REVIEW OF DEVELOPMENT ECONOMICS

MANUSCRIPT No: RDE-Q02, Acceptance Data: June 9th 2010

Environmental Product Standards in North-South Trade*

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RRH: ENVIRONMENTAL PRODUCT STANDARDS

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Abstract

Consumption is one channel through which the environment is damaged. To protect the environment, various product standards have been introduced across the world. This paper uses a new economic geography framework to explore the effects of environmental product standards on environment in a North-South trade model. We examine the situation in which North unilaterally introduces an environmental product standard. Specifically, those products that do not meet the standard are not allowed to be sold in North's market. We find that such a standard may worsen North's environment but improve South's environment due to firm relocation.

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JEL Classification Numbers: F18, Q54

Abbreviations: NEG, R&D, U.S., EU,CRS,CES,D-firm,C-firm

Number of Figures: 0 Number of Tables: 0 Date: 29th September 2010

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1. Introduction

There is growing concern for the environmental destruction of the world. To protect environment, various environmental policies have been adopted. However, attitudes of countries towards environmental destruction differ leading some countries to adopt more stringent policies than others. Examples of differing environmental regulation include environmental "product" standards (such as auto emission standards) where a government may prohibit firms from selling those products that do not meet the required environmental product standards.

Three examples of these environmental product standards are i) the U.S. Clean Air Act of 1970, called the Muskie Act, that prohibited car manufacturers from selling cars that failed to meet the emission standards,[1] ii) the EU prohibition on the use and import of chrysotile asbestos products in 1998, and iii) the China Compulsory Certification introduced in 2002, under which foreign firms cannot export to China without implementing certain standards.

Environmental policies could affect firm locations. Polluting firms are expected to move to countries with laxer environmental policies.[2] This expectation has been enforced by recent improvements in transportation and communications technology, as well as trade liberalization that allows firms to choose their locations more easily. Similarly, prohibitive environmental product standards may also affect firm locations with firms having little incentive to locate in a country with prohibitive standards. An important point is that firm relocations caused by environmental product standards could affect environment.

In this paper, we analyze the theoretical effects of prohibitive environmental product standards on firm locations and environment. To this end, we adopt a new economic geography (NEG) framework, because firm locations are the central issue in the NEG literature. Because of its simplicity, we specifically employ the so-called footloose capital model developed by Martin and Rogers (1995).[3] In this model, there are two countries (North and South), two sectors (agriculture and manufacturing), and two factors (capital and labor). The agricultural sector is perfectly competitive, firms produce from labor alone with constant-returns-scale (CRS) technology, and the product is freely traded internationally. The manufactured products are subject to the Dixit–Stiglitz (1977) type of monopolistic competition, are costly to ship internationally, and damage local environment in the *process* of consumption. Capital is mobile across countries and determines firm location, though capital owners and labor are not mobile.

North is more concerned about the environment and so unilaterally introduces an environmental product standard. If firms do not comply with it, then they cannot serve North's market. Due to the possibility of firm relocation, those firms producing goods that do not meet North's standard operate in South (due to trade costs) and serve only South's market. Those firms that conform to North's standard by incurring extra costs can serve both markets and locate in either North or South.

Our main finding is that North's environmental product standards may fail to protect North's environment. With the standard implemented, those products that do not meet the standard (henceforth, dirty products) are excluded from consumption in North, but consumption of the other products, i.e., products satisfying the standard (henceforth, clean products) could increase a lot. Unless clean products never damage environment, North's environment could deteriorate as a result. Moreover, South's environment may be improved by North's environmental product standards. We show such paradoxical effects of North's environmental product standards in the presence of firm relocation.

There are many studies that theoretically investigate the relationship between environmental policies and firm locations (Markusen et al. 1993, 1995; Rauscher, 1995). However, the existing literature mostly deals with "production" externalities in a monopoly or oligopoly model. When "consumption" itself generates negative externalities, environmental product standards are applied.

Relatively little attention has been paid to environmental and trade policies with consumption externalities. In particular, only a few studies analyze environmental product standards in the open economy framework. In an international duopoly model, Fischer and Serra (2000) consider optimal minimum standards and examine whether they are protectionist. Haupt (2000) examines the relationship between environmental product standards and environmental R&D in a monopolistically competitive sector in a two-country model. Toshimitsu (2008) shows that a strict emission standard on imported products may or may not increase social surplus by using model with environmentally differentiated products and heterogeneous consumers. Ishikawa and Okubo (2009) also show that prohibitive environmental standards may worsen environment. However, they use an international duopoly model in which environmental deterioration is caused by R&D or licensing.

There are only a few NEG studies that examine environmental policies. Pfluger (2001) considers Pigouvian emission taxes in an NEG model. Venables (1999) studies the impact of energy taxes on equilibrium in a vertical linkage model. Elbers and Withagen (2004) explore the impact of an emission tax on labor agglomeration in the presence of labor migration. By using the footloose capital model, Zeng and Zhao (2009) examine pollution haven in the presence of both cross-border and cross-sector externalities. Ishikawa and Okubo (2008) use the footloose capital model to compare tax on emissions and quota policies for controlling greenhouse-gas emissions.

The rest of the paper is organized as follows. In Section 2, we present our basic model and analyze the initial equilibrium. As an example of environmental product standards, we consider emission standards such as car exhaust emission regulations. In Section 3, the equilibrium under emission standards is explored. In the presence of standards, some firms incur costs to conform to them, but the others do not. In Section 4, some extensions are investigated. Section 5 concludes the paper.

2. NORTH-SOUTH TRADE MODEL

2.1 Basic model with wage gap and factor mobility

We employ the Dixit-Stigliz type of monopolistic competition model with international capital mobility (firm migration) developed by Martin and Rogers (1995). There are two countries (North and South), two production factors (labor, L, and physical capital, K) and two sectors (agriculture, A-sector, and manufacturing, M-sector). Labor is mobile between sectors but immobile between countries. Capital is mobile across countries, though capital owners are not.

We incorporate the following two features into Martin and Rogers (1995): 1) negative externalities are caused (by emissions) when M-sector products are consumed, and 2) an international wage gap exists. North has a larger population than South, however North's (nominal) wage rate is higher than South's wage rate.[4]

The agricultural product is produced from labor alone by perfectly competitive firms under CRS technology and is traded without any trade cost. This product serves as a numéraire. To produce one unit of the agricultural product, North and South, respectively, require $\frac{1}{w}$ units of labor and $\frac{1}{w^*}$ units of labor. "*" indicates variables and parameters in South. We assume that the wage rate in North is higher than that in South. By setting $\frac{1}{w}=1$ (that is, North's wage rate equal to unity), South's wage rate, w^*, satisfies $w^* < 1$.

