often developing countries – this is not a coincidence. For instance, Rose (2004) only chooses 7 out of almost 200 RTAs as RTA indicators. Undoubtedly, how such estimations impact RTAs is very vague. To assess the effect of RTAs precisely, based on the World Trade Organization (WTO) RTA dataset that lists details of each RTA (the date of entry into force, membership, and status change of each RTA), I constructed a dataset that includes all 319 RTAs. However, for the purpose of this paper, I only include free trade agreements (FTAs) and Customs Unions (CUs) for goods, which still make up 199 of the WTO RTAs. This is entirely unprecedented, as indicated by Rose’s (2004) study of only 7. The impact of RTAs on trade should depend on how many agreements a country has (the number of RTAs), how many signatories there are (the size/coverage of the RTAs), and which countries are the signatories (the importance of the RTAs). With this comprehensive dataset, I am able to know each particular RTA a country possesses in each year. Consequently, I have made assessing the aggregate impact of RTAs on each country both feasible and accurate.

Second, I incorporate foreign direct investment (FDI) as a form of strategic interaction with RTAs to explain the indirect cumulative effects they have on environmental degradation. The

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5 Bair and Bergstrand (2006) organized the most recent RTA dataset, but they only included RTAs until 2000, while RTAs among developing countries increasing rapidly in the 21st century, and their dummy dataset is not publicly available
indirect effect of trade liberalization on the environment has always been overlooked in the literature. Previous literature (Blonigen and Piger 2011, Blomstrom and Kokko 1997) shows that RTA is one of the major determinants of FDI inflows, both in terms of structure and magnitude. This means that even were the impacts of FDI beneficial to the environment (when considering solely FDI), the effects of the strategic interactive term of FDI and RTAs are still uncertain. To make up for this lack, we first need to divide FDI inflows into intra-regional FDI inflows and inter-regional FDI inflows. When RTAs force regional integration, for intra-regional investment, the tariff-jumping FDI would be expected to decline because the reduction of trade barriers makes exporting more attractive. For FDI that is primarily undertaken to internalize the exploitation of intangible assets, the overall FDI would rather upsurge, and they usually have positive technology spillover effects. For intra-regional FDI, the net effects of RTAs are subject to the pre-existing investment. For inter-regional FDI flows, both tariff-jumping and internalization models result in an increase of FDI inflows. The FDI inflows from non-RTA-member countries into the region could obviously increase if the formation of an RTA raises the level of protection of its member states. Overall, even if broad trade liberalization is possibly partially credited to RTAs, RTAs do not necessarily lead to more openness. In the meantime, the possible increase in FDI inflows caused by RTAs may impose a negative effect on the environment due to the scale effect, a positive impact through the technique effect, and the composition effect depending on income levels.

Last but not least, instead of looking at broad liberalization, this paper analyzes the impact of RTAs on the environment and whether these effects vary depending on: the importance of RTAs, FDI inflows, income levels, geographical locations, and time periods. One controversial reason the impact of RTAs on the environment is unclear and could be different from the impact of free trade on environment is how RTAs affect openness. Some literature suggests that RTAs may lead to higher external tariffs to protect member countries against outside blocs (Panagariya and Findlay 1996, Cadot, de Melo, and Olarreaga 1999). While Richardson (1995) believed trade diversion caused by RTAs can result in larger declines in external tariffs endogenously, similarly, Bond and Syropoulos (1996), Syropoulous (1999), Ornelas (2005), and Ornelas (2007) all proposed that liberalization of intra-union trade create incentives as a way to reduce optimal external tariffs; such a reduction means to generate overall trade creation between RTA members and non-members. Since theoretical literature is so ambiguous, taking an empirical look at the
The rest of the paper is organized as follows. In Section 2, I develop the economic model and describe my strategy for dealing with econometric issues. In Section 3 I present my empirical results and give explanations of results. Section 4 concludes. Appendix contains a summary statistic of data and supplement figures.

II. Empirical Methodology

2.1. Econometric model

To estimate the effects of regional trade agreements on environmental quality for a given level of income per capita, I rely on the Frankel and Rose’s (2006) specification, which explains pollutions with openness and income per capita and address the endogeneity. So far, earlier literature has been trying to persuade people that unlike what opponents of globalization fear, freer trade can be good for the environment. Instead of broad trade liberalization, this methodology gives a focus on the direct and indirect effects of the relatively more realistic regional liberalization by adding RTA dummies, FDI inflows, GDP intensity and their interaction terms. I also augment the Frankel and Rose (2006) specification with a set of time fixed effects in order to account for factors such as global business cycle, and oil shocks, etc.

The environmental quality specification is as follows:

\[
Pollution_{i,t} = \alpha_0 + \alpha_1 \ln(Y/pop)_{i,t} + \alpha_2 [\ln(Y/pop)]^2_{i,t} + \alpha_3 (Openness)_{i,t} + \alpha_4 G_i t_i + \\
\alpha_5 FDI_{i,t} + \alpha_6 RA_{i,t} + \alpha_7 GI_{i,t} \ast RTA_{i,t} + \alpha_8 FDI_{i,t} \ast RTA_{i,t}
\]

\[+ \alpha_9 (Policy)_{i,t} + \alpha_{10} \ln(Area/Pop)_{i,t} + \sum \mu_t T_t + \varepsilon_{i,t}, \tag{1}\]
where \( i \) denotes country, \( t \) denotes year, and the variables are defined as follows:

- \( \text{Pollution}_{i,t} \) is one of the measures of pollution for country \( i \) in period \( t \). It is measured in two ways: log of average pollution concentrations and emissions per capita. The first one is to examine the impact on aggregate pollution, and the latter one is to inspect the impacts on pollution scaled by population size, in other words, pollution intensity per capita. Sulfur dioxide is measured by log of average concentrations while carbon dioxide is measured by emissions per capita. The emission concentration is a more reasonable way to measure environmental quality rather than emissions per capita since only concentrations include pollutions in past periods left in the air and spillover effects. However, because carbon dioxide is purely global externality, and it could not be addressed by country level regulation, reducing emissions represents willingness to contribute to climate change mitigation.

- \( \ln(Y/pop)_{i,t} \) is the natural logarithm of real GDP per capita for country \( i \) at time \( t \),

- \( \text{Openness}_{i,t} \) is the ratio of nominal exports and imports to GDP. It shows the importance of trade to the home country,

- \( GI_{i,t} \) is GDP intensity, which is the ratio of aggregate GDP for RTA member countries to total GDP for all countries in the sample. It measures the importance of RTA member countries to the world, and it interacts with \( RTA_{i,t} \) to measure the importance of RTAs to the host country, since it represents the additional impacts RTAs have on the environment after controlling the size of RTAs,

- \( FDI_{i,t} \) is the ratio of FDI inflows to country \( i \) at time \( t \) to GDP. And it interacts with \( RTA_{i,t} \) as well since signing RTAs might affect domestic FDI inflows, which has effects to the environment,

- \( RTA_{i,t} \) is RTA dummy, and it symbolizes the size of RTAs. The RTA intensity for country \( i \) at time \( t \) is measured by the ratio of the sum of country \( i \)'s total intra-group trade volume with RTA partners to its total trade volume. If this RTA intensity is equal to or greater than a certain threshold, such as 15\%, 30\%, etc., then the RTA dummy is one, otherwise 0. Different from a binary dummy variable simply proxy have RTAs or not in previous studies, this term assesses the importance or size of the RTAs to the home
country at time t. With this term, the effect of RTA is able to be tested more comprehensive and straightforward,

- Polity measures democracy (versus autocracy) levels of the government,
- Area/Pop per capita land area in square kilometers,
- \( \sum_t \mu_t T_t \) is a comprehensive set of time “fixed effects”,
- \( \varepsilon_{i,t} \) is a mean zero error term representing the omitted other causes of environmental pollution

The parameters of interest terms are \( \alpha_4, \alpha_5, \alpha_6, \alpha_7, \alpha_8 \). The coefficient \( \alpha_6 \) captures the direct effect of RTAs on environment, regardless of the importance of RTA partners. The coefficient \( \alpha_5 \) measures the environmental impact of FDI for all countries in the sample. The one \( \alpha_8 \) explains the additional environmental impacts of FDI when RTAs exist. Therefore, the sum of the two coefficients \( \alpha_5 + \alpha_8 \) represents what overall environmental influences FDI have when RTAs enter into force. This is the key variable that reflect the total indirect effects of RTAs on environment through FDI. Similar to FDI, the summation term of the two coefficients \( \alpha_4 + \alpha_7 \) represents the additional impacts RTAs have on the environment after controlling the size of RTAs. If environmental quality is better regulated when RTAs are signed, coefficients should be negative when the dependent variable is pollution concentrations and positive if it is pollution emissions.

The income per capita along with its quadratic term captures the environmental Kuznets curve (EKC). According to the EKC hypothesis, there is a U-shaped relationship between the economic growth and pollution. It implies the coefficient on the quadratic term should be negative when the dependent variable is pollution concentrations, otherwise if it is pollution emissions. The land area per capita reflects the effect of population density on environmental outcomes while the inclusion of polity reveals the impact of government regulation on environmental quality.

2.2 Endogeneity

The trade intensity endogeneity has been first noted in the trade and growth literature. Helpman (1988), Rodrik (1995), Harrison (1995), and Rodriguez and Rodrik (2001) have shown that whether it is growth driving trade or a reverse relationship is still unresolved. Therefore, even if we get a positive (negative) correlation between trade and environmental quality we still cannot
conclude that trade is good (bad) for the environment. This is because it might be the reverse causality, running from environmental regulation to growth, that affects the trade patterns consequently, just as what Porter hypothesis suggested. Later, the trade and environment papers such as Harbaugh, Levinson, and Wilson (2000), Copeland and Taylor (2001), and Frankel and Rose (2006) all raised up this issue. Consider that the RTAs intra-group trade intensity is part of the general trade intensity; endogeneity is obviously a problem that we need to deal with.

