Foreign Direct Investment and Border Carbon Adjustments

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Abstract

This paper examines the effect of border carbon adjustments on greenhouse gas emissions and national welfare under a possibility that firms relocate production through foreign direct investment. In a North-South setting based on an intra-industry trade model, border carbon adjustments in the North cannot prevent relocation of production to the South if the North firm has sufficiently “cleaner” technology than the South firm. Such relocation of production does not necessarily harm the global environment. In fact, given the technology gap between the North and the South, relocation of production to the South could result in a reduction in total emissions. Border carbon adjustments introduced by the North could also benefit the South as well as the North when the international relocation of production arises.

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1 Introduction

In recent years, developed nations introduced regulation on greenhouse gas emissions through an emission trading scheme and/or a carbon tax. However, emerging market countries such as China and India are reluctant to limit greenhouse gas emissions even though they have become major nations in terms of emissions. This asymmetry in climate change policy across nations may significantly influence international trade. Firms located in countries that regulate emissions would incur a cost of carbon price. As a result, they may have disadvantage in international markets as compared to firms located in countries without regulation on their emissions because firms that produce in these countries do not have to pay for such carbon price. In addition, such a cross-country difference in carbon price may cause international relocation of production, and as a result, carbon leakage can arise, i.e., an increase in emissions of nations that do not regulate greenhouse gas emissions. If such leakage is significant, unilateral climate change policy may harm the global environment through an increase in global emissions.

In response to this concern about carbon leakage, policy makers in developed nations proposed border carbon adjustments, i.e., imposing carbon tariffs on imports from countries that do not limit emissions and/or refunding exporting firms carbon price for their export sales to those countries. How do border carbon adjustments affect relocation of production to countries without regulation on greenhouse gas emissions? What is the effect of border carbon adjustments on global emissions and national welfare under a possibility that firms relocate production across countries? In this paper, we examine these issues by using a model of international trade with imperfect competition. We extend a framework a la Brander and Krugman (1983) to a North and South setting in which cross-border pollution is generated by production and foreign direct investment (FDI) arises. We consider an emission tax as an instrument of climate change policy. The government of the North

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1 In the context of climate change policy, the term Border Carbon Adjustments refers to the measure that takes the form of a tax or a regulation imposed at the border aiming at equal treatment of the embedded carbon content of like foreign and domestic products (Horn and Mavroidis, 2010). If the measure of a Border Carbon Adjustment takes the specific form of a tax, then it is called a “Border Tax Adjustment (BTA).” There has been an extensive legal debate over the eligibility of domestic carbon/energy taxes for border tax adjustments (Hufbauer et al., 2009). See World Trade Organization (2009) for the consistency of border carbon adjustments to the GATT/WTO rules.

Helm et al. (2012) reviewed recent policy discussion over border carbon adjustments. Atkinson et al. (2011) used input-output analysis and estimated ‘virtual carbon’ in flows of international trade. They showed that a tax on virtual carbon could lead to substantial effective tariffs on imports from carbon-intensive developing countries.
introduces an emission tax with or without a border tax adjustment (BTA).\footnote{Since we consider an emission tax as a policy instrument, we use “border tax adjustments” instead of border carbon adjustments. In the context of this paper, border carbon adjustments can be interchangeable with border tax adjustments without any confusion.} We show that the BTA cannot prevent the North firm from relocating its production to the South if the North firm has sufficiently cleaner technology than the South firm. Given the technology gap, such relocation of production does not necessarily harm the global environment. In fact, FDI to the South could result in a reduction in total emissions. In addition, the emission tax with the BTA introduced by the North benefits the South as well as the North when the relocation of production arises through FDI.

This paper is related to the recent literature on border carbon adjustments. The work such as Matoo et al. (2009), McKibben and Wilcoxen (2009), and Boehringer et al. (2010) examined the effect of border adjustments with the computable general equilibrium (CGE) analysis. These studies used perfectly competitive settings and did not consider international relocation of firms. Babiker (2005) is closely related to our work in that he introduced imperfectly competitive markets into CGE analysis so that he could take into account of relocation of production across countries for the analysis on carbon leakage. Babiker (2005) considered a model in which relocation of production arises through entry and exit of firms in each country’s market. Unlike his work, we consider a model with limited entry and each firm chooses the location of production. Furthermore, we analyze the effects of border carbon adjustments, which were not examined in his work. In addition, there are theoretical studies motivated by border carbon adjustments, including Gros (2009), Horn and Mavroidis (2010), and Tarui, Yomogida, and Yao (2010). They used competitive settings and did not take into account of international relocation of production by firms.

Fowlie (2009) and Ritz (2009) examined the effect of incomplete environmental regulation on carbon leakage in an imperfectly competitive sector. Their studies are similar to our work in that they used Cournot oligopoly settings with limited entry and examined how emissions leakage arise from regulated to unregulated firms. However, unlike our model, they did not consider relocation of regulated firms. Furthermore, they did not explicitly consider international trade so that they did not examined the effects of border carbon adjustments on global emissions and national welfare.

The rest of this paper is organized as follows. In section 2, we introduce the model and examine how the emission tax with the BTA affects relocation of production across countries. In Section 3, we compare the emission tax with and without the BTA in terms...
of the effects on worldwide emissions. In Section 4, we examine the impact of each emission
tax policy on national welfare. In Section 5, we close the paper with concluding remarks.

2 The Model

There are two countries, a country $N$ (the North) and a country $S$ (the South). The
industry is a homogeneous product duopoly with each firm located in each country. The
technology of each firm is described by a constant marginal cost. Each country’s firm
can make foreign direct investment (FDI) to move its production abroad. To make FDI,
each firm has to incur a fixed cost. The production of each firm generates emissions of
pollution such as greenhouse gases. Pollution emissions cause cross-border externalities
that negatively affect the welfare of consumers in each country. The firms do not incur
transport costs to ship their products across the borders, but such costs are prohibitively
high for any third party arbitragers. Thus, the demand curves in the two markets are
independent. The firms compete a la Cournot in the markets.