The manufactured goods are subject to the Dixit–Stiglitz type of monopolistic competition and are traded with trade costs. Firms in M-sector can move between countries, but there is no entry and exit. M-sector uses labor and exclusively employs the capital of the two countries. Specifically, each firm is required to use one unit of capital, which represents fixed costs, and "*a*" units of labor per output. The cost function for firm *j* is given by $TC_j = \pi_j + awx_j$, where the fixed cost part of total cost, π, represents the payment for capital and *w* is the wage rate. Trade costs, τ (> 1), are the iceberg type, where $\tau = 1$ and $\tau = \infty$, respectively, mean free trade and autarky.

Turning to the demand side, a representative consumer (in North) has the following quasi-linear utility function:

$$(1)\quad U = \mu \ln M + A - g(\chi),\ M \equiv \left(nc^{1-1/\sigma} + n^* c_S^{\ 1-1/\sigma}\right)^{1/(1-1/\sigma)}, \qquad 1 > \mu > 0, \quad \sigma > 1,$$

where *M* and *A* stand for consumption of M-sector varieties and that of A-sector product respectively, and μ is the intensity of preference towards M-sector varieties. *n* is the number of differentiated varieties. *c* is the quantity of North's consumption of each variety produced in North, similarly c_S is the quantity of North's consumption of each variety produced in South.[5] σ in the CES function for differentiated varieties denotes the constant elasticity of substitution between two varieties. The mirror image holds for South.

The disutility is caused by local emissions and is expressed as an monotonically increasing function of the total emissions of M-sector varieties, *g*(χ), where χ is the total emissions in North (χ^* is for South).[6] By an appropriate choice of units, one unit of consumption of M-sector varieties generates one unit of emissions, that is, $\chi \equiv nc + n^* c_S$. Following Fischer and Serra (2000), we assume that the representative consumer ignores the negative externalities when making her consumption decisions.[7]

Each consumer has one unit of capital as well as one unit of labor and obtains income from both endowments. It should be noted that the quasi-linear utility function eliminates the income effect and hence each consumer buys a certain number of units of M-goods regardless of her income.

While capital is mobile between two countries, capital owners are immobile and hence capital rewards are repatriated to the country of origin. Because capital endowment is initially allocated in proportion to labor endowment (market size), North's share of initial capital and labor endowments are given by $s_K \equiv \frac{K}{K^W} = \frac{L}{L^W} \equiv s_L$, where "*W*" stands for values pertaining to the world. However, after firms relocate, capital share is generally not equal to population share. Whereas population share always corresponds to the labor share, s_L, the capital share is always identical to the firm share, $\frac{n}{n^W} = s_K$. This is because each internationally mobile firm needs one unit of capital.

Because no income effect exists, the quasi-linear utility function ensures $s \equiv s_E = s_L$, where the share of North's expenditure, *E*, is defined as $s_E \equiv \frac{E}{E^W}$, which equals population share but is independent of the wage gap. Since North is larger than South, s_E is greater than 0.5. For simplicity, the total expenditure E^W and the total labor and capital endowments, L^W and K^W (thus the total number of firms, n^W), are normalized to be one. Thus, *n* is North's share of firms.[8]

2.2 Initial equilibrium

Utility maximization results in the CES demand function in the M-sector. This, together with Dixit-Stiglitz monopolistic competition implies "mill pricing" is optimal. Thus local and export prices of the variety of a North-based M-sector firm are given by:

$$(2) \qquad p = \frac{a}{1-\frac{1}{\sigma}}, \quad p^* \equiv p\tau = \frac{\tau a}{1-\frac{1}{\sigma}}.$$

Local and export prices of the product variety of a South-based M-sector firm are given by:

$$(3) \qquad p_S^* = \frac{aw^*}{1-\frac{1}{\sigma}}, \quad p_S \equiv p_S^*\tau = \frac{\tau a w^*}{1-\frac{1}{\sigma}},$$

where "a" is the unit labor requirement and w^* (<1) is South's wage rate, which is exogenously given as a constant. North's (South's) consumers pay p (p_S^*) for local variety and p_S (p^*) for imported variety. Consumption per local variety and imported (foreign) variety in North are respectively given by:

$$(4) \qquad c = \frac{\mu p^{-\sigma} s}{np^{1-\sigma} + n^*(p_S^*\tau)^{1-\sigma}} \quad \text{and} \quad c_S = \frac{\mu (p_S^*\tau)^{-\sigma} s}{np^{1-\sigma} + n^*(p_S^*\tau)^{1-\sigma}}.$$

Utilizing (2) (3) and (4), the profit for a representative firm in North is given by

$$\pi(n) = \left(\frac{s}{\overline{\Delta}(n)} + \frac{\tau^{1-\sigma}(1-s)}{\overline{\Delta}^*(n)} \right) \frac{\mu}{\sigma} a^{1-\sigma},$$

where $\overline{\Delta}(n) \equiv [n + (1-n)(w^*\tau)^{1-\sigma}]a^{1-\sigma}$ and $\overline{\Delta}^*(n) \equiv [n\tau^{1-\sigma} + (1-n)w^{*1-\sigma}]a^{1-\sigma}$.[9] Noting South's wage rate is w^*, the profit for a South-based firm is

$$\pi^*(n) = \left(\tau^{1-\sigma} \frac{s}{\overline{\Delta}[n]} + \frac{1-s}{\overline{\Delta}^*[n]} \right) \frac{\mu}{\sigma} (aw^*)^{1-\sigma}.$$

2.3 Long-run equilibrium (without Environmental Policy)

In the long-run equilibrium, capital is freely mobile between countries and the profits are equalized between North and South. The profit equalization determines North's firm shares, n_0 (we let a subscript "0" denote the initial equilibrium):

(5) $$\pi(n_0) - \pi^*(n_0) = \frac{\mu}{\sigma}\left((1-(\tau w^*)^{1-\sigma})\frac{s}{\bar{\Delta}[n_0]} + (\tau^{1-\sigma} - w^{*1-\sigma})\frac{1-s}{\bar{\Delta}^*[n_0]} \right) = 0.$$

Then solving (5), we can obtain the long-run equilibrium firm share,

(6) $$n_0 = \frac{w^{*1-\sigma}[s(1-\tau^{2(1-\sigma)}) + \tau^{1-\sigma}(\tau^{1-\sigma} - w^{*1-\sigma})]}{(1-(\tau w^*)^{1-\sigma})(w^{*1-\sigma} - \tau^{1-\sigma})}.$$

Noting that $w^{*1-\sigma} > 1$ due to $w^* < 1$, and $\tau^{1-\sigma} < 1$ due to $\tau > 1$, we have $w^{*1-\sigma} - \tau^{1-\sigma} > 0$. In the following, we mainly consider the case with $0 < n_0 < 1$, which holds only if $1-(\tau w^*)^{1-\sigma} > 0$, and investigate the impact of environmental standards on firm location.[10] However, we also consider the case with $1-(\tau w^*)^{1-\sigma} < 0$ (i.e., with a low wage rate and small trade costs) as a special case. In this special case, all firms concentrate in South, i.e., n_0=0.