As in Frankel and Rose (2006), I instrument for per capita income, per capita income square, and openness in equation (1). But different from Frankel and Rose (2006) who analyze with a cross-country approach, I use panel data. Therefore, I employ a general method of moments (GMM) approach. Frankel and Rose (2006) argue that there is little advantage for them to use a panel study rather than cross-section, because “openness is driven by cross-country geographical variation, which does not change over time”, so there is little problem for the unobservable heterogeneity. But what I focus on is the RTAs’ direct and indirect impacts, which are determined by the RTAs, the variables that are absolutely time-variant in terms of both quantity and quality. So the use of panel data analysis is crucial for my research question.

I apply the gravity model for bilateral trade between pairs of countries to instrument for the relevant trade intensities. First, I form the prediction of bilateral trade intensity by estimating the gravity equation that predicts trade with the exogenous regressors such as country size (population, and land area) and the distance between countries (both physical distance and culture distance (common language, common border, landlocked, colony, common currency, etc.)). I then aggregate (the exponential of) the fitted value of bilateral trade intensity across a country’s trade partners to construct a prediction of the total trade intensity. In the second stage, I use this predicted trade intensity variable as an instrument for actual trade intensity (openness).

\[ \ln(BilateralInt_{ijt}) = \beta X_{ijt} + u_{ijt}, \]  

(2)

Where \( BilateralInt_{ijt} \) is the bilateral trade intensity between trading partners country i and country j in year t, \( X_{ijt} \) is a vector of control variables of country i and j which includes logarithm population of country i and j, the product of log of land area of country i and j, log distance between the countries, a dummy variable that shows if they share a border, a dummy variable that indicates if they have a common language, a dummy variable which is unity if i
ever or currently colonized j or vice versa, a dummy variable that might be (0,1,2) indicate the number of landlocked countries in the country pair. The above dummy variables are time invariant. The control vectors also include a series of time varying variables, such as a dummy variable shows if they have a common currency, a variable that shows the total number of RTAs between country i and j at time t, and a dummy variable indicate if country i is a GATT/WTO member at time t (same for country j), and a comprehensive set of time dummies. Therefore, I use these plausible exogenous geographical indicators to identify the causal effect of trade on economic growth and environmental quality.

As for the growth equation, there are enormous literature discussing the endogeneity of income per capita. Frankel and Rose (2006) chose a second set of instrumental variables from the neoclassical growth theory. I follow their specifications directly and add the time dummy:

\[
\ln (Y/\text{Pop})_{it} = \gamma_1 \ln (\hat{Y}/\text{Pop})_{it} + \gamma_2 \ln (\hat{Y}/\text{Pop})_{it}^2 + \gamma_3 \ln (\text{Area}/\text{Pop})_{it} + \sum_t \mu_t T_t + v_{1it} \tag{3}
\]

\[
\ln (Y/\text{Pop})_{it}^2 = \gamma_1 \ln (\hat{Y}/\text{Pop})_{it} + \gamma_2 \ln (\hat{Y}/\text{Pop})_{it}^2 + \gamma_3 \ln (\text{Area}/\text{Pop})_{it} + \sum_t \mu_t T_t + v_{2it} \tag{4}
\]

Where \( \ln (\hat{Y}/\text{Pop})_{it} \) is the predicted value from:

\[
\ln (Y/\text{Pop})_{it} = \theta_0 + \theta_1 GT_{it} + \theta_2 \ln (Y/\text{Pop})_{it-k} + \theta_3 \ln (\text{Pop})_{it} + \theta_4 n_{it} + \theta_5 (I/Y)_{it}
+ \theta_6 (\text{School1})_{it} + \theta_7 (\text{School2})_{it} + \sum_t \mu_t T_t + \tilde{v}_{1it} \tag{5}
\]

The dependent variable is the log income per capita measured in real PPP-adjusted dollars for country i at time t, the lagged income per capita is for the conditional convergence hypothesis (k=10,20), GTI is the general trade intensity (openness) for country i, n denotes population growth rate, \((I/Y)_{it}\) is the average rates of investment rates over the sample period, \((\text{School1})_{it}\) and \((\text{School2})_{it}\) present the human capital formation, which are average primary and secondary schooling enrollment rates over the sample period respectively, and \(\tilde{v}_{1it}\) is the mean zero error term. The general trade intensity here should be instrumented by aggregating the fitted bilateral trade value obtained from equation (2), so equation (5) is estimated by IV via GMM as well. With equation (3) and (4), the model is exactly identified.
2.3 Data

2.3.1 RTAs and Bilateral Trade Data

The RTA dataset is quite novel. I organize the RTA data based on the WTO RTA database, which lists details of each RTA, such as the date of entry into force, membership, and status change of each RTA. This dataset is much more comprehensive than those used in the previous papers that either only cover several selected RTAs or treat RTAs as binary dummy variables, which may result in omitting small countries or endogeneity problems. According to the WTO’s official dataset, RTAs have become increasingly prevalent since the early 1990s. As of 15 January 2012, some 511 notifications of RTAs (counting goods and services separately) had been received by the GATT/WTO. Of these, 319 were in force. All RTAs in the WTO are reciprocal trade agreements to each other. For the purpose of this paper, I only select free trade agreements (FTAs) and Customs Unions (CUs) for goods in my analysis. With this comprehensive dataset, I could identify the type, the date, and the signatories of each RTA, allowing me to evaluate the impact of RTAs from various aspects. Figure 2 shows the trend of RTAs over years.

The bilateral trade flows come from Direction of Trade Statistics (DOT) provided by International Monetary Fund. It is the only dataset containing a panel of worldwide bilateral trade. Data for the years 1948-2006 relative to 178 IMF trading entities were organized by Head, Mayer, and Ries (2010). There are two major problems relates to the DOT dataset. First, it often reports two values for the same flow. This is because it contains both country A’s import report and country B’s export report. Head et. al (2006) consider for the fact that exports are FOB while imports are CIF, with a 10% difference in value. And due to the problematic zeros in the dataset, they choose the larger value reported by the two countries. Second, the dataset make trade below $0.005 million as zero, which makes 529,663 out of 1,204,671 total observations to zero trade. After a thorough test by applying Possion PMLE and Tobit, they conclude that there is no problem to follow the traditional method of taking log of actual trade and dropping observations that record trade as zero on gravity model. Therefore, I simply borrow their inference in my gravity model estimation.

2.3.2 Environmental Data
The availability of environmental dataset is always a problem for empirical environmental analysis. To the author’s knowledge, the environmental dataset I use here is the most comprehensive panel dataset for air quality measurements so far, in terms of pollutant categories, country coverage, and time length. I include two major air quality indicators: sulfur dioxide and carbon dioxide.

The data on sulphur dioxide concentrations is extremely limited, especially for panel data. The best available data is the Global Environment Monitoring System GEMS/AIR dataset supplied by the World Health Organization (WHO). This dataset contains data of concentrations of sulphur dioxide at observation sites in major cities around the world. But this project ceased after 2000. Since then there has been no such project that provides panel sulphur dioxide data covering both industrial and developing countries. Even though this dataset is a little outdated, its coverage, sample size, and overlapping with RTAs periods are able to generate a solid result for the purpose of this paper. I have obtained this data from authors of Anteweiler et al. (2001). Their data is a more comprehensive version of what is released by United States Environmental Protection Agency, who provided this data to the public. This dataset include 2555 observations from 290 sites in 108 cities of 43 countries covers the period 1971-1996. Because the distribution of SO2 concentrations is highly-skewed towards zero, using a logarithmic transformation of the median SO2 concentrations is more suitable.

Carbon dioxide emissions are distributed to the public by the World Bank. The raw data is supplied by Carbon Dioxide Information Analysis Center, Environmental Sciences Division, and Oak Ridge National Laboratory in Tennessee. The CO2 emissions are measured in metric tons and the data extends start from 1960 to 2008. The specifications of sulfur dioxide covers from 1971-1996, while the specifications of carbon dioxide range from 1960-2008. As it is shown in Figure 5 and 6, neither of the pollutants follow a specific pattern among different countries. And as it is shown in Figure 3 and 4, the trend of the total SO2 concentrations and CO2 emissions per capita are not quite different from each other. They both decrease first and increase around 1980.

2.3.3 Other data

Other data like population, GDP, and investment rate are obtained from the typical source--Penn World Table. Country-specific variables, such as land area, landlocked, borders, colonizers, are time invariant and are taken from CIA’s World Factbook. Polity is time variant and it ranges
from -10 (strongly autocratic) to +10 (strongly democratic) follows Frankel and Rose (2006)’s standard. Dates of accession of GATT/WTO membership come from WTO website. And education in terms of elementary and secondary schooling is got through Barro and Lee dataset, which is available every five years.

III. Empirical Results

Table 3.1 presents key estimation results where the dependent variable is log of average sulfur dioxide. The four columns at the left of the table are the OLS estimates, and the GMM estimates are on the right. The first column is the benchmark estimation where RTA dummy is 1 as long as the home country has any RTA, in other words the RTA intensity is great than 0, and 0 otherwise. Variables of major interest are the ones relate to RTAs. The RTA dummy is negative and significant, which means SO2 concentrations decreases, indicating that regional integration is good for environment. The SO2 concentrations is found to fall with both broad liberalization and regional liberalization, which is consistent with the findings in Grossman and Krueger (1991) -- NAFTA will cause countries to generate less pollution. However, one feature makes regional liberalization different from broad liberalization is that the impact of regional liberalization to the host country varies, depending on the number and the size of member countries’ GDP. The variable GDP intensity synthesizes the number and the size of member countries, which is the ratio of aggregate member countries’ GDP to the world total GDP, measuring the importance of RTAs to the host country. Therefore, the sum of GDP intensity and the interactive term of RTA dummy and GDP intensity represents the additional impacts RTAs have on the environment after controlling the size of RTAs. The summation term shows that the more important the RTA member countries are, the worse the RTAs are for the environment. The reason will be illustrated later. In column (6)-(9), the significance of broad liberalization diminishes as intra-regional trade among RTA countries takes a larger share of overall trade volume for the host country. It can be interpreted as along with the increasing in intra-regional trade percentage, the RTA dummy

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6 As robustness check, the GMM benchmark estimation for SO2 and CO2 are listed in table 3.5 in appendix, and it is consistent, so it is sufficient to use the RTA cutoff dummy in the specification.
gradually converges to openness, therefore regional liberalization is getting similar with broad liberalization for the host country. The coefficient of RTA dummy takes the role of the coefficient of openness to some extent. Besides, because openness changes in a small percentage, the insignificance is acceptable here.