Let $x_i$ denote firm $i$’s sales to the domestic market (country $i$) and $y_i$ denote firm $i$’s
sales to the other country’s market (country $j$, $j \neq i$), $(i, j = N, S)$. The total output of
firm $i$ is $x_i + y_i$, and the total sales in the market of country $i$ is $q_i = x_i + y_j$ $(i, j = N, S,$
$i \neq j)$. The demand curves are linear and the inverse demand function in the market of
country $i$ is $p_i(q_i) = a_i - b_i q_i$, $a_i, b_i > 0$ ($i = N, S$).

Let $c_i$ denote a constant marginal cost for production of firm $i$ when firm $i$ produces in
country $i$, $(i = N, S)$. We assume that $c_S < c_N$ because a cost advantage of the North firm
due to the North’advanced technology is overwhelmed by a cost advantage of the South
firm due to the South’s lower wage. The production of each firm generates pollution such
as greenhouse gases and one unit of production by firm $i$ generates $e_i$ units of pollution
$(i = N, S)$. We assume that $e_N < e_S$ since the North firm has less pollution-intensive
technology than the South firm. Total emissions of firm $i$ are $E_i = e_i(x_i + y_i)$. Let $\tau_i$ denote
an emission tax of country $i$. We assume that $\tau_N > \tau_S = 0$, i.e., only the government of
the North imposes a tax on emissions. The lower wage and zero emission tax provide an
incentive for the North firm to move its production to the South through FDI. To make
FDI, the North firm has to incur a fixed cost $f_N > 0$. In the South, the North firm produces
with a constant marginal cost $c^F_N < c_N$ and a constant emission coefficient $e_N$. We also
assume that $c^F_S > c_S$, i.e., it is more costly for the South firm to produce in the North
rather than in the South due to a higher wage in the North. This preclude the South firm
from moving its production to the North.

Let us first consider an emission tax policy without a Border Tax Adjustment (BTA). The government of the North levies a tax $\tau_N$ on emissions generated by domestic production. If the North firm produces in the North, then the profit of the North firm is

$$\pi_N = p_N(q_N)x_N + p_S(q_S)y_N - (c_N + \tau_N e_N)(x_N + y_N),$$

If the North firm makes FDI in the South, the profit of the North firm is

$$\pi^F_N = p_N(q_N)x_N + p_S(q_S)y_N - c^F_N(x_N + y_N) - f_N.$$  

FDI allows the North firm to avoid the burden of the emission tax imposed by the government of the North. This creates a pollution-haven motive for the firm to move its production to the South. Since the South firm does not incur any emission tax, the profit of the South firm is

$$\pi_S = p_S(q_S)x_S + p_N(q_N)y_S - c_S(x_S + y_S).$$

In an emission tax policy with a Border Tax Adjustment (BTA), the government of the North levies a pollution-content tariff $t_N$ on imports from the South.\(^3\) Also, the government of the North exempts the North firm from an emission tax for export sales to the South. We will consider a case in which the GATT/WTO rule requires that the pollution-content tariff rate is equal to the emission tax rate, $t_N = \tau_N$, and one hundred percent of the emission tax rate is exempted for export sales. If the North firm produces in the North, then the profit of the North firm is

$$\pi_{NB} = p_N(q_N)x_N - (c_N + \tau_N e_N)x_N + p_S(q_S)y_N - c_N y_N.$$  

The North firm incurs the emission tax only for its emissions generated by production for its sales to the North market. If FDI arises, then the profit of the North firm is

$$\pi^F_{NB} = p_N(q_N)x_N - (c^F_N + \tau_N e_N)x_N + p_S(q_S)y_N - c^F_N y_N - f_N.$$  

Due to the pollution-content tariff, the North firm cannot avoid the tax burden even if it

\(^3\)Copeland (1996) examined the pollution-content tariff in a different context.
moves its production to the South. The South firm also incurs the pollution-content tariff for its export sales to the North market. The profit of the South firm is

$$\pi_{SB} = p_S(q_S)x_S - c_Sx_S + p_N(q_N)y_S - (c_S + \tau_N e_S)y_S. \quad (6)$$

Firm’s profit maximization problem consists of two stages. In the first stage, each firm chooses its location of production. In the second stage, given the location of production, firms compete ala Cournot in each country’s market. We will solve the problem backward. Suppose that the government of the North does not implement the BTA. The first order conditions for the North firm and the South firm in the North market are respectively,

$$a_N - 2b_N x_N - b_N y_S = c'_N + e_N \tau'_N,$$
$$a_N - b_N x_N - 2b_N y_S = c_S,$$

where \((c'_N, \tau'_N) = (c_N, \tau_N)\) if the North firm produces domestically and \((c'_N, \tau'_N) = (c'_F, 0)\) if the North firm makes FDI in the South. Solving the first order conditions simultaneously, we can derive the equilibrium sales of each firm in the North market.

$$x_N = \frac{a_N - 2c'_N + c_S - 2e_N \tau'_N}{3b_N}, \quad (7)$$
$$y_S = \frac{a_N - 2c_S + c'_N + e_N \tau'_N}{3b_N}. \quad (8)$$

Similarly, in the South market, the first order conditions are

$$a_S - 2b_S x_S - b_S y_N = c_S,$$
$$a_S - b_S x_S - 2b_S y_N = c'_N + e_N \tau'_N.$$

Equilibrium sales of the North firm and the South firm are derived respectively as

$$x_S = \frac{a_S - 2c_S + c'_N + e_N \tau'_N}{3b_S}, \quad (9)$$
$$y_N = \frac{a_S - 2c'_N + c_S - 2e_N \tau'_N}{3b_S}. \quad (10)$$