The highest trade costs below which all firms locate in South (i.e., n_0=0), τ_S, is given by $\tau_S^{1-\sigma} = \frac{w^{*1-\sigma} - \sqrt{w^{*2(1-\sigma)} - 4s(1-s)}}{2(1-s)}$.[11] When $\tau < \tau_S$, all firms concentrate in South. We differentiate τ_S with respect to w^* to obtain $\frac{\partial \tau_S}{\partial w^*} < 0$. A lower w^* enhances the cost advantage of South and attracts more firms to South. Hence, a lower w^* increases the likelihood of full agglomeration in South and implies an increase in τ_S (the full agglomeration cutoff point).

Proposition 1: The larger the North-South wage gap (i.e., the lower South's wage rate in relation to North's), the more firms are attracted to South. If there are sufficiently small trade costs

and/or South's wage rate is substantially low, then all firms to concentrate in South (i.e., full agglomeration in South).

2.4 Negative externalities

Negative externalities are generated locally when the M-goods are consumed. Emissions are assumed to affect each consumer's utility as seen in (1) but never negatively affect production in either sector. The quantity consumed by North's (South's) residents for a local good is given by $c = \dfrac{\mu\gamma s}{[n+(1-n)(w^*\tau)^{1-\sigma}]a}$ $\left(c_S^* = \dfrac{\mu\gamma(1-s)}{[n\tau^{1-\sigma}+(1-n)w^{*1-\sigma}]aw^{*\sigma}} \right)$ and that for an imported good is $c_S = \dfrac{\mu\gamma s}{[n+(1-n)(w^*\tau)^{1-\sigma}]a(w^*\tau)^{\sigma}}$ $\left(c^* = \dfrac{\mu\gamma(1-s)}{[n\tau^{1-\sigma}+(1-n)w^{*1-\sigma}]a\tau^{\sigma}} \right)$, where $\gamma \equiv (1-\dfrac{1}{\sigma})$. It follows that the total emissions in North and South in the initial equilibrium are respectively:

(7) $$\chi_0 = n_0 c + (1-n_0)c_S = \frac{\mu\gamma s}{[n_0+(1-n_0)(w^*\tau)^{1-\sigma}]a}\left(n_0 + \frac{1-n_0}{(w^*\tau)^{\sigma}} \right),$$

(8) $$\chi_0^* = n_0 c^* + (1-n_0)c_S^* = \frac{\mu\gamma(1-s)}{[n_0\tau^{1-\sigma}+(1-n_0)w^{*1-\sigma}]a}\left(\frac{n_0}{\tau^{\sigma}} + \frac{1-n_0}{w^{*\sigma}} \right).$$

We next consider the case where all firms concentrate in South (i.e., $n_0 = 0$). Full agglomeration in South could occur when trade costs are small enough and/or South's wage rates are low enough: 1) $1-(\tau w^*)^{1-\sigma} > 0$ and $\tau < \tau_S$, or 2) $1-(\tau w^*)^{1-\sigma} < 0$. In both cases, North's and South's emissions are given by

(9) $$\chi_0 = c_S = \frac{\mu\gamma s}{w^*\tau a}, \chi_0^* = c_S^* = \frac{\mu\gamma(1-s)}{w^* a}.$$

This implies that smaller trade costs and a lower wage in South increase North's emissions. Lower consumption prices in North (due to smaller trade costs and lower wage rate in South) increase North's consumption and hence North's emissions.

3. ENVIRONMENTAL PRODUCT STANDARDS AND COMPLIANCE COSTS

3.1 Compliance costs

Now North's government unilaterally introduces a product standard for emissions caused by consumption. The maximum level of emissions allowed per unit consumption is z (<1), which is called the emission standard level. If a product meets the standard (that is, if a product is a "clean" product), then it can be sold in North's market. However, if it does not meet the standard (that is, if it is a "dirty" product), then it cannot be sold in North. Thus, North-based firms producing dirty products stop their operation in North and relocate to South due to trade costs. South-based firms producing dirty products cannot export their products to North.

In response to North's standard, some firms incur costs to comply with the standard, while the others do not. For simplicity, the number of firms complying with the standard (henceforth C-firms) and firms without compliance (henceforth D-firms) are *exogenously* given as N_C and N_D, where $N_C + N_D = 1$.[12] We assume that a firm's type never changes even if that firm changes its location. The compliance requires additional labor forces per unit of production, therefore the labor coefficient for C-firms, "b", satisfies $b > a$, while that of D-firms remains to be "a". It follows that "b-a" can be interpreted as the additional units of labor per output required to conform to the standard.

The standard forces D-firms out from North and all D-firms concentrate in South. North bans all imports of D-firm products. In other words, D-firms become local firms in South, which locate and sell only in South. On the other hand, since C-firm products meet the standard, C-firms can locate in either North or South to maximize their own profits and can sell in both markets by incurring trade costs.

3.2 Long-run Equilibrium

Now we investigate the long-run equilibrium under the environmental product standard. Capital is mobile and so profits equalize across North and South. Although all D-firms locate in South due to the standard, C-firms are able to choose their location which could be divided between the two countries.