Effects of trade liberalization that do not operate via economic growth can be classified into three categories: the adverse average global effect—the “race to the bottom” hypothesis, the beneficial average global effect— the “gains from trade” hypothesis, and the effects vary across countries—the “pollution haven” hypothesis and the “factor endowment” hypothesis. The “race to the bottom” expresses concerns that, to the extent countries are open to international trade and investment, environmental standards will be put downward under the pressures of foreign competitors; while “gains from trade” allows countries to obtain more from trade liberalization, including environmental goods. Therefore, whether trade liberalization is good or bad to the environment depends on which effect dominates: “race to the bottom” or “gains from trade”. In the case of RTAs, when considering the importance of RTAs, the empirical results show that the former dominates. Besides, one issue that has been overlooked is that trade agreements have been increasingly accompanied by environmental policies. Many developed countries like US, EU, and New Zealand are inclined to enforce RTAs with environmental policies and seeking for legally binding resolution, while developing countries prefer to address the issue separately. Enforcing RTAs with environmental policies could be a direct and efficient contributor that accounts for the pollution emissions reduction results from regional integration.

Next consider the indirect effects of RTAs on the environment. Besides the classical scale, composition and technique effects, RTAs are able to apply an indirect effect on the environment through FDI, holding income levels and openness constant. When it refers to FDI alone, the average impacts are beneficial to the environment. However, as for my test of the association between environmental quality and the interactive term of FDI and the RTA dummy, I find a statistically significant detrimental relationship. The sum of FDI and the interactive term is consistently positively affect SO2 concentrations. These three terms explain the impact of FDI on the environment through different channels. The First coefficient captures the effects of FDI on environmental quality for all countries in the sample. The second one explains when RTAs enter into force the additional indirect impacts FDI have on the environment. Such additional
impacts include effects on the environment by the volume change in FDI inflows that results from the enforcement of RTAs, or by the structural change in FDI holding the magnitude constant. Because RTA is a dummy variable taking a value of 1 if the ratio of trade among RTA participants to the total trade volume is above a certain cutoff, and zero otherwise, the RTA dummies in each specification proxy policy treatment and are able to bring difference in difference effect into the estimation. Therefore, the last summation term of the previous two coefficients enlightens when RTAs exist what overall influences FDI is capable to put on the environment. This is the key variable reflect the total indirect effects RTAs have on the environment through FDI. When the RTA dummy equals to one, this term captures the gross impact of FDI on the environment for the subgroup of countries that trade heavily in RTAs.

To see how FDI affects the environment through RTAs, we need to understand the relationship between RTAs and FDI first. According to Blomstrom and Kokko (1997), when regional integration is implemented, for intra-regional investment, the tariff-jumping FDI—the type of FDI tends to regard trade and capital movements as substitutable modes of serving foreign markets, would decline, since trade barrier reduction makes import become more attractive and therefore substitute FDI; in the meantime, FDI that is primarily undertaken to internalize the exploitation of intangible assets is more likely to be stimulated rather than shrink. This type of FDI normally has positive technology spillover effects to the host country. Therefore, for intra-regional FDI, the net effects of RTAs are subject to the structure and motives for pre-existing investment. Turning to inter-regional FDI inflows, both tariff-jumping and internalization models would stimulate FDI inflows. Blomstrom and Kokko (1997) conclude that even though the relationship between RTAs and FDI is not forthright considering both intra and inter regional FDI, we can say that the stronger investment environment change by regional integration and the stronger the locational advantages of the individual country, the more likely it is that RTAs will lead to FDI inflows from the outside as well as from the rest of the integration region.

Regarding environmental quality, we can divide FDI into two categories: FDI with high or clean technology that is good for pollution reduction and FDI with low or dirty technology that is bad for environment where scale effects dominate technical effects. From “gains from trade” we know that one possible way that trade liberalization benefit the environment is technological and managerial innovation, and the other way is an international ratcheting up of environmental
standards. It is worth noting that according to Frankel (2009), openness could encourage innovation which is beneficial to environmental improvement as well as economic progress. He specifically pointed out that multinational corporations on average often set higher standards than if the host country were undertaking the same activity on its own. So the technological progress does not only refer to production efficiency but also indicate cleaner technology. After considering how RTAs affect FDI, we now investigate how these FDI affect the environment. If the internalization type FDI dominates tariff-jumping FDI, then FDI comes with high technology and positive technology spillover effects that are good for the environment, vice versa. The empirical results thus show that the effects of FDI due to the formation of RTAs on environmental quality is generally negative for the environment, indicating that RTAs attract relative more tariff-jumping FDI to the host country, and tariff-jumping FDI takes a relative large percentage in gross FDI. This outcome is different from previous studies’ impression that there is little relationship between FDI and its pollution level (Antweiler, Copeland and Taylor 2001). However, it coincides with the common hypothesis that multinationals locate in poor countries because of their lax environmental protection.
<table>
<thead>
<tr>
<th>VARIABLES</th>
<th>OLS</th>
<th>GMM</th>
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</thead>
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<td></td>
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<td>(2)</td>
</tr>
<tr>
<td></td>
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</tr>
<tr>
<td>Income/capita</td>
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<td>1.636**</td>
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<tr>
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</tr>
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<td>-0.0954***</td>
</tr>
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<td>(0.0446)</td>
</tr>
<tr>
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<td>-1.597**</td>
</tr>
<tr>
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<td>-2.844***</td>
</tr>
<tr>
<td>(RTA Dummy(x))</td>
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<td>(0.395)</td>
</tr>
<tr>
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<td>24.87***</td>
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<td>(4.790)</td>
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<td>39.66***</td>
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<td>(8.564)</td>
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<tr>
<td>(Communist)</td>
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<td>(0.184)</td>
</tr>
<tr>
<td>Land Area/capita</td>
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<td>-0.0824***</td>
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<tr>
<td>(Land Area/capita)</td>
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<tr>
<td>Observations</td>
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<td>432</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.258</td>
<td>0.300</td>
</tr>
</tbody>
</table>

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1
Sulfur dioxide is only a local pollution; hence its internal attribute allows national government to address it. When it comes to cross-border global public bad, free rider problem makes multilateral cooperation necessary and harder to achieve. Table 3.2 reports the OLS and GMM estimates for carbon dioxide emissions per capita.

Interestingly, different from the sulfur dioxide concentrations, the carbon dioxide emissions per capita is found to rise with broad liberalization, which is in line with Frankel and Rose (2005), but it declines with regional liberalization. Regardless of the importance of RTA trade, the significance of regional liberalization on the environment diminishes as the cutoff of RTA percentages is increased. The summation of GDP intensity and the interactive term RTA dummy and GDP intensity shows that the importance of RTA member countries have consistently positive and significant impact on the environment, which displays the more important the RTA member countries are the better the RTAs are for the environment. The overall result indicates that RTAs do work for GHG reductions. There are several reasons make regional liberalization effective for GHG reductions while broad liberalization does not. First of all, environmental agreement is easier to achieve among fewer members. Not only because, as mentioned above, a number of recent signed RTAs include environmental policies that can affect emissions directly, but also that countries are able to tailor their carbon dioxide emissions standard in different RTAs with different partners. Considering economic benefits of signing RTAs, countries are more inclined to agree with the environmental standard when RTAs take a modest percentage in host country’s economy, and the cost of carbon dioxide reduction is smaller than the gain from signing it. However, when trade volume in integration region takes a relatively large percentage in host country’s economy, in order to avoid losing international competitiveness by the increasing cost of GHG reductions, countries will be more cautious on emission reductions when it refers to pollutants as carbon dioxide. It is a global public good after all. Therefore, in the case of carbon dioxide, “gain from trade” dominates “race to the bottom” when there is regional liberalization.

As for FDI, the coefficients of “FDI, the interactive term of FDI and the RTA dummy, and the sum of the FDI and the interactive term variable” are all negative and statistically significant. Therefore, in sum, FDI is beneficial for GHG reductions when RTAs take into force. Hence we can conclude that regional liberalization is good for GHG reductions considering either direct or
indirect effects. It seems that comparing with openness, regional cooperation is more effective to reduce GHG than global cooperation. It may be because the level of GHG reduction is easier to achieve among a relative smaller number of members under similar interests rather than a large group of diverse members.