Next, suppose that the government of the North adopts the emission tax policy with the BTA. The first order conditions for the North firm and the South firm in the North
market are respectively,
\[ a_N - 2b_Nx_N - b_Ny_S = c'_N + e_N\tau_N, \]
\[ a_N - b_Nx_N - 2b_Ny_S = c_S + e_S\tau_N, \]
where \( c'_N = c_N \) if the North firm produces domestically and \( c'_N = c'_F \) if the North firm makes FDI in the South. Using the first order conditions, we can derive the equilibrium sales of each firm in the North market
\[
x_{NB} = \frac{a_N - 2c'_N + c_S + (e_S - 2e_N)\tau_N}{3b_N},
\]
\[ y_{SB} = \frac{a_N - 2c'_N + (e_N - 2e_S)\tau_N}{3b_N}. \]

Similarly, in the South market, the first order conditions are
\[ a_S - 2b_Sx_S - b_SY_N = c_S, \]
\[ a_S - b_Sx_S - 2b_SY_N = c'_N. \]

Equilibrium sales of the North firm and the South firm are respectively
\[
x_{SB} = \frac{a_S - 2c_S + c'_N}{3b_S},
\]
\[ y_{NB} = \frac{a_S - 2c'_N + c_S}{3b_S}. \]

### 2.1 The Effects of the Emission Tax Policy on FDI

In this section, we will examine how the emission tax policy of the North affects the North firm’s decision on FDI.

First, let us consider the effects of the emission tax policy without the BTA. The profitability of making FDI can be derived as
\[
\Delta\pi^F_N = \pi^F_N - \pi_N = \pi^F_{N0} - \pi_{N0} + \frac{4e_N}{3} \left[ (x_{N0} + y_{N0})\tau_N - \left( \frac{1}{b_N} + \frac{1}{b_S} \right) \left( \frac{e_N}{3} \right)^2 \tau_N^2 \right],
\]
where the subscript 0 indicates variables associated with a laissez-faire policy in which the emission tax rate is zero in the North, \( \tau_N = 0 \). In the laissez-faire equilibrium, the effects
of an increase in the emission tax rate on the profitability of FDI can be derived as

$$\left. \frac{\partial \Delta \pi_N^F}{\partial \tau_N} \right|_{\tau_N=0} = \frac{4e_N (x_{N0} + y_{N0})}{3} > 0. \quad (16)$$

An increase in the emission tax rate in the North would induce the North firm to make FDI in the South. The reason is obvious. FDI allows the North firm to avoid the emission tax imposed by the North. The North firm moves its production to the South due to the pollution haven motive.

Next, let us turn to the emission tax policy with the BTA. The profitability of FDI can be derived as

$$\Delta \pi_{NB}^F = \pi_{NB}^F - \pi_{NB} = \pi_{N0}^F - \pi_{N0} + \frac{4(c_N - c_N^F)(e_S - 2e_N)\tau_N}{9b_N}. \quad (17)$$

In the laissez-faire equilibrium, the effect of an increase in the emission tax rate on the profitability of FDI is

$$\left. \frac{\partial \Delta \pi_{NB}^F}{\partial \tau_N} \right|_{\tau_N=0} = \frac{4(c_N - c_N^F)(e_S - 2e_N)}{9b_N}. \quad (18)$$

The effect depends on a difference in the environmental technology between the North and the South. If the North firm has a sufficiently smaller emission coefficient than the South firm and $e_S > 2e_N$ holds, then an increase in the emission tax in the North makes FDI by the North firm more profitable. However, the difference in the environmental technology is sufficiently small and $e_S < 2e_N$ holds, then a rise in the emission tax rate in the North would reduce the profitability of FDI by the North firm.

This result is somewhat surprising because FDI does not provide any reduction or increase in a tax burden per unit of emissions for the North firm. Under the policy with the BTA, the North government imposes the pollution-content tariff on imports from the South and the tariff rate is identical to the emission tax rate that is applied to the domestic production. Thus, regardless of the location of production, identical tax rates are applied to the North firm with respect to its production for its sales to the North market. In addition, since the emission tax is exempted for the North firm’s export sales, FDI does not provide the North firm any savings in the tax on production for its sales to the South market. Nonetheless, as long as the North firm has sufficiently cleaner technology than the South firm, a rise in the emission tax rate induces the North firm to move its production.
to the South.

This result is caused by an output reallocation effect of the emission tax rate. The profitability of FDI can be written as follows,

\[
\Delta \pi^F_{NB} = \frac{2 (c_N - c^F_N)(x^F_{NB} + x_{NB} + y^F_{NB} + y_{NB})}{3},
\]

(19)

where \(x^F_{NB}\) and \(y^F_{NB}\) are the North firm’s sales to the North and South markets in the equilibrium with FDI, respectively. Under the policy with the BTA, a rise in the emission tax rate increases a marginal cost for the South firm as well as for the North firm. An increase in its own marginal cost negatively affects the output of the North firm. However, at the same time, an increase in the South firm’s marginal cost positively affects the output of the North firm. In fact, if the emission coefficient of the South firm is sufficiently greater than the emission coefficient of the North firm and \(e_S > 2e_N\) holds, the latter positive effect overwhelms the former negative effect. As shown in (11) and (12), an increase in the emission tax rate raises the output of the North firm at the expense of the output of the South firm. Since (18) implies that the profitability of FDI is proportionally increases with the output of the North firm, an increase in the emission tax rate promotes FDI by the North firm.

We can state the above result as follows.

**Proposition 1.** Suppose that the government of the North adopts the emission tax policy with the BTA and the North firm has sufficiently cleaner technology than the South firm, i.e., \(e_S > 2e_N\). Then, an increase in the emission tax rate in the North induces foreign direct investment by the North firm to the South.

Next, let us examine how the BTA affects the North firm’s decision on FDI to the South. By comparing (16) with (18), we can show that

\[
\frac{\partial \Delta \pi^F_N}{\partial \tau_N} \bigg|_{\tau_N=0} - \frac{\partial \Delta \pi^F_{NB}}{\partial \tau_N} \bigg|_{\tau_N=0} = \frac{4}{3} e_N(x_{N0} + y_{N0}) - \frac{4(c_N - c^F_N)(e_S - 2e_N)}{9b_N},
\]

\[
> 0 \text{ if } \frac{2e_N(x^F_{N0} + y_{N0})}{x^F_{N0} - x_{N0}} > e_S.
\]

This result suggests that the BTA can make FDI less likely to occur under the condition on the technology gap between the North and the South. In fact, we can show that there
is a range of the emission tax rate in which FDI arises only in the policy without the BTA (see Figure 1).