We denote the share of C-firms located in North by "*m*" ($0 \le m \le 1$). Since all D-firms locate in South, the firm share in North under the standard (the subscript "1") can be defined as

(10) $$n_1 \equiv \frac{m_1 N_C}{N_C + N_D} = m_1 N_C .$$

We note that the number of C-firms is $m_1 N_C$ in North and $(1-m_1)N_C$ in South. The total number of firms in South is $N_D + (1-m_1)N_C$ and the total number of firms in the world is unity, i.e., $m_1 N_C + N_D + (1-m_1)N_C = N_C + N_D = 1$. N_C and N_D are *exogenously* given, however *m* is *endogenously* determined by profit equalization, $\pi_C - \pi_C^* = 0$. The profits of a North-based C-firm and a South-based C-firm are given by:

(11) $$\pi_C = \left(\frac{s}{\Delta} + \frac{\tau^{1-\sigma}(1-s)}{\Delta^*} \right) \frac{\mu\beta}{\sigma},$$

(12) $$\pi_C^* = \left(\frac{\tau^{1-\sigma}s}{\Delta} + \frac{(1-s)}{\Delta^*} \right) \frac{\mu\beta w^{*1-\sigma}}{\sigma},$$

where $\Delta \equiv m_1 N_C \beta + (1-m_1)N_C \beta(\tau w^*)^{1-\sigma}$, $\Delta^* \equiv N_D \alpha w^{*1-\sigma} + m_1 N_C \beta \tau^{1-\sigma} + (1-m_1)N_C \beta w^{*1-\sigma}$, $\alpha \equiv a^{1-\sigma}$ and $\beta \equiv b^{1-\sigma}$. Note that $\alpha > \beta$ holds, because *a*<*b*. Solving

(13) $$\pi_C - \pi_C^* = \frac{\mu\beta}{\sigma}\left(\frac{s}{\Delta} + \frac{\tau^{1-\sigma}(1-s)}{\Delta^*} \right) - \frac{\mu\beta w^{*1-\sigma}}{\sigma}\left(\frac{\tau^{1-\sigma}s}{\Delta} + \frac{1-s}{\Delta^*} \right) = 0,$$

we have

(14) $$m_1 = \frac{w^{*1-\sigma}\{sN_D\alpha[1-(\tau w^*)^{1-\sigma}] + \beta N_C[\tau^{2(1-\sigma)} - s\tau^{2(1-\sigma)} + s - (\tau w^*)^{1-\sigma}]\}}{\beta N_c[1-(\tau w^*)^{1-\sigma}](w^{*1-\sigma} - \tau^{1-\sigma})}.$$

Therefore, the total number of firms in North, n_1, is given by

(15) $$n_1 = m_1 N_C = \frac{w^{*1-\sigma}\{sN_D\alpha[1-(\tau w^*)^{1-\sigma}] + \beta N_C[\tau^{2(1-\sigma)} - s\tau^{2(1-\sigma)} + s - (\tau w^*)^{1-\sigma}]\}}{\beta[1-(\tau w^*)^{1-\sigma}](w^{*1-\sigma} - \tau^{1-\sigma})}.$$

Appendix 1 shows m_1 is always greater than North's firm share in the initial equilibrium (i.e., $m_1 > n_0$) so long as both $m_1 > 0$ and $n_0 > 0$ hold. Moreover, the share of available varieties in North is increased by the standard, i.e., $n_1 = m_1 N_C > n_0$.[13] By excluding D-firms and attracting more C-firms to North, North can raise the share of made-in-North varieties. Then the total number of producers in North is always greater with the standard. Intuitively, the concentration of D-firms in South and no imports of D-firm products to North reduce competition in North, which attracts more C-firms to North. Since the prices (marginal costs) of C-firms are higher than those of D-firms and C-firms have less impact on market competition in North, more C-firms can locate in North. Therefore, the standards could increase firm share in North.

Proposition 2: Unless all firms concentrate in South, an environmental product standard introduced in North attracts more C-firms to North by forcing D-firms to move to South. The standard increases the total number of firms in North.

The total emissions in each country are given by

$$\chi_1 = z[m_1 N_C c_C + (1-m_1) N_C c_{CS}], \tag{16}$$

$$\chi_1^* = z[m_1 N_C c_C^* + (1-m_1) N_C c_{CS}^*] + N_D c_{DS}^*. \tag{17}$$

North's consumption of a local good (C-firms) is given by $c_C = \frac{\mu\gamma s}{\Delta b^\sigma}$ and that of an imported variety is $c_{CS} = \frac{\mu\gamma s}{\Delta (bw^*\tau)^\sigma}$. South's consumption of a local C-firm variety is given by $c_{CS}^* = \frac{\mu\gamma(1-s)}{\Delta^*(bw^*)^\sigma}$, that of an imported variety is $c_C^* = \frac{\mu\gamma(1-s)}{\Delta^*(b\tau)^\sigma}$, and that of a D-firm variety is $c_{DS}^* = \frac{\mu\gamma(1-s)}{\Delta^*(aw^*)^\sigma}$.

3.3 Policy impact on North's emissions

We compare North's emissions with and without emission standards. Total emissions without the standard are given by (7) and those with the standard are given by

$$\chi_1 = \frac{z\mu\gamma s}{[m_1 + (1-m_1)(w^*\tau)^{1-\sigma}]b}\left(m_1 + \frac{1-m_1}{(w^*\tau)^\sigma}\right), \tag{18}$$

where χ_1 is independent of N_C.[14]

Appendix 2 proves that $\chi_1 > \chi_0$ if $a \cong b$ and $z \cong 1$ hold, or (more precisely) $\frac{1}{a} \cong \frac{z}{b}$ holds. In other words, when compliance costs are very small (*b* is close to *a*) and the emission standard level is fairly lax (*z* is close to unity), then the standard increases North's emissions, $\chi_1 > \chi_0$.[15] Intuitively, the standard increases the made-in-North varieties. Since made-in-North varieties do not involve trade cost payment, consumption and hence emissions expand in North.[16]

Turning to the special case in which full agglomeration arises in South (i.e., $n_2 = 0$ and $m_2 = 0$, where a subscript "2" denotes the full agglomeration in South), the emissions are always less under the standard than in the initial equilibrium, $\chi_0 > \chi_2$, drawing a comparison between (9) and $\chi_2 = \frac{z\mu\gamma s}{b\tau w^*}$. As long as all firms agglomerate in South, North's standards work perfectly and effectively reduce emissions.

Proposition 3: Unless all firms concentrate in South, North's environmental product standards could worsen North's environment. This is more likely to occur when compliance costs are low and standards are lax. On the other hand, if all firms concentrate in South, then North's product standards necessarily improve environment in North.