The number of RTAs cover the environment topic is increasing. Some developed countries such as US include binding environmental provisions in certain RTAs and countries like New Zealand include nonbinding provisions, while developing countries usually state environmental related topics in side agreements separately. For instance, the EU has consistently included a set of climate and energy related initiatives and binding legislation under their framework since 1990. In 1991, the strategy to reduce 25% CO2 emissions by voluntary commitments of car makers and the energy products taxation have been proposed. In 2000, the European Climate Change Programme (ECCP) has been established to target on GHG reductions. The ECCP I include the important the Emissions Trading System (ETS), and the ECCP II suggested other methods such as carbon capture and storage. The ETS is the key method for EU in GHG emissions reduction from large-scale facilities in the power and industry sectors, as well as the aviation sector. It covers around 45 percent of the EU's GHG emissions. In 2007, the “20-20-20” targets were set and enacted in legislation in 2009 by EU in order to be a low carbon economy in 2020. The package sets three key targets: 20 percent cut in greenhouse gas emissions from 1990 levels, 20 percent of EU energy from renewables, and 20 percent improvement in energy efficiency. The EU is looking at cost-efficient ways to make the European economy more climate-friendly and less energy-consuming. Its most recent low-carbon economy roadmap suggests that: by 2050, the EU should cut emissions to 80% below 1990 levels, all sectors need to contribute, and the low-carbon transition is feasible & affordable. Besides, NAFTA has signed a side agreement The North American Agreement on Environmental Cooperation (NAAEC) for the commitment of environmental laws of member countries. Furthermore, the North American Commission for Environmental Cooperation (CEC) was established later to enhance regional environmental cooperation and prevent from race to the bottom. The above facts show evidence that GHG is easier to achieve an agreement under RTA framework.
Table 3.2. Effect of Economic Integration on CO2 emissions per capita

<table>
<thead>
<tr>
<th>VARIABLES</th>
<th>OLS</th>
<th>GMM</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
</tr>
<tr>
<td></td>
<td>Benchmark</td>
<td>15% RTA/TotalTrade</td>
</tr>
<tr>
<td>Income/capita</td>
<td>-22.58***</td>
<td>-22.83***</td>
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<tr>
<td>(1.220)</td>
<td>(1.202)</td>
<td>(1.205)</td>
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<tr>
<td>(Income/capita)^2</td>
<td>1.592***</td>
<td>1.604***</td>
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<tr>
<td>(0.0795)</td>
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<td>Openness</td>
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<td>(0.00184)</td>
<td>(0.00185)</td>
<td>(0.00183)</td>
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<tr>
<td>GDP Intensity</td>
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<td>20.00***</td>
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<td>(1.184)</td>
<td>(4.047)</td>
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<td>FDI/GDP</td>
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<td>(0.319)</td>
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<td>(0.189)</td>
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<td>(3.955)</td>
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<td>Land Area/capita</td>
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<td>-0.179***</td>
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<tr>
<td>(0.0397)</td>
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<tr>
<td>Constant</td>
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<tr>
<td>R-squared</td>
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Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1
IV. Conclusion

This paper investigates the impact of regional trade liberalization on pollution with the purpose of assessing the environmental consequences of regional trade agreements. I adopted a specification as to which pollution is explained by using income, population, land area, openness in relative terms, bilateral trade, FDI, and a dummy for RTA agreements. The model treats total trade, income, and RTA-related trade as endogenous, estimating the overall impact of RTAs on the environment using the generalized method of moments technique. An RTA is proxy by a dummy variable using RTA trade volume intensity that symbolizes the importance/size of RTAs; this avoids the potential endogeneity of the RTA variables. This study has analyzed the effects of regional liberalization on sulfur dioxide and carbon dioxide emissions by using extensive annual data for both developing and developed countries.

My results consistently indicate that whether regional liberalization has a beneficial effect on the environment on average depends on the pollutant. Different from the broad liberalization, regional liberalization has an adverse total direct effect on sulfur dioxide concentrations, but a beneficial total direct effect on carbon dioxide emissions in reducing it. The indirect effects on the environment caused by regional liberalization cannot be neglected; this is because there are the possible structural and volume changes in FDI. For economic policy, my results confirmed a strong link between trade, FDI, and the environment. In particular, I found that trade policy, as reflected by RTAs, has effects not only on trade but also on FDI, which has the potential to lead toward relocation of FDI. The environmental change caused by changes in FDI is substantial rather than trivial. When RTAs are in force, for intra-regional investment, the tariff-jumping FDI would decline since imports are more attractive compared with FDI; FDI undertaken to internalize the exploitation of intangible assets is going to be stimulated in the meantime. In addition, both tariff-jumping and internalization models promote inter-regional FDI inflows. The indirect effects increase sulfur dioxide concentrations and decrease carbon dioxide concentrations. Results show that when the RTA countries take relatively more important roles, RTAs are worse for sulfur dioxide concentrations but better for carbon dioxide emissions.

My results also indicate that, compared to global cooperation, regional cooperation is more effective in reducing GHG. This may be because a relatively small number of members with similar interests are more suitable to executing agreements on GHG reduction. Even so, such
agreement seems relatively ineffective to reduce sulfur dioxide concentrations. The explanation could be the fundamental difference of the two pollutants – reducing carbon dioxide emissions is a global public good and affects member state interests, necessitating more attention; on the other hand, sulfur dioxide as a local pollutant only matters to a single domestic government.

Further research concerning other pollutants such as nitrogen oxide, and pm 2.5 are also desirable to investigate the relationship between RTAs and pollution.

Appendix

Figure 2. Trend of RTAs (Only include free trade agreements (FTAs) and Customs Unions (CUs))
Figure 3. Trends of sum of SO2 of all countries (SO2 is measured as averaged log of SO2 concentrations)

Figure 4. Trends of sum of CO2 of all countries (CO2 is measured as CO2 emissions per capita)
Figure 5. Trends of SO2 of selected countries (SO2 is measured as averaged log of SO2 concentrations)

Figure 6. Trends of CO2 of selected countries (CO2 is measured as CO2 emissions per capita)
Table 3.3. Summary Statistics of intra-group trade intensity to total trade (the ratio of intra-group trade to total trade, average weighted by total trade)

<table>
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<th>year</th>
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<th>min</th>
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<td>0.805387</td>
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<td>1988</td>
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<td>1989</td>
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<td>0.314141</td>
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<td>1990</td>
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<td>1991</td>
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<td>0.307746</td>
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<td>0.923517</td>
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<td>0.276119</td>
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<td>0</td>
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<td>191</td>
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<td>1995</td>
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<td>0</td>
<td>0.277968</td>
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<tr>
<td>1996</td>
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<td>0.824338</td>
<td>0</td>
<td>0.276282</td>
<td>192</td>
</tr>
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<td>1997</td>
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<td>0.83299</td>
<td>0</td>
<td>0.276396</td>
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</tr>
<tr>
<td>1998</td>
<td>0.381999</td>
<td>0.842734</td>
<td>0</td>
<td>0.277528</td>
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</tr>
<tr>
<td>1999</td>
<td>0.386763</td>
<td>0.854319</td>
<td>0</td>
<td>0.285944</td>
<td>192</td>
</tr>
<tr>
<td>2000</td>
<td>0.373219</td>
<td>0.85672</td>
<td>0</td>
<td>0.287453</td>
<td>192</td>
</tr>
<tr>
<td>2001</td>
<td>0.384</td>
<td>0.88586</td>
<td>0</td>
<td>0.290293</td>
<td>192</td>
</tr>
<tr>
<td>2002</td>
<td>0.38514</td>
<td>0.891189</td>
<td>0</td>
<td>0.293922</td>
<td>192</td>
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</tbody>
</table>
Table 3.4. Number of countries in each RTA dummy cutoff in year 2006

<table>
<thead>
<tr>
<th>Variable</th>
<th>Number of countries</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;=0% RTA/ Total Trade</td>
<td>192</td>
</tr>
<tr>
<td>&gt;0% RTA/ Total Trade</td>
<td>180</td>
</tr>
<tr>
<td>&gt;=15% RTA/Total Trade</td>
<td>131</td>
</tr>
<tr>
<td>&gt;=30% RTA/Total Trade</td>
<td>96</td>
</tr>
<tr>
<td>&gt;=45% RTA/Total Trade</td>
<td>71</td>
</tr>
<tr>
<td>&gt;=50% RTA/Total Trade</td>
<td>64</td>
</tr>
</tbody>
</table>

Table 3.5. Effect of Economic Integration on SO2 concentrations and CO2 emissions per capita by GMM

<table>
<thead>
<tr>
<th>VARIABLES</th>
<th>GMM(SO2) Benchmark Binary RTA</th>
<th>GMM(CO2) Benchmark Binary RTA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Income/capita</td>
<td>3.692*** (1.299)</td>
<td>-17.37*** (0.836)</td>
</tr>
<tr>
<td>(Income/capita)^2</td>
<td>-0.206*** (0.0718)</td>
<td>1.228*** (0.0561)</td>
</tr>
<tr>
<td>Openness</td>
<td>-0.0100*** (0.00371)</td>
<td>0.0143** (0.00625)</td>
</tr>
<tr>
<td>GDP Intensity</td>
<td>1.720** (0.753)</td>
<td>-4.205*** (1.126)</td>
</tr>
<tr>
<td>FDI/GDP</td>
<td>-14.65*** (5.319)</td>
<td>0.00515 (0.382)</td>
</tr>
<tr>
<td>RTA Dummy(x)</td>
<td>-0.502*** (0.192)</td>
<td>-0.0325 (0.157)</td>
</tr>
<tr>
<td>polity</td>
<td>0.907** (0.380)</td>
<td>-0.0214 (0.0135)</td>
</tr>
<tr>
<td>Land Area/capita</td>
<td>-0.114*** (0.0417)</td>
<td>-0.0409 (0.0534)</td>
</tr>
<tr>
<td>Constant</td>
<td>-19.29*** (5.765)</td>
<td>59.59*** (3.271)</td>
</tr>
<tr>
<td>Observations</td>
<td>400</td>
<td>3,186</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.267</td>
<td>0.701</td>
</tr>
</tbody>
</table>

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
### Table 3.6. Effect of Economic Integration on pollutants after year 1980 (GMM)