**Proposition 2** Suppose that (i) the North firm has sufficiently cleaner technology than the South firm, i.e., \( 2e_N < e_S < \frac{2e_N(x_{N0} + y_{N0})}{x_{N0} - x_{N0}} \) holds, (ii) FDI is not profitable at \( \tau_N = 0 \), i.e., \( \pi_{N0}^F - \pi_{N0} < 0 \), and (iii) there exists \( \tau_N^* \) that satisfies \( \Delta \pi_{N}^F = \Delta \pi_{NB}^F > 0 \). Let \( \tau_N \) and \( \tau_{NB} \) denote the emission tax rates which satisfy \( \pi_{N} = 0 \) and \( \pi_{NB} = 0 \), respectively, and \( \tau_N^{\max} \) denote the maximum emission tax rate that satisfies \( \tau_N^{\max} = \min\{x_{N0}/2e_N, y_{N0}/2e_N, y_{S0}/(2e_S - e_N)\} \). Then, we have \( \tau_N < \tau_{NB} \) such that

1. If \( \tau_N \in [0, \tau_N) \), then the North firm produces in the North.
2. If \( \tau_N \in [\tau_N, \tau_{NB}) \), then the North firm makes FDI in the policy without the BTA but it produces domestically in the policy with the BTA.
3. If \( \tau_N \in [\tau_{NB}, \tau_N^{\max}) \), then the North firm makes FDI either in the policy with or without the BTA.

### 3 The Effects of the Emission Tax Policy on Emissions

In this section, we will examine how the emission tax policy of the North influences emissions of greenhouse gases under a possibility of FDI by the North firm. It is convenient to rewrite emissions of firm \( i \) (\( i = N, S \)),

\[
E_i = e_i(x_i + y_i).
\]

Note that we focus on emissions of each firm instead on emissions of each country. Clearly, in the present setting, FDI causes zero emissions in the North due to complete “hollowing out.” Even after the relocation of production, the North firm is responsible for emissions generated by its production in the South. Also, greenhouse gas emissions cause cross-border pollution and thus total emissions do matter for the global environment. Thus, we will examine how the emission tax with and without the BTA affect each firm’s emissions and the total emissions of the world.

First, suppose that the government of the North introduces the emission tax policy without the BTA. If FDI does not occur, the impacts of the policy on emissions are derived
as

\[
\Delta E_N = E_N - E_{N0} = -\frac{2e_N^2\tau_N}{3} \left( \frac{1}{b_N} + \frac{1}{b_S} \right) < 0,
\]

\[
\Delta E_S = E_S - E_{S0} = \frac{e_S e_N \tau_N}{3} \left( \frac{1}{b_N} + \frac{1}{b_S} \right) > 0,
\]

\[
\Delta E_W = \Delta E_N + \Delta E_S = \frac{(e_S - 2e_N)e_N \tau_N}{3} \left( \frac{1}{b_N} + \frac{1}{b_S} \right).
\]

Clearly, the implementation of the emission tax policy by the North reduces emissions of the North firm. However, it causes emissions leakage, i.e., an increase in emissions of the South firm. This leakage effect results in an increase in the total emissions of the world if the North firm has sufficiently cleaner technology than the South firm, i.e., \(2e_N < e_S\).

A further increase in the emission tax rate may induce FDI by the North firm. If a higher emission tax rate induces the North firm to move its production to the South, the impacts on emissions are derived as

\[
\Delta E_N^F = E_N^F - E_{N0} = \frac{2e_N(c_N - c_N^F)}{3} \left( \frac{1}{b_N} + \frac{1}{b_S} \right) > 0,
\]

\[
\Delta E_S^F = E_S^F - E_{S0} = -\frac{e_S (c_N - c_N^F)}{3} \left( \frac{1}{b_N} + \frac{1}{b_S} \right) < 0,
\]

\[
\Delta E_W^F = \Delta E_N^F + \Delta E_S^F = -\frac{(e_S - 2e_N) (c_N - c_N^F)}{3} \left( \frac{1}{b_N} + \frac{1}{b_S} \right).
\]

FDI results in an increase in the output of the North firm and a reduction in the output of the South firm. As a result, emissions of the North firm rise but those of the South firm decline. Again, the effect on the total emissions of the world depends on the technology gap between the North and the South. If the North firm has sufficiently cleaner technology than the South firm, i.e., \(e_S > 2e_N\) holds, then the total emissions of the world decline.

We can state the results in the following proposition (See Figure 2).

**Proposition 3** Suppose that the conditions (i)-(iii) in Proposition 2 hold and the government of the North adopts the emission tax policy without the BTA.

1. If \(\tau_N \in (0, \tau_N)\), then the emission tax implemented by the North government reduces emissions of the North firm but causes emissions leakage, i.e., an increase in emissions of the South firm. The emissions leakage leads to a rise in total emissions of the world.
2. If $\tau_N \in [\bar{\tau}_N, \tau_N^{\max})$, then the emission tax implemented by the North government causes North firm’s FDI to the South, and as a result, it raises emissions of the North firm but reduces those of the South firm. The total emissions of the world decline.

These results are somewhat surprising since it has been pointed out that a unilateral regulation on greenhouse gas emissions in the North causes the migration of emission-intensive production from the North to the South, and as a result, emissions leakage results in an increase in global emissions. The above result suggests that FDI caused by the pollution-haven motive does not necessarily lead to a rise in global emissions. In fact, the global emissions decline as long as the North firm has much cleaner technology than the South firm.