3.4 Why do North's environmental standards increase emissions? Location effect and import embargo effect

An environmental product standard generates two effects which increases emissions. The first is the "location" effect of C-firms in North, which lowers trade-costs and allows higher levels of consumption. When North enforces the regulation, all available varieties in North are only C-firm products, which charge higher prices than in the initial equilibrium due to the compliance costs. As a result, North's market potential increases due to a fall in competition (a fall of Δ). On the other hand, all D-firms locate in South charging lower prices, which causes South's market potential to decrease due to tougher market competition (a rise of Δ*). North can attract more C-firms by the standard. Since the number of domestic C-firms in North increases, North's consumers pay less trade costs and can consume more. Thus, North's emissions increase. This stems from an increase in the number of C-firms in North, which is called the "location" effect.

The second is the "import embargo" effect. The total number of consumed varieties in North declines because of the ban on D-firm products. When the number of available varieties decreases, the consumption of each variety increases, which dominates the decrease in the available varieties with the CES preferences in (1). As a result, more emissions are generated. This is called the "import embargo" effect. This effect is promoted by smaller σ (more substitution between varieties).

These two effects increase emissions. As South's wage rate or the trade costs fall, more C-firms are attracted to South, which reduces the location effect and decreases emissions. An increase in the number of C-firms, N_C, reduces the import embargo effect and can mitigate emissions (see Section 4.2).

4. EXTENSIONS

This section considers some extensions of our basic model to understand the impacts of environmental product standards more generally.

4.1 Global Emissions

In this subsection, we discuss the case of transboundary emissions, those emissions whose externalities are not just local but affect both countries' environments. Our model framework is kept as in Section 3 except that emissions are transboundary. For simplicity, we focus on the case where emissions are completely transboundary and hence the environment deterioration depends on the global emissions which are defined as aggregate of both countries' emissions: $\chi_1^W \equiv \chi_1 + \chi_1^*$, where North's emissions are given by (18) and South's emissions are given by

$$\chi_1^* = \frac{z\mu\gamma(1-s)}{[m_1\tau^{1-\sigma} + (1-m_1)w^{*1-\sigma}]N_C\beta + w^{*1-\sigma}N_D\alpha}\left(\frac{m_1}{(b\tau)^\sigma} + \frac{1-m_1}{(bw^*)^\sigma} + \frac{1}{(aw^*)^\sigma}\right), \tag{19}$$

Suppose $\frac{1}{a} \cong \frac{z}{b}$. Then standards always increase North's emissions and always decrease South's emissions, $\chi_0 - \chi_1 < 0$ and $\chi_0^* - \chi_1^* > 0$ (see Appendixes 2 and 3). Therefore, in this case, the effect on global emissions is generally ambiguous. Global emissions depend on firm share, *m*, which is determined by the number of C-firms, N_C and population share, *s*. For instance, higher share of C-firms in North, *m*, increases χ_1 but decreases χ_1^*, and could increase χ_1^W and vice versa.

Moving from general case to the special case where all firms concentrate in South. The emissions with standards (denoted by a subscript "2") and without standards (denoted by a subscript "0") are given by

$$\chi_0 = \frac{\mu\gamma s}{a\tau w^*}, \quad \chi_0^* = \frac{\mu\gamma(1-s)}{aw^*}, \quad \chi_0^W = \frac{\mu\gamma}{aw^*}\left(\frac{s}{\tau} + 1 - s\right),$$

$$\chi_2 = \frac{z\mu\gamma s}{b\tau w^*}, \quad \chi_2^* = \frac{z\mu\gamma(1-s)}{bw^*}, \quad \chi_2^W = \frac{z\mu\gamma}{bw^*}\left(\frac{s}{\tau} + 1 - s\right).$$

Since $\frac{1}{a} > \frac{z}{b}$, we always have $\chi_0^W > \chi_2^W$. Therefore, in this case emission standards can always reduce the global emissions.

Proposition 4: If compliance costs are sufficiently low and emission standards are sufficiently lax, then the emissions increase in North but decrease in South. The effect on the global emissions is generally ambiguous unless all firms locate in South.

4.2 C- and D-firm ratio

The environmental product standard generates two types of firms. C-firms incur compliance costs, while D-firms do not. The total numbers of C-firms and D-firms are *exogenously* given and *m* is *endogenously* determined through location choice by C-firms. This subsection investigates the exogenous changes in N_C by keeping the total number of firms in the world constant, i.e., $N_C + N_D = 1$.

When N_C is positive but is not very large, all C-firms prefer to locate in North which has the larger market. In the range where N_C is greater than $\widetilde{N}_C$, as N_C rises, the share of North's firms m_1 decreases, because some C-firms choose to locate in South, $\frac{dm_1}{dN_C} < 0$.[17] The threshold value, $\widetilde{N}_C$, is derived by setting $m_1 = 0$ in (14):

$$\text{(20)} \qquad \widetilde{N}_C = \frac{w^{*1-\sigma} s\alpha(1-(\tau w^*)^{1-\sigma})}{w^{*1-\sigma} s\alpha[1-(\tau w^*)^{1-\sigma}] + [w^{*1-\sigma} - \tau^{1-\sigma} - sw^{*1-\sigma}(1-\tau^{2(1-\sigma)})]\beta}.$$

At extreme, if almost all firms are type C-firms, there is a moderate wage gap and trade costs, then their locations are diversified between North and South.

We now investigate North's emissions with standards (denoted by a subscript "1") and without standards (denoted by a subscript "0") when N_C increases. North's emissions in the initial equilibrium are independent of N_C as shown in (7). Under the standard, North's firms are diversified (i.e., $0< m_1 <1$) when $N_C > \widetilde{N}_C$ and hence emissions, χ_1, are dependent on N_C, or, m_1. Utilizing (18) and noting $w^*\tau > 1$, we obtain

$$\text{(21)} \qquad \frac{d\chi_1}{dm_1} = \frac{z\mu\gamma s(w\tau - 1)}{[m_1 + (1-m_1)(w\tau)^{1-\sigma}]^2 b(w\tau)^{\sigma}} > 0.$$

Thus, an increase in N_C decreases m_1 as well as χ_1. If N_C is large, then the emissions are more likely to be less than those without standards.

If the number of C-firms is large enough, i.e., $N_C \geq N_C^S$, where

$$N_C^S \equiv \frac{s\alpha[1-(\tau w^*)^{1-\sigma}]}{s\alpha[1-(\tau w^*)^{1-\sigma}] + \beta[(1-s)\tau^{2(1-\sigma)} + s - (\tau w^*)^{1-\sigma}]},$$

then all firms concentrate in South, i.e., m=0. As we have discussed as a special case in the last section, emissions are always less than the initial ones, $\chi_2 < \chi_0$.