<table>
<thead>
<tr>
<th>VARIABLES</th>
<th>(2) SO2</th>
<th>(3) SO2</th>
<th>(4) SO2</th>
<th>(5) SO2</th>
<th>(6) CO2</th>
<th>(7) CO2</th>
<th>(8) CO2</th>
<th>(9) CO2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>15%</td>
<td>30%</td>
<td>45%</td>
<td>50%</td>
<td>15%</td>
<td>30%</td>
<td>45%</td>
<td>50%</td>
</tr>
<tr>
<td></td>
<td>RTA/TotalTrade</td>
<td>RTA/TotalTrade</td>
<td>RTA/TotalTrade</td>
<td>RTA/TotalTrade</td>
<td>RTA/TotalTrade</td>
<td>RTA/TotalTrade</td>
<td>RTA/TotalTrade</td>
<td>RTA/TotalTrade</td>
</tr>
<tr>
<td>GDP Intensity</td>
<td>-1.073</td>
<td>-2.577***</td>
<td>-0.172</td>
<td>0.277</td>
<td>12.11***</td>
<td>9.716***</td>
<td>1.018</td>
<td>-1.667</td>
</tr>
<tr>
<td></td>
<td>(0.790)</td>
<td>(1.159)</td>
<td>(0.689)</td>
<td>(0.647)</td>
<td>(3.645)</td>
<td>(2.847)</td>
<td>(1.327)</td>
<td>(1.226)</td>
</tr>
<tr>
<td>FDI/GDP</td>
<td>-28.44***</td>
<td>-34.78***</td>
<td>-35.41***</td>
<td>-37.74***</td>
<td>-0.517*</td>
<td>-3.120*</td>
<td>-1.309*</td>
<td>-0.664*</td>
</tr>
<tr>
<td></td>
<td>(9.683)</td>
<td>(6.566)</td>
<td>(6.604)</td>
<td>(6.874)</td>
<td>(1.603)</td>
<td>(2.074)</td>
<td>(1.482)</td>
<td>(1.361)</td>
</tr>
<tr>
<td>RTA Dummy(x)</td>
<td>-3.006***</td>
<td>-8.400***</td>
<td>-7.247***</td>
<td>-6.450***</td>
<td>-1.553***</td>
<td>-2.098***</td>
<td>0.0896</td>
<td>0.361</td>
</tr>
<tr>
<td></td>
<td>(0.481)</td>
<td>(1.888)</td>
<td>(1.829)</td>
<td>(1.913)</td>
<td>(0.222)</td>
<td>(0.210)</td>
<td>(0.208)</td>
<td>(0.263)</td>
</tr>
<tr>
<td>GDP Intensity*RTA(x)</td>
<td>8.657***</td>
<td>27.94***</td>
<td>21.69***</td>
<td>18.23***</td>
<td>-22.97***</td>
<td>-11.16***</td>
<td>-10.72***</td>
<td>-8.142***</td>
</tr>
<tr>
<td>FDI*RTA(x)</td>
<td>47.38***</td>
<td>47.00***</td>
<td>48.36***</td>
<td>54.69***</td>
<td>-1.992</td>
<td>-9.195*</td>
<td>-5.675*</td>
<td>-3.978*</td>
</tr>
<tr>
<td>Constant</td>
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<td>-28.99***</td>
<td>-32.28***</td>
<td>-31.76***</td>
<td>53.56***</td>
<td>52.14***</td>
<td>53.54***</td>
<td>53.01***</td>
</tr>
<tr>
<td></td>
<td>(8.064)</td>
<td>(7.762)</td>
<td>(7.328)</td>
<td>(7.414)</td>
<td>(3.272)</td>
<td>(3.450)</td>
<td>(3.234)</td>
<td>(3.294)</td>
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<tr>
<td>Observations</td>
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<td>270</td>
<td>270</td>
<td>270</td>
<td>2,708</td>
<td>2,708</td>
<td>2,708</td>
<td>2,708</td>
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<tr>
<td>R-squared</td>
<td>0.293</td>
<td>0.301</td>
<td>0.275</td>
<td>0.253</td>
<td>0.715</td>
<td>0.713</td>
<td>0.714</td>
<td>0.712</td>
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</tbody>
</table>

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1
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CHAPTER 4
THE FOREIGN DIRECT INVESTMENT CONSEQUENCES OF NATURAL DISASTERS

I. Introduction

Natural disasters, a type of productivity shock, are one of the rare unpredictable exogenous shocks that we can observe. Natural disasters affect the economy immediately as well as having a long-term effect. The extensive infrastructure, inventories, agricultural resources, physical capital, and human capital loss caused by natural disasters makes the effect of natural disasters crucial to investment. Interestingly, the response of investment to natural disasters has yet to be fully explored. Specifically, the effect of natural disasters on foreign direct investment is rarely investigated.

In the wake of the recent devastating events, such as the 2004 Indian Ocean tsunami and earthquake, the 2005 hurricane Katrina in the southern region of United States, the 2008 Sichuan earthquake in China, and the 2011 Tohoku earthquake and tsunami in Japan, natural disaster risks have received growing awareness from public and policy makers. In the 2004 Indian Ocean tsunami, the combined death toll in Indonesia was a total of 350,000 people which is almost ten times the deaths from all other natural disasters together in the past 7 years. The estimated cost of total damage for the tsunami has been estimated to be 2,920.4 million dollars (Athukorala & Resosudarmo 2005). According to the Japanese Cabinet Office, the magnitude 9.0 Tohoku earthquake and tsunami in 2011, the fourth strongest earthquake in the world, has cost damage more than 200 billion dollars in damaged houses, factories and infrastructure such as roads and bridges. Even a country with the world’s most advanced state of prediction and warning systems had a hard time dealing with a disaster of this magnitude (Japanese Cabinet Office 2011). The disasters around the world over the past
couple of years have brought the “site selection” issue to the forefront.

Natural disasters result in the potential destruction of physical and transportation infrastructure, as well as labor stocks. Therefore, in addition to the macroeconomic aftermath, it seems reasonable to investigate if the capital inflows of foreign countries would also be affected by the disasters. Most existing literature has focused on how to take precautions against or mitigate the costs of natural disasters, such as the post-disaster aid flows, however, only a few papers concentrate on evaluating the economic consequences of disasters, and even fewer analyze its effects on foreign capital inflows. Some literature have mentioned the possibility (Mudambi 1999, Kreimer, Arnold, and Carlin 2003, Escaleras and Register 2011), but they either lack formal analysis or only use one disaster measurement and only include certain types of disasters for a limited period. In this paper, a much broader disaster dataset is used with a longer time period than previous studies, as well as more complete types of disasters, and three disaster measurements from different perspectives that are often used in the analysis of natural disasters. Using these, I investigate the impacts of natural disasters on foreign direct investment in a comprehensive way.

Both foreign direct investment and natural disasters went through a dramatic increase over the past several decades, but their trends do not completely coincide with each other. Figures 3 and 4 show that with the accelerating pace of global and regional integration, foreign direct investment net inflows have experienced a substantial increase since the 1980’s, but the growing trend is not smooth. The three downturns result from different reasons. The first deep recession in 2001 was influenced by the terrorist attack to the World Trade Center, while the second sharp downturn resulted from the global financial crisis in 2008, and the most recent big decline in 2014 was attributed to the uncertain world economic situation and geopolitical risks including regional conflicts according to the Annual Investment Meeting Report 2015. Overall, despite these economic downturns in the past, foreign direct investment net inflows in current US dollars have increased drastically from 23 billion dollars in 1975 to 929 billion dollars in 2014. While, Figures 5, 6, and 7 display the growing tendency in the past several decades in terms of the number of natural disasters, estimated
total damage, and total affected people, respectively. As shown in these figures, trends in these three measurements are not proportionally bound up with each other. The number of disasters increases until 2004 and declines afterwards, while estimated damages and total affected people rise gradually at different rates but neither have risen smoothly, and there are different downturns as well. The figures indicate that the frequency of natural disasters is not equivalent with the loss of physical or human capital of disasters. Therefore, even though we cannot tell whether foreign direct investment is related with the number of disasters, estimated total damage, and total affected people simply from the figures, it is worthwhile to analyze whether the frequency or intensity of natural disasters will affect foreign investors’ decision making in “site selections”.

One obvious advantage of doing empirical studies of natural disasters is its exogeneity. Previously, economists have used wars or technological improvement as exogenous shocks to test their economic theories. However, all of those shocks are not fully exogenous. For example, wars are driven by the potential gain of the initiating country while wars result in a cost to the same country. This kind of endogeneity affects the robustness of the analysis. Natural disasters can easily solve this problem. The randomness of natural disasters makes them perfect for the role of exogenous shocks compared to other accidents.

Existing literature on the economic effects of natural disasters is still not conclusive. There is disagreement about whether natural disasters showed an average positive impact in the short run (Albala-Bertrand 1993) and long run (Skidmore and Toya 2002), or negative in the short run (Noy 2009) and long run (Noy and Nualsri 2007, Cuaresma et al. 2008, Raddatz 2009), or no significant impact (Loayza et al. 2009, Melecky and Raddatz 2011, Cavallo et al. 2010) on macro-economy. Moreover, the correlation between the natural disasters and foreign direct investment (FDI), a key channel of international capital flow, is ambiguous. An exogeneous productivity shock in the host country may affect whether or not the FDI investors decide to invest at all, and how much to invest (Razin et al. 2008). Foreign investors always have alternative choices to invest in countries other than the country hit with disaster. To understand the ambiguous effects of natural disasters on FDI, consider a generic profit profile.
of a potential investor:
\[ \pi = -C + E(V) \]

First, there is a fixed cost $C$ to set up a firm in the host country. Second, there is an expected present value of returns from investment satisfies $E(V) = P_D V_1 + (1 - P_D) V_2$, where $P_D$ is the probability that disasters occur in the future. A concept called “creative destruction” has prevailed in the long run economic growth patterns (Aghion and Howitt 1998, Skidmore and Toya 2002, Okuyama et al. 2004). It argues that when a disaster affects capital stock, the incentive to replace these facilities with updated capital stock that embodies newer technology constitutes a positive productivity shock. If natural disasters work as creative destruction, on one hand, it causes improvement in marginal profitability of new investment, and on the other hand, it also results in an increase in input demands e.g. labor, and hence, the wage rates might increase. In that case, disasters have an adverse effect on variable costs and the wage associated with setup costs. Natural disasters as a positive productivity shock increases the marginal productivity but reduces the total profitability of a new investment at the same time. Moreover, foreign investors may become cautious of their decisions due to concerns that the risk of disasters will occur in the future and the associated higher sunk cost to prevent disasters (thereby influencing the investor’s probability assessment $P_D$). Therefore, the conflicting effects of marginal profitability and total profitability resulting from the so-called creative destruction make this research noteworthy.