Next, let us turn to a case in which the government of the North implements the emission tax policy with the BTA. If the North firm produces domestically, then the effects on emissions are derived as follows.

$$
\Delta E_{NB} = E_{NB} - E_{N0} = \frac{e_N \tau_N (e_S - 2e_N)}{3b_N},
$$

$$
\Delta E_{SB} = E_{SB} - E_{S0} = \frac{e_S \tau_N (e_N - 2e_S)}{3b_N},
$$

$$
\Delta E_{WB} = \Delta E_{NB} + \Delta E_{SB} = \frac{-2\tau_N [(e_S - e_N)^2 + e_S e_N]}{3b_N} < 0,
$$

where a subscript $B$ indicates variables in the emission tax policy with BTA. If the technology gap is large enough and $e_S > 2e_N$, then emissions of the North firm increase. However, emissions of the South firm decline as long as the North has cleaner technology than the South. The total emissions of the world fall regardless of the technology gap.

If the North firm moves its production to the South, the impact on emissions are derived as follows.

$$
\Delta E_{NB}^F = E_{NB}^F - E_{N0} = \Delta E_{NB} + \Delta E_{N}^F,
$$

$$
\Delta E_{SB}^F = E_{SB}^F - E_{S0} = \Delta E_{SB} + \Delta E_{S}^F,
$$

$$
\Delta E_{WB}^F = \Delta E_{NB}^F + \Delta E_{SB}^F = \Delta E_{WB} + \Delta E_{W}^F,
$$

where superscript $F$ indicates variables in the presence of FDI by the North firm. FDI
enhances the effects on emissions if the technology gap is sufficiently large, i.e., \( e_S > 2e_N \).

As compared to the equilibrium with domestic production by the North firm, the emission tax policy leads to a greater increase in emissions of the North firm, a greater decline in the emissions of the South firm, and a greater fall in the total emissions of the world. The reason is clear. FDI results in an expansion in the output of the North firm at the expense of the output of the South firm.

We can state the results in the following proposition (see Figure 2).

**Proposition 4** Suppose that the conditions (i)-(iii) in Proposition 2 hold, and the government of the North adopts the emission tax policy with the BTA.

1. If \( \tau_N \in (0, \tau_{NB}) \), then the emission tax implemented by the North increases emissions of the North firm, but decreases those of the South firm. The total emissions of the world decline.

2. If \( \tau_N \in [\tau_{NB}, \tau_{N}^{\text{max}}) \), then the emission tax implemented by the North causes FDI by the North firm and enhances the effects on emissions, i.e., a greater rise in emissions of the North firm, a greater decline in those of the South firm, and a greater fall in those of the world, as compared to the equilibrium with domestic production by the North firm.

Lastly, we examine how the implementation of the BTA affect emissions of each firm and those of the world. We can derive the following results.

**Proposition 5** Suppose that the conditions (i)-(iii) hold in Proposition 2.

1. If \( \tau_N \in (0, \tau_N) \), i.e., the North firm chooses domestic production, then \( \Delta E_N < 0 < \Delta E_{NB}, \Delta E_{SB} < 0 < \Delta E_S, \) and \( \Delta E_{WB} < 0 < \Delta E_W \).

2. If \( \tau_N \in [\tau_N, \tau_{NB}) \), i.e., the North firm chooses to make FDI in the policy without the BTA and it chooses domestic production in the policy with the BTA, then it is ambiguous how the BTA affects emissions of each country’s firm and worldwide emissions.

3. If \( \tau_N \in [\tau_{NB}, \tau_N^{\text{max}}) \), i.e., the North firm chooses to make FDI in either the policy with or without the BTA, then \( 0 < \Delta E_N^F < \Delta E_{NB}^F, \Delta E_{SB}^F < \Delta E_S^F < 0, \) and \( \Delta E_{WB}^F < \Delta E_W^F < 0 \).
Proof: If $\tau_N \in (0, \tau_N)$, then the results are easily shown by Proposition 3 and 4. If $\tau_N \in [\tau_N, \tau_{NB})$, then $\Delta E^F_N$, $\Delta E^F_S$, and $\Delta E^F_W$ are constant, but $\Delta E_{NB}$, $\Delta E_{SB}$, and $\Delta E_{WB}$ are proportionally change with $\tau_N$. Thus, the impacts of BTA are ambiguous since they depend on the level of the emission tax rate. If $\tau_N \in [\tau_{NB}, \tau_N^{max})$, then Proposition 4 implies that $0 < \Delta E_{NB} = E^F_{NB} - E^F_N$, $\Delta E^F_{SB} - \Delta E^F_S = \Delta E_{SB} < 0$, and $E^F_{WB} - \Delta E^F_W = \Delta E_{WB} < 0$. Q.E.D.

As long as the North firm has sufficiently cleaner technology than the South firm, the BTA allows emissions of the North firm to expand and those of the South firm to decline in either a domestic production equilibrium or a FDI equilibrium. The emission tax policy with the BTA necessarily achieves a lower level of worldwide emissions as compared to the policy without the BTA, regardless of the production location of the North firm.

4 The Impacts of the Emission Tax Policy on Welfare

In this section, we will examine the impacts of the emission tax policy on the total welfare of each country. We will first look at the welfare impact in the North, and then turn to the welfare effect on the South.

Let $u_i$ denote the gross benefit of consumers in country $i$, $(i = N, S)$,

$$u_i(q_i) = \int_0^{q_i} p_i(z) dz.$$ 

The consumer surplus of country $i$ is $CS_i = u_i - p_i q_i$. Emissions of pollution generate external costs to consumers in each country. The external cost of pollution emissions to consumers in country $i$ is

$$h_i(E_W) = \theta_i E_W,$$

where $\theta_i > 0$ is a constant marginal external cost of country $i$, $(i = N, S)$.