Proposition 5: As the proportion of C-firms increases, the C-firm locations are more likely to be diversified (i.e., *m* falls) and North's environmental destruction led by standards can be mitigated.

4.3 Endogenous Firm Type

While our basic model exogenously gives the total numbers of C-firm and D-firm, we now relax this assumption. N_C and N_D are now *endogenously* determined so as to equalize both types' profits. It should be noted that no entry and exit is still assumed in the model and hence the total number of firms is always unity ($N_C + N_D = 1$). Each firm chooses its type but each type has both cost and benefit. D-firms have lower marginal costs, *a*, but are required to locate in South, the smaller market, and cannot export to North under environmental product standards. C-firms involve higher marginal costs, *b*, but can freely choose location and export to the foreign country.

In the long-run equilibrium, N_C and *m* are determined so as to satisfy location condition for C-firms $\pi_C - \pi_C^* = 0$ as well as firm type condition, $\pi_C^* - \pi_D^* = 0$. Two conditions are given by

(22) $$\pi_C^* - \pi_D^* = \frac{\mu\beta w^{*1-\sigma}}{\sigma}\left(\tau^{1-\sigma}\frac{s}{\Delta} + \frac{1-s}{\Delta^*}\right) - \frac{\mu\alpha w^{*1-\sigma}}{\sigma}\left(\frac{1-s}{\Delta^*}\right) = 0,$$

(23) $$\pi_C - \pi_C^* = \frac{\mu\beta}{\sigma}\left(\frac{s}{\Delta} + \tau^{1-\sigma}\frac{1-s}{\Delta^*}\right) - \frac{\mu\beta w^{*1-\sigma}}{\sigma}\left(\tau^{1-\sigma}\frac{s}{\Delta} + \frac{1-s}{\Delta^*}\right) = 0.$$

In general, however, both conditions are not simultaneously binding in the equilibrium.[18] There are only four possibilities: 1) $\pi_C - \pi_C^* > 0$ and $\pi_C^* - \pi_D^* = 0$ and 2) $\pi_C - \pi_C^* = 0$ and $\pi_C^* - \pi_D^* < 0$, 3) $\pi_C - \pi_C^* < 0$ and $\pi_C^* - \pi_D^* = 0$ and 4) $\pi_C - \pi_C^* = 0$ and $\pi_C^* - \pi_D^* > 0$. The equilibrium in each case is as follows: 1) All firms are C-firms and locate in North (*m*=1 and $N_C = 1$); 2) All firms are D-firms and locate in South ($N_D = 1$); 3) All firms locate in South (mixed types) ($0 < N_C < 1$ and *m*=0); and

4) All firms are C-firms and locate in North and South ($N_C = 1$ and $0<m<1$). Whereas 1) and 2) occur if $\frac{\beta\tau^{1-\sigma}}{\alpha-\beta} < \frac{1-w^{*1-\sigma}\tau^{1-\sigma}}{w^{*1-\sigma}-\tau^{1-\sigma}}$, 3) and 4) occur if $\frac{\beta\tau^{1-\sigma}}{\alpha-\beta} > \frac{1-w^{*1-\sigma}\tau^{1-\sigma}}{w^{*1-\sigma}-\tau^{1-\sigma}}$ (see Appendix 4).

Case 1: North's emissions are written as $\chi_3 = \frac{z\mu\gamma s}{b}$. Thus, North's emissions under North's standard may or may not be less than the initial emission level. In this case, North's environmental product standard may worsen its environment. With smaller b (smaller compliance costs) and/or larger z (lax environmental regulations), North's emissions are more likely to exceed the initial emission level, χ_0.

Case 2: Since all firms are D-firms, they cannot export to North. North cannot consume M-goods and thus generate no emissions. No consumption in North leads to welfare loss. This can be regarded as a kind of market failure.

Case 3: Only the "type" condition is binding and this determines N_C.[19] Solving the type condition, we obtain $N_C = \frac{s\alpha}{\alpha-\beta}$. North's emissions can be written as $\chi_4 = \frac{z\mu\gamma s}{b\tau w^*}$. Obviously this is always less than the initial level, χ_0.[20]

Case 4: The firm share, n_S, in the long-run equilibrium can be solved as

$$(24)\qquad n_5 = m_5 N_C = \frac{w^{*1-\sigma}[s(1-\tau^{2(1-\sigma)}) + \tau^{1-\sigma}(\tau^{1-\sigma} - w^{*1-\sigma})]}{[1-(\tau w^*)^{1-\sigma}](w^{*1-\sigma} - \tau^{1-\sigma})}.$$

Note that firm share is the same as the initial equilibrium, $n_0 = n_6$. North's emissions are written as

$$\chi_5 = \frac{z\mu\gamma s}{[n_6 + (1-n_6)(w^*\tau)^{1-\sigma}]b}\left(n_6 + \frac{1-n_6}{(w^*\tau)^{\sigma}}\right)$$

which is less than the initial emission level, χ_0.

Proposition 6: Suppose that firms can freely choose either C- or D-firm under environmental product standards. Then, in a range of parameterizations, all firms become C-firms and locate in

North. In this case, North's environment deteriorates if the compliance costs are sufficiently low and the standard is sufficiently lax.

5. CONCLUDING REMARKS

We have explored the effects of environmental product standards on the environment in a North-South trade model with firm relocation. Specifically, we have examined a case where North unilaterally introduces a product standard under which dirty products (i.e., products not meeting the standard) are not allowed to be sold in North's market. Our model has uncovered a possibility that such environmental product standards worsen North's environment and improve South's environment. In particular, we have found that small compliance costs and lax emission standards tend to generate this paradoxical result. It is expected that as the environmental standard becomes laxer, the costs to comply with the standard become smaller. Thus, no environmental standard is likely to be better than a lax standard from the viewpoint of environmental protection in North. Even when environmental damage is not local but global, North's environmental product standards could worsen global environment.

Our model operates on the basis of monopolistic competition. We do not claim that monopolistic competition is the best market structure for investigating the issue. Our focus is on the environmental effects caused by firm location choices due to environmental product standards. Firm location choices have been extensively studied in the NEG framework which strongly depends on monopolistic competition. Thus, a monopolistically competitive model based on the NEG framework is the natural starting point for analyzing how firm locations affect the environment. However, examination the same issue in alternative market structures is certainly worthwhile.