I estimate the impacts of natural disasters on foreign direct investment by OLS and fixed effects, using three disaster measurements in the specification to compare the effects: (i) the number of total disasters occurring, (ii) the estimated damage caused by disasters, (iii) the other is total affected people resulting from disasters. The first measurement is the probability and frequency of disasters occurring, while the second and the third measurements denote the magnitude of disasters on physical and human capital respectively. The characteristics of these three variables provide different implications on natural disasters. While intuition might suggest that natural disasters have negative impacts (Cuaresma et al. 2008), some argued that natural disasters may serve as a means of creative destruction by providing opportunity to upgrade capital and absorb new technologies (Skidmore and Toya 2002). Results using panel
data of all countries suggest that the long-run adverse impact is only present for total number and total affected people of natural disasters. There is less evidence that disasters have such effect in the short run. Also, there was no systematic evidence of a negative correlation between the estimated total damage and natural disasters. Additionally, this adverse impact is more pronounced in the earlier periods than recent periods. This could be interpreted as in recent years, countries gradually improve domestic recovery systems and warning systems to be able to quickly prevent losses and recover from natural disasters, so that they minimize the negative effects and keep competitiveness in the international investment market.

This paper is structured as follows. Section II describes details of the dataset, including disasters data, FDI data, and other control variables. Section III presents details of the specification. Section IV reports estimation results for different OLS and fixed effects focusing on the frequency and intensity of natural disasters. Section V summarizes this study and concludes by providing policy recommendations.

II. Data

I constructed one macroeconomic annual panel dataset from 1985 to 2014. The linkage between natural disasters and foreign direct investment is a key concern. This dataset comprises a sample of 214 countries, including both developing and developed countries. Due to data availability constraints, this dataset contains data from 1985 to 2014 for all countries, for which data is available in the World Bank’s World Development Indicators. Observations with missing data were dropped so the sample is an unbalanced panel data. However, the omitted observations do not follow a specific pattern. As it is standard in the literature on FDI determinants (Asiedu & Lien (2011), Escaleras & Register (2011), Asiedu (2002)), the dependent variable is the ratio of net FDI inflows to GDP. Data for the dependent variable FDI comes primarily from World Development Indicators (WDI), and it is most commonly applied in the FDI research area. The World Bank defines FDI as the sum of
equity capital, reinvestment of earnings and other long and short term capital, and they are observed only when their profitability exceeds a certain threshold. According to reports of OECD, FDI now dwarf flows of official development assistance.

Data on natural disasters are taken from the EM-DAT: Emergency Events Database made available by the Center for Research on the Epidemiology of Disasters (CRED). EM-DAT contains essential core data on the occurrence and effects of over 21,000 mass disasters in the world from 1900 to present. The database is compiled from various sources, including UN agencies, non-governmental organizations, insurance companies, research institutes and press agencies. This database records natural disasters since 1900 based on the following conditions: (1) 10 or more people reported killed; (2) 100 people reported affected; (3) a call for international assistance; (4) a declaration of a state of emergency. The disasters contain all types of natural disasters, including hydro-meteorological disasters, such as floods, storms, droughts, landslides and avalanches; geophysical disasters, like earthquakes, tsunamis, and volcanic eruptions; and biological disaster, like epidemics and insect infestations. EM-DAT is a country-level database, meaning that the disasters data are entered at a country-aggregated level. When the same disaster event affects several countries, the disaster event will result in several country-level disasters being entered into the database. These accurate and comprehensive standards make sure most disasters are included in the database. Once a disaster is identified, the EM-DAT reports both the number of people affected, and the estimated damages in thousands of dollars in the year of occurrence. Three types of disaster data from this dataset to proxy natural disasters were chosen: the total number of natural disasters occurring, the estimated damage caused by disasters, and the total affected people result from disasters.

Some literature uses only the frequency data in their study. Skidmore and Toya (2002) argue that damage and affected people data are not always available and sometimes predictions for

1 By CRED definition, the affected people are the sum of injured, homeless, and those who require immediate assistance during the period of emergency. See CRED glossary for more definitions: http://www.emdat.be/glossary/9
missing values are not very accurate, besides, damage is sometimes exaggerated in developing countries in order to get international assistance. However, it is worthwhile to notice that many of the disasters in the dataset do not reveal the catastrophic concept of natural disasters when people think about the effects of natural disasters on the economy. Therefore, the latter two disaster variables were chosen to measure disaster magnitudes. Since it is presumed that the impact of a natural disasters on the economy depends on the magnitude of the disaster relative to the size of the economy, the three disaster measures were standardized by dividing the direct cost measure of the disaster by the previous year’s GDP, and dividing the number of people affected by the population size in the year prior to the disaster. Measuring the latter two variables will be illustrated in detail in the next section.

Following the literature on the determinants of FDI, I consider several explanatory variables of the decisions on FDI inflows. Data on real GDP per capita, GDP growth rate, CPI inflation, and openness come from World Bank’s World Development Indicators as well. Data for education is used as a proxy for human capital from Barro-Lee dataset, which measures the rate of population enrolled in secondary schools. Because of limitations with the education dataset—which is collected every five years until 2010, the panel dataset in this paper is from 1985 to 2014. The four-years education data gap between each five years is considered to be the same value as the initial year of each five years. Formal definitions and descriptive statistics are shown in Table 4.1.
<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>FDI net inflows (% of GDP)</td>
<td>Foreign direct investment are the net inflows of investment to acquire a lasting management interest (10 percent or more of voting stock) in an enterprise operating in an economy other than that of the investor. This series shows net inflows in the reporting economy from foreign investors, and is divided by GDP.</td>
<td>3.61</td>
<td>6.54</td>
<td>-82.89</td>
<td>91.01</td>
</tr>
<tr>
<td>GDP per capita (constant 2005 US$)</td>
<td>GDP per capita is gross domestic product divided by midyear population.</td>
<td>10110.9</td>
<td>16143.16</td>
<td>50.04</td>
<td>158802.5</td>
</tr>
<tr>
<td>GDP growth rate (annual %)</td>
<td>Annual percentage growth rate of GDP at market prices based on constant local currency.</td>
<td>3.46</td>
<td>3.87</td>
<td>-33.10</td>
<td>50.25</td>
</tr>
<tr>
<td>Inflation (consumer prices)</td>
<td>Inflation as measured by the consumer price index reflects the annual percentage change in the cost to the average consumer of acquiring a basket of goods and services that may be fixed or changed at specified intervals, such as yearly.</td>
<td>28.35</td>
<td>400.24</td>
<td>-18.11</td>
<td>23773.13</td>
</tr>
<tr>
<td>Openness (Trade (% of GDP))</td>
<td>Trade is the sum of exports and imports of goods and services measured as a share of gross domestic product.</td>
<td>81.62</td>
<td>49.34</td>
<td>0.31</td>
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To provide insights on comparing short and long term effects, I include total number, total estimated damage, and total affected people of disasters occurring five, ten, twenty, and twenty-five years prior to the measurement of FDI in individual regression to compare. Besides, the total estimated damage is calculated as a percentage of current GDP, and the total affected people is estimated as a percentage of the current total population. To have a simple idea of the correlations between FDI ratio and these natural disasters variables before running formal estimations, I initially check their correlations, and the results are shown in Tables 4.2, 4.3 and 4.4. It seems that the total number of disasters are consistently negatively correlated with FDI ratio. Total estimated damages are in general negatively affect FDI ratio as well, except for the most recent year. And total affected people are positively correlated with FDI ratio. These simple correlations cannot provide a certain and strong impacts of natural disasters with three different measurements on FDI. Therefore, I need further formal analysis. Moreover, Table 4.5 shows a test for stationarity in FDI using all 214 countries in the sample. I use the Fisher-type (Choi 2001) ADF test for stationarity. All four of the tests strongly reject the null hypothesis that all the panels contain unit roots at the 1% level of statistical significance. This means there are no unit roots in the panels under the given test conditions.

III. Methodology

In this paper, three measures of natural disasters are used to capture the essence of natural disasters. These three variables are the major variables that are available and previous papers use to represent disasters. The total number of disasters occurring measures the effect of frequency of disasters while the estimated damage measures the effect of magnitude of physical capital loss of disasters, and the total affected people proxy the effect of magnitude of human capital affected by disasters. The estimated damage reported in EM-DAT database only take account of direct damage such as infrastructure, crops, landed property but not include indirect damage like potential revenue, consequential unemployment. These indirect
effects are part of the goal of this paper. Since I presume the damage of natural disasters on the macro-economy is based on the magnitude of the disaster relative to the size of the economy. The estimated disaster damage is standardized following previous studies: the total average loss caused by the disasters as a percentage of GDP in the year that FDI is measured (last year). Similarly, I presume the affected people are based on the magnitude that people affected by disaster relative to the total population. The total affected people are standardized as a percentage of total population in the year FDI is measured. In the case that FDI investors treat natural disaster risk as part of their investment decision, and the decision of investment is always made years in advance, it is very possible that both current disasters and longer term disaster trends should be considered when making decisions. Consequently, to capture the long term effects and the effects of some consequential indirect damage of prior natural disasters, regression is utilized that contains the sum of lagged disasters in the prior n years to further test the impact of the risks of past natural disasters to current FDI ratio. I examine these variables separately because both recent disasters and long term trend could be crucial from a risk perspective when investors make investment decisions.