4.1 The Effects on the Welfare of the North

Let us first look at the welfare of the North when the North firm chooses domestic production. The total welfare of the North depends on its emission tax policy. If the government of the North adopts the emission tax policy without the BTA, then the total welfare of the North is

$$w_N = CS_N + \pi_N + T_N - h_N,$$
where $T_N = \tau_N E_N$ is tax revenue. If the North government initially takes a laissez-faire policy and $\tau_N = 0$, then the impact of the emission tax on the total welfare of the North can be derived as

$$
\frac{\partial w_N}{\partial \tau_N} \bigg|_{\tau_N=0} = -\frac{e_N(2x_N0 + y_N0 + y_S0)}{3N} - \frac{e_N(e_S - 2e_N)}{3N} \left( \frac{1}{b_N} + \frac{1}{b_S} \right) \theta_N.
$$

A rise in the emission tax rate reduces the consumer surplus and the firm’s profit, but it raises the tax revenue. Since the former negative effects outweigh the latter positive effect, the first term is negative. The second term captures the externality effect of emissions. As we have shown in Proposition 4, as long as the North firm has sufficiently cleaner technology than the South firm and $2e_N < e_S$, the total emissions of the world increase due to the emissions leakage effect. Thus, under this condition on the technology gap, the introduction of the emission tax reduces the total welfare of the North.

If the North government implements the BTA for its emission tax policy, then the total welfare of the North can be written as

$$
w_{NB} = CS_N + \pi_{NB} + T_{NB} - h_N,
$$

where $T_{NB} = \tau_N(e_Nx_N + e_Sy_S)$. At the initial laissez-faire equilibrium, the effect of the emission tax on the North welfare can be derived as

$$
\frac{\partial w_{NB}}{\partial \tau_N} \bigg|_{\tau_N=0} = \frac{[(e_S - 2e_N)x_N0 + (2e_S - e_N)y_S0]}{3b_N} \theta_N + \frac{2(e_S - e_N)^2 + e_S e_N}{3b_N} \theta_N.
$$

As in the policy without the BTA, an increase in the emission tax raises the market price and thus it reduces the consumer surplus in the North. The effect on the profit of the North firm depends on the technology gap. If the North firm has sufficiently cleaner technology than the South firm, then the emission tax raises the profit of the North firm because it allows the North firm to expand its output at the expense of the South firm. Given the technology gap, this increase in the firm’s profit and a rise in the tax revenue outweigh the loss in the consumer surplus and thus the first term on the RHS is positive. The second term is the externality effect, which is also positive because the emission tax with the BTA reduces the total emissions of the world regardless of the technology gap between the countries. Therefore, implementing the emission tax policy with the BTA raises the total welfare of the North if the gap in the environmental technology is sufficiently large.
between the North and the South.

Next, let us turn to the welfare effect of the emission tax policy in the presence of a FDI by the North firm. In the policy without the BTA, the total welfare of the North is

\[ w^F_N = CS_N + \pi^F_N - h_N. \]

Clearly, there is no impact of the emission tax on the total welfare of the North since production completely moved to the South.

Under the emission tax policy with the BTA, the total welfare of the North is

\[ w^F_{NB} = CS_N + \pi^F_{NB} + T_{NB} - h_N. \]

We can rewrite \( w^F_{NB} \) as

\[ w^F_{NB} = w_{NB} + w^F_{N0} - w_{N0} - \frac{(c_N - c^F_N)e_N\tau_N}{3b_N}. \tag{20} \]

The impact of the emission tax on the total welfare is

\[ \frac{\partial w^F_{NB}}{\partial \tau_N} = \frac{\partial w_{NB}}{\partial \tau_N} - \frac{(c_N - c^F_N)e_N}{3b_N}. \]

The effect on the total welfare is equivalent to that in the absence of FDI except for the second term on the RHS. This second term negatively affects the impact of the emission tax on the welfare of the North since \( c^F_N < c_N \).\(^4\) Recall that \( w_{NB}/\partial \tau_N |_{\tau_N=0} > 0 \), i.e., in the absence of North firm’s FDI, the emission tax policy with the BTA benefits the North at the laissez-faire equilibrium. In fact, we can show that \( w^F_{NB}/\partial \tau_N |_{\tau_N=0} > 0 \) if the technology gap between the North and the South is sufficiently large, i.e., \( 2e_N < e_S \).

**Lemma 1** Suppose that \( 2e_N < e_S \). Then, we have \( w^F_{NB}/\partial \tau_N |_{\tau_N=0} > 0 \).

\(^4\)The second term captures the effects on consumer surplus, tax revenue, and the firm’s profit. This term does not include the externality effect since the marginal impact on total emissions does not depend on the location of production of the North firm. As compared to the effect without FDI, a rise in the emission tax rate leads to a larger decline in the consumer surplus, a smaller increase in the tax revenue, and a greater rise in the firm’s profit. The former two negative effects outweigh the last positive effect and thus the second term negatively affects the welfare impact of the emission tax.
Proof: Note that \((c_N - c_N^F)e_N/3b_N = (x_{N0}^F - x_{N0})e_N/2\). Thus,

\[
\frac{\partial w_{NB}^F}{\partial \tau_N}\bigg|_{\tau_N=0} = \frac{\partial w_{NB}}{\partial \tau_N}\bigg|_{\tau_N=0} - \frac{(c_N - c_N^F)e_N}{3b_N}
\]

\[
= \frac{1}{3} \left[ (x_{N0} + 2y_{s0})e_N - \frac{e_N(2y_{s0} + 5x_{N0} - x_{N0}^F)}{2} \right] + \frac{2(e_N - e_S)^2 + e_N e_S |\theta_N|}{3b_N}.
\]

The first term is positive if \(e_S > 2e_N\). Since the second term, the externality effect, is necessarily positive, \(w_{NB}^F/\partial \tau_N|_{\tau_N=0} > 0\) if \(e_S > 2e_N\). Q.E.D.

In order to evaluate the welfare effect of the emission tax policy, we need to show the following lemma.

**Lemma 2** Suppose that FDI by the North firm benefits the North at the laissez-faire equilibrium, i.e., \(w_{N0}^F > w_{N0}\). Let \(\tau_{NB}\) denote an emission tax rate that satisfies \(w_{NB}^F = w_{NB}\). If \(f_N\) is sufficiently small, then \(\tau_{NB} < \tau_{NB}\).