Furthermore, we can extend our model in many ways to analyze other various situations. A possible extension of our model is to consider type switch involving environmental R&D activities, where firms may invest in R&D to comply with standards. Another extension would be to incorporate entry and exit into the model. For example, D-firms may choose exit rather than relocation. However, with this addition the model would become much more complex and may not provide analytical solutions, so we would rely on numerical simulations.

Environmental product standards in our model are very stringent in the sense that those firms that do not conform to the standards relocate to foreign countries. However, governments may be more generous or permissive. In the real world, governments tend to subsidize firms required to make products meet stricter standards. However, our model does not capture this issue. To study the policy from this perspective may require the application of incentive theory with asymmetric information.

APPENDIX 1: FIRM SHARE

We prove $m_1 > n_0$ and $n_1 > n_0$.

$$n_0 = (\tau^{2(1-\sigma)} - s\tau^{2(1-\sigma)} + s - \tau^{1-\sigma} w^{*1-\sigma})\Gamma, \; m_1 = \left[\frac{sN_D \alpha (1-(\tau w^*)^{1-\sigma})}{\beta N_C} + (\tau^{2(1-\sigma)} - s\tau^{2(1-\sigma)} + s - (\tau w^*)^{1-\sigma}) \right]\Gamma,$$

where $\Gamma \equiv \dfrac{w^{*1-\sigma}}{(1-(\tau w^*)^{1-\sigma})(w^{*1-\sigma} - \tau^{1-\sigma})}$. Since $1-(\tau w^*)^{1-\sigma} > 0$ implies $\dfrac{sN_D \alpha (1-(\tau w^*)^{1-\sigma})}{\beta N_C} > 0$, we obtain $m_1 > n_0$.

Likewise, we can show $n_1 > n_0$:

$$n_1 = \left[\frac{sN_D \alpha (1-(\tau w^*)^{1-\sigma})}{\beta} + (\tau^{2(1-\sigma)} - s\tau^{2(1-\sigma)} + s - (\tau w^*)^{1-\sigma}) \right]\Gamma > n_0, \text{ because } \frac{sN_D \alpha (1-(\tau w^*)^{1-\sigma})}{\beta} > 0.$$

Furthermore, $\dfrac{dm_1}{dN_C} = -\dfrac{1}{N_C^2}\Gamma \dfrac{s\alpha(1-(\tau w^*)^{1-\sigma})}{\beta} < 0$ holds.

APPENDIX 2: EMISSIONS

We show that $\chi_1 > \chi_0$ if $\dfrac{1}{a} \cong \dfrac{z}{b}$ holds.

$$\chi_0 - \chi_1 = \frac{\mu\gamma s}{(n_0 + (1-n_0)(w^*\tau)^{1-\sigma})a}\left(n_0 + \frac{1-n_0}{(w^*\tau)^{\sigma}} \right) - \frac{z\mu\gamma s}{(m_1 + (1-m_1)(w^*\tau)^{1-\sigma})b}\left(m_1 + \frac{1-m_1}{(w^*\tau)^{\sigma}} \right)$$

$$= \frac{\mu\gamma s}{(w^*\tau)^{\sigma}}\left(\frac{n_0 (w^*\tau)^{\sigma} + (1-n_0)}{(n_0 + (1-n_0)(w^*\tau)^{1-\sigma})a} - \frac{m_1 (w^*\tau)^{\sigma} + (1-m_1)z}{(m_1 + (1-m_1)(w^*\tau)^{1-\sigma})b} \right)$$

With a product standard, we have $\dfrac{1}{a} > \dfrac{z}{b}$. As long as $\dfrac{1}{a} \cong \dfrac{z}{b}$, however, we obtain

$$\chi_0 - \chi_1 = \frac{\mu\gamma s}{(w^*\tau)^{\sigma} a}\left(\frac{n_0 (w^*\tau)^{\sigma} + (1-n_0)}{(n_0 + (1-n_0)(w^*\tau)^{1-\sigma})} - \frac{m_1 (w^*\tau)^{\sigma} + (1-m_1)}{(m_1 + (1-m_1)(w^*\tau)^{1-\sigma})} \right).$$

Noting $m_1 > n_0$ (see Appendix 1), and $(w^*\tau)^{\sigma} > 1$ and $(w^*\tau)^{1-\sigma} < 1$ due to $w^*\tau > 1$, we have the following relationships:

$$n_0(w^*\tau)^{\sigma} + (1-n_0) < m_1(w^*\tau)^{\sigma} + (1-m_1) \Leftrightarrow (n_0 - m_1)(w^*\tau)^{\sigma} - (n_0 - m_1) < 0$$

$$n_0 + (1-n_0)(w^*\tau)^{1-\sigma} > m_1 + (1-m_1)(w^*\tau)^{1-\sigma} \Leftrightarrow (n_0 - m_1) - (n_0 - m_1)(w^*\tau)^{1-\sigma} > 0.$$

Thus, $\chi_0 - \chi_1 < 0$ holds.

APPENDIX 3: SOUTH'S EMISSIONS

We first derive South's emissions when $a \approx b$ and $z \approx 1$. We have

$$\chi_0^* = \frac{\mu\gamma(1-s)}{[n_0\tau^{1-\sigma} + (1-n_0)w^{*1-\sigma}]a}\left(\frac{n_0}{\tau^{\sigma}} + \frac{1-n_0}{w^{*\sigma}}\right), \chi_1^* = \frac{\mu\gamma(1-s)}{[m_1\tau^{1-\sigma}N_C + (1-m_1N_C)w^{*1-\sigma}]a}\left(\frac{m_1N_C}{\tau^{\sigma}} + \frac{1-m_1N_C}{w^{*\sigma}}\right).$$

Thus,

$$\chi_0^* - \chi_1^* = \frac{(1-s)\mu\gamma}{w^{*\sigma}\tau^{\sigma}a}\left(\frac{n_0w^{*\sigma} + (1-n_0)\tau^{\sigma}}{n_0\tau^{1-\sigma} + (1-n_0)w^{*1-\sigma}} - \frac{n_1w^{*\sigma} + (1-n_1)\tau^{\sigma}}{n_1\tau^{1-\sigma} + (1-n_1)w^{*1-\sigma}}\right).$$

Now we define the following function Ω in terms of a variable, *x*: $\Omega(x) \equiv \frac{xw^{*\sigma} + (1-x)\tau^{\sigma}}{x\tau^{1-\sigma} + (1-x)w^{*1-\sigma}}$. We differentiate it with respect to x and obtain $\frac{d\Omega(x)}{dx} \equiv \frac{w^* - \tau}{(x\tau^{1-\sigma} + (1-x)w^{*1-\sigma})^2} < 0$. Using $n_1 = m_1N_C > n_0$, we have $\Omega(n_0) > \Omega(n_1)$, i.e., $\frac{n_0w^{*\sigma} + (1-n_0)\tau^{\sigma}}{n_0\tau^{1-\sigma} + (1-n_0)w^{*1-\sigma}} - \frac{n_1w^{*\sigma} + (1-n_1)\tau^{\sigma}}{n_1\tau^{1-\sigma} + (1-n_1)w^{*1-\sigma}} > 0$. Thus, $\chi_0^* - \chi_1^* > 0$. We can conclude that as n_1 (namely, m_1) rises by more stringent standards in North, South's emissions fall.