Following the literature on FDI determinants and effects of disasters on the macroeconomy and R&D, this paper runs fixed effect panel regressions and OLS specifications to compare the results. The benchmark model is:

\[ Y_{it} = \beta_0 + \beta_1 D_{it} + \beta_2 X_{it} + \delta Y_{it} + u_i + \epsilon_{it} \]

Where Yit is the net foreign direct investment inflows as percentage of GDP for country i, Dit is the disaster variable for country i in year t measured as stated previously, and Dit is proxy by the total number of natural disasters, the total estimated damage, and the total affected people of disasters, respectively, and each variable occurs one, five, ten, twenty, and twenty-five years prior to the measurement of FDI. Yrt is the time fixed effect to control for time-varying effects of FDI. Xit are independent variables selected from previous works which will be defined in detail later. ui is the unobserved variable to capture country’s heterogeneity, which implies the differences in country specific trends are systematic and preexisting, and hence does not change overtime, \( \epsilon_{it} \) is the idiosyncratic error term.
The selected variable $X_{it}$ includes the following terms: GDP per capita, GDP growth rate, CPI Inflation, Openness, and Education. Market size is evaluated in two ways, GDP per capita, and GDP growth rate. I choose real GDP per capita because an attraction factor should be considered here. A large portion of FDI inflows fits market-seeking rule, so the GDP per capita after deflated here measure the market size of the FDI host country. Same as previous studies, the correlation is expected to be positive. The GDP growth rate measures the potential market size. The GDP growth rate included here is not the current growth rate, but the geometric average of GDP growth rates over the last five years. Not only because the assumption in this paper is FDI reacts to the trends in growth over a period, which is adopted from Nonnemberg and Mengonca (2004); but also for the GDP growth of the disaster year has already been affected by the negative shock. Therefore, this paper uses a stream of growth rate before the disaster year to estimate the growth rate, and the FDI is expected to react positively to growth rate. Openness represent the easiness of foreign investment entering the home country. It is calculated by the ratio of trade, including imports and exports, to GDP. The openness is also interpreted as trade restrictions. When investments are market-seeking, the “tariff jumping” hypothesis results in openness having a negative impact on the FDI ratio. This is because the motivation of such investment is to jump the obstacles of exporting products to the home country. Meanwhile, in contrast, when investments are export-oriented, multinational firms would be more inclined to invest in the home country to take advantage of lower transaction cost. So the relationship between FDI ratio and openness depends on the types of investments. Inflation rate measures economic stability. The inflation rate is a measure of the overall economic stability of the country. A low inflation rate means the economy of the host country is well under control by the government. The higher level of inflation indicates the higher level of instability, which leads to higher risk of capital loss. The author assumes investors are risk averse, therefore I expect a negative relationship between inflation and FDI ratio. Education measures the productivity of domestic labor. I use the secondary school enrollment rate as a proxy of overall education level. The higher the enrollment rate, the better the quality of the labor.
V. Empirical Results

I use three different measurements to analyze natural disasters by different perspectives. I begin my analysis by measuring natural disasters with the total number of natural disasters in explaining the variation in FDI for my sample. I use ordinary least square (OLS) for estimations as benchmark, and I next include country fixed effects and year fixed effects to obtain results by fixed effects estimations. Results of estimations are reported in Table 4.6. Columns (1)-(5) are the results from OLS estimations, where variables are averaged over the 30 years period, 1985-2014. Column (6)-(10) report results for fixed effects estimations, where variables are averaged over the same 30 years period.

The results reported in Table 4.6 indicate that the variation in FDI rate can be explained by a small number of factors, namely, natural disasters, GDP per capita, GDP growth rate, inflation, openness to trade, and education. The results from Column (6)-(10) indicate that although initially natural disasters do not have significant effects on FDI ratio to the home country, as time goes by, they are consistently negative and statistically significantly associated with FDI ratio from a long time perspective, which are significant at least at 10% level. Besides, the coefficients on the natural disasters variables also show a steadily falling trend from -0.0275, when the variable is total number of disasters occurred in the current year, to -0.011, when the variable is total number of disasters occurred in the 25 years prior to the year in which FDI is measured. This falling pattern indicates that although natural disasters risks significantly affect FDI ratio in a long term, when foreign investors make decisions, relatively recent disasters make larger impacts to their decisions. And even though the coefficients are small in magnitude, because the FDI variables are percentages to GDP, these are large impacts to private foreign investors.

Table 4.6 also shows that the basic parameters of the model corroborate most of the hypotheses formulated in the previous section. The size of the economy, as measured by GDP per capita, positively affected the FDI ratio in both specifications, and being strongly
significant in fixed effects specification. The average GDP growth rate which proxy the willingness to accept foreign investment is positively influencing FDI ratio, and is strongly significant in both estimations. These two coefficients together imply countries with larger current domestic markets and larger potential markets are more attractive to foreign direct investors. The openness is positively and significantly correlated with FDI in all estimations. It is consistent with expectations that more open economy is more likely to attract foreign direct investments. The inflation as an indicator of economic stability and education as a proxy for human capital are not significant. These results are consistent with previous studies, such as Asiedu (2002) and Escaleras and Register (2011).
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Robust standard errors in brackets

*** p<0.01, ** p<0.05, * p<0.1
So far I have focused on the impacts of the total number of natural disasters on FDI. Besides the total number of natural disasters, there are other methods to measure natural disasters from different perspectives. Since it is not only the possibility of natural disasters happens could affect foreign investors’ decisions, but also the possible losses caused by natural disasters might matter. I next investigate whether the impacts of natural disasters on FDI are the same for total damage of natural disasters. It should be noted that the measurement of total damage is less accurate than the total number of natural disasters. As I mentioned earlier that damage and affected people data are not always available, data can be missing simply for no one knows the amount of damage and affected people, and prediction values for missing data are sometimes not very accurate. Moreover, there is over-reporting problem that damage is sometimes exaggerated in countries in order to get international assistance.

The same models as Table r.6 are applied, but instead of total number of disasters, I use total damage of natural disasters to measure the magnitude of natural disasters. Table 4.7 reports the estimated results. Table 4.7 shows that total damage of natural disasters do not have a significant impact on FDI ratio when using fixed effects estimations, even though they are negative and statistically significant in OLS estimations. Other variables perform same as previous. Whether this implies that foreign direct investment is not affected by total damage of natural disasters cannot be determined. One possible reason could be related to the accuracy of data as indicated before. The calculation of total damage of natural disasters is not as simple and precise as total number of natural disasters. Besides, this is the averaged effects of total damage across all countries, it is very likely that for countries total damage of natural disasters take a relative small percentage of GDP, foreign investors would not consider these damage of disasters as major concerns when making decisions. Therefore, it is not surprising to see that FDI is not affected by total damage of natural disasters. Moreover, due to lack of data, instead of differentiating FDI by types of FDI, I here apply total FDI in estimations. And I do not have enough data to show what types of damage or what industry that natural disasters cause the most damage. For instance, if FDI is mainly natural resource based in a country, as in many African countries, whether total damage is large or not would not have significant effects on FDI because where natural resources located is the primary
elements in decision making. However, this result is consistent with Cavallo et al. (2013) and Loayza et al. (2009) to some extent. Cavallo et al. (2013) examines the average impact of catastrophic natural disasters on per capita income in the short and long run and compare them with counterfactual cases. It is found that even those extremely large disasters do not display any significant effect on economic growth, except when followed by radical political turmoil they have a negative effect on output. And those relative smaller but still very large natural disasters have no effect on output as well. Both Cavallo et al. (2013) and Loayza et al. (2009) finds no significant effects of disasters in general, but none of them explain the reason behind the estimated results.
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Robust standard errors in brackets

*** p<0.01, ** p<0.05, * p<0.1
With the previous two estimations from different point of views, I further investigate whether FDI ratio are more or less vulnerable to the impact of natural disasters by measuring it with total affected people of natural disasters. When natural disasters occur, it affects physical capital and human capital at the same time, which both types of capital together compose key elements that affect foreign investment decision makers. On one hand, total damage of natural disasters represents the extent to which natural disasters destroy local physical capital, and on the other hand, total affected people of natural disasters expresses the influence of natural disasters to local human capital. I am interested in whether human capital has differing effects on the FDI ratio.

Table 4.8 presents the results. Other control variables consistently perform as before. Similar to the results of total number of natural disasters in Table 4.6, natural disasters do not have significant effects on FDI inflows to the home country at the beginning. As time lags extend longer, finally, negative significance at 10% level is found in the 20 years lag case and 25 years lag year case for total affected people. It suggests that while total affected people do not have an impact on FDI in the short term, the loss of human capital does significantly negatively affect FDI inflows in a long term. Melecky and Raddatz (2011) categorized natural disasters as geological disasters includes earthquakes, landslides, volcano eruptions, and tidal waves; and climatic disasters includes floods, droughts, extreme temperatures, and windstorms. And they find no significant output impacts in the short run for each category even from large natural disasters. And the no significant short term effects here are similar to what Melecky and Raddatz (2011) states, while the negative long term effects are along the lines of Noy and Nualsri (2007).
Table 4.8: Total Affected People of Natural Disasters and Foreign Direct Investment

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Robust standard errors in brackets

*** p<0.01, ** p<0.05, * p<0.1
As for the above three variables that measure natural disasters from different point of views, we can see that natural disasters are negatively and statistically associated with FDI ratio in the long term, when it is represented by two of them—total number of natural disasters and total affected people of natural disasters. When it is measured by total damage of natural disasters, it does not have significant impacts on FDI ratio when using fixed effects estimations, while they are negative and statistically significant in OLS estimations. The negative relationship between FDI and natural disasters are consistent with Escaleras and Register (2011) except that they found statistically significance in the short term as well. But it could be because of the different dataset that they only cover until 2004 and with less countries. We can tell from Figure 3, 4, 5, 6, and 7 that both FDI and natural disasters experience larger fluctuations after 2004. Therefore, I next divide the data into two time periods to see if this pattern holds.