Proof: By using (17), we have \(\tau_{NB} = -9b_N(\pi_{N0}^F - \pi_{N0})/4(c_N - c_N^F)(e_S - 2e_N)\), which is positive since we have assumed that \(\pi_{N0}^F - \pi_{N0} < 0\). We can also derive \(\tau_{NB} = 3b_N(w_{N0}^F - w_{N0})/e_N(c_N - c_N^F)\) with the use of (20). Given other parameters are equal, a sufficiently small \(f_N\) guarantees that \(\tau_{NB} < \tau_{NB}\) because a fall in \(f_N\) reduces \(-\pi_{N0}^F - \pi_{N0}\) and increases \(w_{N0}^F - w_{N0}\). Q.E.D.

We can state the welfare impacts of the emission tax policy in the following proposition (see Figure 3).

**Proposition 6** Suppose that the condition (i)-(iii) in Proposition 2 are satisfied and Lemma 2 holds. Then, we have

1. If \(\tau \in (0, \tau_N)\), then the emission tax policy with the BTA achieves higher welfare of the North as compared to the policy without the BTA, \(w_{NB} > w_N\).

2. If \(\tau \in [\tau_N, \tau_{NB})\), then FDI by the North firm improves the welfare of the North, \(w_{N}^F > w_N\), in the policy without the BTA. It is ambiguous whether or not the emission tax policy with the BTA benefits the North as compared to the policy without the BTA.

3. If \(\tau \in [\tau_{NB}, \tau_{NB})\), then FDI by the North firm improves the welfare of the North, \(w_{NB}^F > w_{NB}\), in the policy with the BTA. The emission tax policy with the BTA achieves higher welfare of the North as compared to the policy without the BTA, \(w_{NB}^F > w_N^F\).
If the emission tax rate is low enough and the North firm chooses domestic production, then the total welfare of the North is higher in the policy with the BTA as compared to that without the BTA. An increase in the emission tax rate causes FDI by the North firm. It is ambiguous whether the BTA benefits the North or not when the North firm chooses FDI in the policy without the BTA and it chooses domestic production in the policy with the BTA. When the North firm chooses FDI in either policy, the total welfare of the North is higher in the policy with the BTA as compared to the one in the policy without the BTA. In addition, FDI by the North firm always benefits the North in either policy scheme.

4.2 The Effects on the Welfare of the South

Next, let us turn to the policy impact on the total welfare of the South. First, consider an equilibrium in which the North firm chooses domestic production. When the government of the North adopts the emission tax policy without the BTA, the total welfare of the South is

\[ w_S = CS_S + \pi_S - h_S. \]

Since the government of the South does not impose any emission tax, there is no tax revenue. At the laissez-faire equilibrium, the impact of a rise in the emission tax on the total welfare can be derived as

\[ \frac{\partial w_S}{\partial \tau_N} \bigg|_{\tau_N=0} = \left( x_{S0} - y_{N0} + 2y_{S0} \right) c_N - \left( \frac{1}{b_N} + \frac{1}{b_S} \right) \left( \frac{c_S - 2c_N}{3} \right) e_N \theta_S. \] (21)

The first term captures the effects on the consumer surplus of the South and the profit of the South firm. A rise in the emission tax reduces the consumer surplus of the South due to a rise in the market price, but it raises the profit of the South firm since the North firm reduces its sales to the South market. Under the condition that \( c_S < c_N \), the effect of a rise in the firm’s profit outweighs the loss of the consumer surplus and thus the first term is positive. If the North firm has sufficiently cleaner technology as compared to the South firm, the second term negatively affects the welfare of the South due to an increase in the total emissions of the world. Thus, in the case of the large technology gap, i.e., \( \epsilon_S > 2\epsilon_N \), if the marginal external cost \( \theta_S \) is sufficiently small, then the effect of the first term dominates the externality effect and thus a rise in the emission tax of the North raises the total welfare of the South.

When the North government implements the BTA, the total welfare of the South is
derived as
\[ w_{SB} = CS_S + \pi_{SB} - h_S. \]

The impact of a rise in the emission tax rate on the total welfare is
\[
\left. \frac{\partial w_{SB}}{\partial \tau_N} \right|_{\tau_N=0} = -\frac{2(e_S - e_N)y_{S0}}{3} + \frac{2[(e_N - e_S)^2 + e_S e_N]\theta_S}{3b_N} \quad (22)
\]

The first term negatively affects the welfare of the South since the pollution-content tariff reduces the profit of the South firm. The second term captures the externality effect and it has a positive impact on the total welfare since the total emissions of the world decline. Thus, an increase in the emission tax raises the total welfare of the South as long as the marginal external cost is sufficiently large.

Next, let us turn to an equilibrium in which the North firm chooses to make FDI to the South. If the North government adopts the emission tax policy without the BTA, the welfare of the South is
\[ w^F_S = CS_S + \pi^F_S - h_S. \]

The emission tax does not have any impact on the total welfare of the South and thus \( w^F_S = w^F_{S0} \). In the laissez-faire equilibrium, the impact of North firm’s FDI on the welfare of the South can be derived as
\[
w^F_{S0} - w_{S0} = \frac{(c_N - c^F_N)(y_{N0} - x_{S0} - 2y_{S0})}{3} + \left( \frac{1}{6b_S} + \frac{1}{9b_N} \right)(c_N - c^F_N)^2
+ \left[ \left( \frac{1}{b_N} + \frac{1}{b_S} \right) \frac{(e_S - 2e_N)(c_N - c^F_N)}{3} \right] \theta_S, \quad (23)
\]

The first and second terms capture the effect of FDI on consumer surplus of the South and the profit of the South firm. The consumer surplus rises but the profit falls. If \( y_{N0} - x_{S0} = -(c_N - c_S)/3b_S < 0 \), i.e., \( c_N > c_S \), the first term is negative. Then, the sum of these two effects can be positive or negative. The third term is the externality effect, which positively affects the welfare of the South. If the sum of the first two terms is negative, then FDI by the North firm does not necessarily benefit the South. In fact, whether it could benefit the South or not depends on the size of the marginal external cost of emissions. We can derive the following lemma.