APPENDIX 4: ENDOGENOUS FIRM TYPE

We prove that both type and location conditions are not binding simultaneously in the case of endogenous firm types. Two conditions can be re-written as

$$\pi_C^* - \pi_D^* = \frac{\mu\beta w^{*1-\sigma}}{\sigma}\left(\tau^{1-\sigma}\frac{s}{\Delta} + \frac{1-s}{\Delta^*}\right) - \frac{\mu\alpha w^{*1-\sigma}}{\sigma}\left(\frac{1-s}{\Delta^*}\right) = 0 \Leftrightarrow \beta\tau^{1-\sigma}\frac{s}{\Delta} + (\beta-\alpha)\frac{1-s}{\Delta^*} = 0$$

$$\pi_C - \pi_C^* = \frac{\mu\beta}{\sigma}\left(\frac{s}{\Delta} + \tau^{1-\sigma}\frac{1-s}{\Delta^*}\right) - \frac{\mu\beta w^{*1-\sigma}}{\sigma}\left(\tau^{1-\sigma}\frac{s}{\Delta} + \frac{1-s}{\Delta^*}\right) = 0$$

$$\Leftrightarrow (1 - w^{*1-\sigma}\tau^{1-\sigma})\frac{s}{\Delta} + (\tau^{1-\sigma} - w^{*1-\sigma})\frac{1-s}{\Delta^*} = 0$$

If both conditions are binding simultaneously, then the following must hold:

$$\frac{\beta\tau^{1-\sigma}}{(\alpha-\beta)}=\frac{(1-w^{*1-\sigma}\tau^{1-\sigma})}{w^{*1-\sigma}-\tau^{1-\sigma}}=\frac{(1-s)\Delta}{s\Delta^*}$$

where Δ and Δ* are functions of the number of firms, and hence the values are endogenously determined. By contrast, since marginal costs, *a* and *b*, wage rate, w^* and trade costs, *τ*, are exogenously given, $\frac{\beta\tau^{1-\sigma}}{(\alpha-\beta)}=\frac{(1-w^{*1-\sigma}\tau^{1-\sigma})}{w^{*1-\sigma}-\tau^{1-\sigma}}$ does not generally hold. In general, therefore, location and firm type conditions are not binding simultaneously.

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Notes

1. Since the original standards were overly strict, no auto producer was expected to be able to achieve them. Subsequently, the target dates were extended a total of three years and then the law was revised as the Clean Air Act of 1977.
2. Henderson (1996), Becker and Henderson (2000), Greenstone (2002), and List et al. (2003) find that pollution-intensive plants are responding to environmental regulations.
3. The footloose capital model is the simplest model in NEG. See Baldwin et al. (2003).
4. South's lower wage rates encourage firms to relocate there. Unless North is bigger than South, all firms could locate in South (without any environmental policy) because of South's cost advantage without a demand advantage in North (no agglomeration force).
5. Since c_S is the quantity of "North" consumption of a variety produced in South, "*" is not attached. A subscript "S" indicates the production location. c^* is the quantity of "South" consumption of a variety produced in North and c_S^* is the quantity of "South" consumption of a variety produced in South.
6. The case in which the disutility is caused by "global" emissions is dealt with in Section 4.1.
7. There is another model in which consumers care about environmental damage when making their consumption decisions. For example, in Moraga-Gonzalez and Padron-Fumero (2002), consumers differ in their willingness-to- pay for goods due to different environmental awareness.
8. The total number of households (population) is one in the world, because each individual has one unit of labor and capital. The level of demand depends on population size rather than income.
9. Note that each firm's profit is $\frac{1}{\sigma}$ times firm revenue. The $(1-\frac{1}{\sigma})$ terms cancel out in the price of a variety and in CES composition.
10. $1-(\tau w^*)^{1-\sigma} > 0$ implies that trade costs are relatively high and South's wage rate is close to unity.

11. The numerator of (6) equals zero with $\tau = \tau_S$.

12. We could assume a situation that firm types are randomly allocated with a certain probability. Or more precisely, we suppose that a firm draws a lottery to decide its own firm type before its operation as in Hopenhayn-Melitz approach. We examine the case where firm types are endogenously determined in Section 4.3.

13. See Appendix 1 for proof.

14. We have $\chi_1 = \frac{z\mu\gamma s}{m_1 N_C b^{1-\sigma} + (1-m_1)N_C(w^*\tau b)^{1-\sigma}}\left(\frac{m_1 N_C}{b^\sigma} + \frac{(1-m_1)N_C}{(w^*\tau b)^\sigma}\right) = \frac{z\mu\gamma s}{[m_1 + (1-m_1)(w^*\tau)^{1-\sigma}]b}\left(m + \frac{(1-m_1)}{(w^*\tau)^\sigma}\right)$. Hence, χ_1 is independent of N_C.

15. North's standards could decrease emissions in South. See Section 4.1.

16. Recall that our basic model assumes that both South's wage rate and trade costs are relatively high (i.e., $1-(\tau w^*)^{1-\sigma} > 0$). The impact of trade costs is more dominant than that of lower wage in South. Thus, import prices from South are still higher than made-in-North prices in North.

17. Appendix 1 shows $\frac{dm_1}{dN_C} < 0$ when $m_1 < 1$.

18. See Appendix 4 for proof.

19. We have $\pi_C^* - \pi_D^* = 0 \Leftrightarrow \frac{\beta\tau}{(\alpha - \beta)} = \frac{(1-s)N_C\beta\tau}{s(N_D\alpha + N_C\beta)} \Leftrightarrow \frac{1}{(\alpha-\beta)} = \frac{(1-s)N_C}{s(\alpha - N_C\alpha + N_C\beta)}$.

20. In this case, all firms locate in South in the initial equilibrium.