Recent studies argue that natural disasters provide opportunities to update the capital stock and adopt new technologies, acting as some type of creative destruction. In the meantime, the concerns of the possible huge loss if disasters happen and big sunk cost make foreign investors cautious of their investment decisions. When a foreign investor makes a decision, he will think about two questions: whether to invest at all? And how much to invest? The product of the first one—the amount of each investment, determined by the marginal product of investment, and the second one—the quantity of investment events, governed by the total profitability, is the FDI inflows. Therefore, even though the disasters provide opportunities for foreign investors to update capital stock and new technologies, considering the historically damage caused by disasters in the home country, the investors would decrease the amount of each investment to avoid possible risks of big loss. This concern lowers the likelihood of foreign investors to make big investments in the home countries. The above results possibly because that the concerns of loss results from disasters and fixed costs dominate or at least cancel out the attractiveness of creative destruction when foreign investors make investment decisions.

Furthermore, to investigate whether this pattern is consistent in different time periods, I test
this proposition by running the fixed effects estimations in Table 4.9, dividing into two time periods 1985-2004 and 2005-2014. Columns (1)-(5) are results from fixed effects estimations over the earlier period, 1985-2014. Column (6)-(10) report results for fixed effects estimations over the relatively recent period. Columns (1)-(5) show results for the prior 1, 5, 15, 20, and 25 years of total number, total damage, or total affected people of natural disasters over the earlier period. Columns (6)-(10) display results for the same coefficients over the recent period. Columns (1)-(5) show that results are consistent with the general results of the whole sample in Table 4.6, 4.7, and 4.8. Natural disasters measured by total number of natural disasters do not have significant effects initially, but they are statistically significant and negatively associated with FDI ratio gradually in the long term. Using data over the 1985-2014 period, I show that foreign direct investment has switched over time from strongly negative correlated to be essentially unrelated to natural disasters. The changing effect of natural disasters on FDI ratio should be interpreted with some caution. It may partially reflect the increasing protective influence of improved disasters prediction and warning systems, infrastructural and financial recovery systems in many countries in recent years. The development of these recovery and warning systems could assist to prevent losses and to recover from natural disasters sooner and more efficiently. It is very important for countries to be affected as slightly as possible in natural disasters to keep their competitive positions in the international investment market. Such patterns are consistent when natural disasters are measured by total affected people of natural disasters. When the estimation is examined by total damage of natural disasters, there is no significant influence over the whole period.
Table 4.9: Total Number, damage, and Affected People of Natural Disasters and Foreign Direct Investment in different periods

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<td>1.222</td>
<td>-0.332</td>
<td>-0.194</td>
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</tbody>
</table>

Standard errors in brackets

*** p<0.01, ** p<0.05, * p<0.1
V. Conclusion

Foreign direct investment is based on the expectation of risks and returns. Previous studies on its determinants consider factors such as economic growth rates, openness, financial risks, government stability, and human capital. This paper investigates natural disasters—another type of risk foreign investors would take into account, that will influence potential physical capital, human capital, and infrastructure damages and reconstruction. Given the potential effects on infrastructure, transportation, physical capital, and labor forces, this paper aims at examining how natural disasters affect FDI from three different perspectives. Because of the conflicting effects on marginal product and total profitability, the impact of disasters becomes ambiguous. The estimates based on observations of countries with complete data from 1985 to 2004 indicate that natural disasters are negatively and statistically correlated with foreign direct investment in the long term when it is measured by total number of natural disasters and total affected people of natural disasters. When natural disasters are estimated in terms of total damage, it appears that there is no significant influence on FDI though possibly because of the less accurate data of dollar losses. In addition, I found that these negative effects between natural disasters and FDI ratios are more obvious in earlier periods than recent periods, which are consistent for all three different measurements of natural disasters. These results are interpreted as evidence that in order to attract foreign direct investment, even though natural disasters are not avoidable, countries should minimize the negative effects of natural disasters. This interpretation is consistent with the recent trends that countries recently gradually improve domestic recovery systems and warning systems to be able to prevent losses and recover from natural disasters quickly, so that they are still competitive in the international investment market. Further path of the research in this topic could modify the measure of disasters to be more accurate, and include the effect of disasters on different types of FDI.
Appendix

Figure 7. World Foreign Direct Investment, Net Inflows (BoP, current US$) between 1975-2014

Figure 8. World Foreign Direct Investment, Net Inflows (% of GDP) between 1975-2014
Figure 9. Total Number of Natural Disasters Reported between 1975-2011

Figure 10. Total Estimated Damage (current US billion$) of Natural Disasters between 1975-2011
Table 4.2.
Correlations between Foreign Direct Investment and Total Number of Natural Disaster

<table>
<thead>
<tr>
<th>FDI/GDP</th>
<th>Total Number of Disasters in the prior 1 year</th>
<th>Total Number of Disasters in the prior 5 years</th>
<th>Total Number of Disasters in the prior 10 years</th>
<th>Total Number of Disasters in the prior 20 years</th>
<th>Total Number of Disasters in the prior 25 years</th>
</tr>
</thead>
<tbody>
<tr>
<td>FDI/GDP</td>
<td>1</td>
<td>-0.0481</td>
<td>0.8331</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

FDI/GDP Total Number of Disasters in the prior 1 year -0.0481 1
Total Number of Disasters in the prior 5 years 0.8331 1
<table>
<thead>
<tr>
<th>FDI/GDP</th>
<th>Total Estimated Damage of Disasters in the prior 1 year</th>
<th>Total Estimated Damage of Disasters in the prior 5 years</th>
<th>Total Estimated Damage of Disasters in the prior 10 years</th>
<th>Total Estimated Damage of Disasters in the prior 20 years</th>
<th>Total Estimated Damage of Disasters in the prior 25 years</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.0245</td>
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<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-0.0047</td>
<td>0.0025</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-0.0037</td>
<td>0.0051</td>
<td>0.7465</td>
<td>1</td>
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<td></td>
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<tr>
<td>-0.0052</td>
<td>0.0041</td>
<td>0.6708</td>
<td>0.8472</td>
<td>1</td>
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<tr>
<td>-0.0025</td>
<td>-0.0034</td>
<td>0.4569</td>
<td>0.3468</td>
<td>0.5773</td>
<td>1</td>
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</tbody>
</table>

Table 4.3
Correlations between Foreign Direct Investment and Total Estimated Damage of Natural Disaster (% of current GDP)
### Table 4.4
Correlations between Foreign Direct Investment and Total Affected People of Natural Disaster (% of current population)

<table>
<thead>
<tr>
<th>FDI/GDP</th>
<th>Total Affected People of Disasters in the prior 1 year</th>
<th>Total Affected People of Disasters in the prior 5 years</th>
<th>Total Affected People of Disasters in the prior 10 years</th>
<th>Total Affected People of Disasters in the prior 20 years</th>
<th>Total Affected People of Disasters in the prior 25 years</th>
</tr>
</thead>
<tbody>
<tr>
<td>FDI/GDP</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Affected People of Disasters in the prior 1 year</td>
<td>0.0117</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Affected People of Disasters in the prior 5 years</td>
<td>0.0036</td>
<td>0.1096</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Affected People of Disasters in the prior 10 years</td>
<td>0.008</td>
<td>0.1176</td>
<td>0.7797</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Total Affected People of Disasters in the prior 20 years</td>
<td>0.012</td>
<td>0.1156</td>
<td>0.6694</td>
<td>0.8458</td>
<td>1</td>
</tr>
<tr>
<td>Total Affected People of Disasters in the prior 25 years</td>
<td>0.0151</td>
<td>0.1231</td>
<td>0.6512</td>
<td>0.8147</td>
<td>0.966</td>
</tr>
</tbody>
</table>

### Table 4.5
Fisher-type unit-root test for FDI based on augmented Dickey-Fuller tests

<table>
<thead>
<tr>
<th></th>
<th>Statistic</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inverse chi-squared(448)</td>
<td>P</td>
<td>1677.782</td>
</tr>
<tr>
<td>Inverse normal</td>
<td>Z</td>
<td>-27.4569</td>
</tr>
<tr>
<td>Inverse logit t(1124)</td>
<td>L*</td>
<td>-30.0082</td>
</tr>
<tr>
<td>Modified inv. chi-squared</td>
<td>Pm</td>
<td>41.0841</td>
</tr>
</tbody>
</table>
References


CHAPTER 5

CONCLUSION

Chapter 2 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 (an import tariff) affects the incentive for an exporting country to levy a tax on the emission of greenhouse gases. 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 than it would if a tariff were not available to the importing country. The result suggests that the emission tax of an exporting country is a strategic substitute for the tariff of an importing country, while it is a strategic complement with the emission tax of an importing country. This result supports our main conclusion that trade restrictions would not encourage other countries to adopt more stringent environmental regulations.

Chapter 3 examines the impact of regional trade liberalization on the environment. This work found that whether regional liberalization has a beneficial effect on the environment depends on the pollutant involved. Opposite to broad trade liberalization, the total direct effects of regional liberalization increase sulfur dioxide concentrations while decreasing carbon dioxide emissions. In addition, I found that trade policy, as reflected by RTAs, has effects not only on trade but also on FDI, which has the potential to lead toward relocation of FDI. The indirect effects on the environment caused by regional liberalization cannot be neglected; this is because there are the possible structural and volume changes in FDI. The environmental change caused by change in FDI is substantial rather than trivial. The indirect effects increase sulfur dioxide concentrations and decrease carbon dioxide concentrations. My results also indicate that regional cooperation is effective in reducing GHG.

Chapter 4 investigates the FDI consequences of natural disasters by fixed effects, using three disaster measurements in the specification to compare the effects. One is the number of total disasters occurring, one is the estimated damage caused by disasters, and the other is total affected people resulting from disasters. The first variable symbolizes the probability and
frequency of disasters occurring, while the second and the third one denote the magnitude of disasters on physical and human capital respectively. The results indicate that when disasters are measured by their total number and their number of affected people, they are negatively and statistically correlated with FDI in the long term, but there is no significant correlation when disasters are measured by their total monetary damage.