**Lemma 3** Suppose that the sum of the first two terms on the RHS of (23) is negative and
the technology gap is sufficiently large, i.e., \( e_S > 2e_N \). Then, a North firm’s FDI benefits the South if and only if \( \theta_S > \bar{\theta}_S \).

Proof: \( w^F_{S0} > w_{F0} > 0 \) iff \( \theta_S > \bar{\theta}_S = [(x_{S0} - y_{N0} + 2y_{S0}) - (1/2b_S + 1/3b_N)(e_N - c^F_N)]/(e_S - 2e_N)(1/b_S + 1/b_N) \). The numerator of \( \bar{\theta}_S \) is positive if North firm’s FDI reduces the sum of the consumer surplus and the profit, and as a result, the sum of the first two terms on the RHS of (23) is negative. Q.E.D.

When the North government chooses the policy with the BTA, the total welfare of the South is

\[ w^F_{SB} = CS_S + \pi^F_{SB} - h_S. \]

We can rewrite the welfare of the South as

\[ w^F_{SB} = w_{SB} + w^F_{S0} - w_{S0} + \frac{2(c_N - c^F_N)(2e_S - e_N)\tau_N}{9b_N}. \]

The impact of a rise in the emission tax rate on the total welfare can be derived as

\[ \frac{\partial w^F_{SB}}{\partial \tau} \bigg|_{\tau_N=0} = \frac{\partial w_{SB}}{\partial \tau_N} \bigg|_{\tau_N=0} + \frac{2(c_N - c^F_N)(2e_S - e_N)}{9b_N}. \]

(24)

The second term captures an additional effect caused by North firm’s FDI. As compared to the equilibrium with domestic production, the export sales of the South firm to the North market is smaller in the FDI equilibrium. A rise in the pollution-content tariff reduces the profit of the South firm and a reduction in the profit is smaller in the FDI equilibrium as compared to that in the equilibrium with domestic production of the North firm. This implies that the additional effect caused by a North firm’s FDI positively affects the welfare of the South. The total effect on the welfare depends on the size of the marginal external cost of the South. As in the equilibrium with domestic production, the externality effect is positive. Thus, a rise in the emission tax rate raises the total welfare of the South as long as the marginal external cost is sufficiently large.

We can state the results in the following proposition (see Figure 3).

**Proposition 7** Suppose that conditions (i)-(iii) in Proposition 2 are satisfied and Lemma 3 hold. Let \( \bar{\theta}_S \) and \( \bar{\theta}_{SB} \) denote the marginal external costs of emissions that satisfy \( \partial w_S/\partial \tau_N \big|_{\tau_N=0} = 0 \) and \( \partial w_{SB}/\partial \tau_N \big|_{\tau_N=0} = 0 \), respectively. If \( \theta_S > \max\{\bar{\theta}_S, \bar{\theta}_{SB}\} \), then we have the following results.
1. If $\tau_N \in (0, \bar{\tau}_N)$, then $w_S < w_{SB} < w_{SB}$, i.e., the emission tax policy with the BTA benefits the South but the policy without the BTA hurts the South. The policy with the BTA achieves higher welfare of the South as compared to the policy without the BTA.

2. If $\tau_N \in [\bar{\tau}_N, \tau_{NB})$, then it is ambiguous whether the welfare of the South in the emission tax policy with the BTA is higher or not than the one in the policy without the BTA.

3. If $\tau_N \in [\tau_{NB}, \tau_N^{\max})$, then $w^F_S < w^F_{SB}$, i.e., the emission tax policy with the BTA results in greater welfare of the South as compared to the policy without the BTA. A higher emission tax rate leads to higher welfare of the South in the policy with the BTA.

As long as the marginal external cost is large enough, the emission tax policy with the BTA can benefit the South due to a reduction in total emissions of the world. In addition, North firm’s FDI results in an extra reduction in total emissions. As a result, in the FDI equilibrium, an emission tax policy with the BTA implemented by the North government achieves higher welfare of the South as compared to the one in the domestic production equilibrium.

## 5 Concluding Remarks

In this paper, we have examined the emission tax policy with the BTA in the presence of a possibility that the North firm moves its production to the South through FDI. The BTA implemented by the North government makes FDI less profitable as compared to the policy without the BTA. However, even in the policy with the BTA, a rise in the emission tax rate causes FDI to the South if the North firm has sufficiently cleaner technology than the South firm.

Given the environmental technology gap between the North and the South, the emission tax policy without the BTA raises the emissions of the world and as a result, it could reduce the total welfare of the South as well as the North. The policy with the BTA reduces worldwide emissions and could benefit both the North and the South. FDI by the North firm does not harm the global environment. It results in an extra reduction in the total emissions and thus provides an additional benefit for either country.
The present paper focused on a situation in which the North firm moves its production to the South through greenfield FDI. However, there are other modes of FDI such as merger and acquisitions of the South firm by the North firm and a joint venture between the North and South firms. In these modes of FDI, international technology transfer might arise between the firms, especially in the environmental technology. In addition, the North firm may engage in international outsourcing of production to the South firm. The mode of offshore production may affect the impact of unilateral environmental regulation on global emissions. This extension is beyond the scope of this paper and left for our future research.

References


Figure 1-a: The impact of the emission tax on the profitability of FDI in a large technology gap.

Figure 1-b: The impact of the emission tax on the profitability of FDI in a small technology gap.
Figure 2-a: The impact of the emission tax on the emissions of the North firm in a large technology gap

Figure 2-b: The impact of the emission tax on the emissions of the North firm in a small technology gap
Figure 2-c: The impact of the emission tax on the emissions of the South firm in a large technology gap.

Figure 2-d: The impact of the emission tax on the emissions of the South firm in a small technology gap.
Figure 2-e: The impact of the emission tax on the emissions of the World in a large technology gap

Figure 2-f: The impact of the emission tax on the emissions of the World in a small technology gap
Figure 3-a: The impact of the emission tax on the welfare of the North

Figure 3-b: The impact of the emission tax on the welfare of the South