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Environmental Product Standards in North-South Trade

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Environmental Product Standards in North-South Trade*

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ABSTRACT.
One channel through which environment is damaged is consumption. To protect environment, various product standards are introduced all over the world. By using a new economic geography framework, this paper explores the effects of environmental product standards on environment in a North-South trade model. We examine a 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 the North market. We find that such a standard may worsen North environment but improve South environment through firm relocation.

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Keywords: environmental product standards, compliance costs, firm location, footloose capital model

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1. INTRODUCTION

Concern for environmental destruction has been growing in the world. To protect environment, various environmental policies are adopted all over the world. However, attitudes towards environmental destruction are different across countries. Thus, some countries adopt more stringent policies than others. Examples include environmental "product" standards such as auto emission standards. In particular, it is often observed that governments prohibit firms from selling those products that do not meet certain environmental product standards. For example, under the U.S. Clean Air Act of 1970 called the Muskie Act, automakers were not allowed to sell cars that do not meet the emission standards.[1] The EU prohibited the use of chrysotile asbestos products and banned their imports from Canada in 1998. In 2002, China introduced the China Compulsory Certification, under which foreign firms cannot export to China without implementing certain standards.

Environmental policies could affect firm locations. It is expected that firms tend to move to countries with lax environmental policies.[2] In particular, recent improvements in transportation and communications technology as well as trade liberalization allow firms to choose their locations more easily. Above-mentioned prohibitive environmental product standards may also affect firm locations. Firms no longer may have much incentive to locate in the country with prohibitive standards. An important point is that firm relocations caused by environmental product standards could affect environment.

In this paper, therefore, we theoretically analyze the 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 the

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[1] Since the standards were overly strict, it was expected that no auto producer could achieve the standards. The target dates were extended a total of three years and the law was subsequently 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).

model, there are two countries (North and South), two sectors (agriculture and manufacturing), and two factors (capital and labor). The agricultural product, which perfectly competitive firms produce from labor alone with constant-returns-scale (CRS) technology, 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 environment and unilaterally introduces an environmental product standard. If firms do not comply with it, they cannot serve the North market. In the presence of the possibility of firm relocation, therefore, those firms producing goods that do not meet the North standard operate in South and serve only South market. Those firms that conform to the North standard by incurring extra costs can serve both North and South markets and locate in either North or South.

Our main finding is that North environmental product standards may fail to protect North environment. With the standard, 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. Unless clean products never damage environment, North environment could deteriorate as a result. Moreover, South environment may be improved by North environmental product standards. We show such paradoxical effects of North environmental product standards in the presence of firm relocation.

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

Relatively little attention has been paid to environmental and trade policies with consumption externalities. In particular, only 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. On the basis of a model with environmentally differentiated products and heterogeneous consumers, Toshimitsu (2008) shows that a strict emission standard on an imported product may or may not increase social surplus. 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 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) also use the footloose capital model to compare between emission tax and quota policies when 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 standard, we consider emission standards such as auto 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. This leads to firm relocation. 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 is bigger than South in population size but the North (nominal) wage rate is higher than the South wage rate.[5]

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 $1/w$ units of labor and $1/w^*$ 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 $1/w$=1 (that is, the North wage rate equal to unity), the South 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 in Martin and Rogers (1995) can move between countries, but there is no entry and exit. M-sector uses labor and exclusively employs capital. 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 π, i.e., the fixed cost part of total cost, 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.

[5] Lower South wage rates attract firms to South. Unless North is bigger than South, all firms could locate in South (without any environmental policy), because of cost advantage in South but no demand advantage in North (no agglomeration force).

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

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

where M and A stand for consumption of M-sector varieties and that of A-sector, respectively, and μ is the intensity of preference towards M-sector goods. n is the number of differentiated varieties. c is the quantity of North consumption of each variety produced in North, while c_S is that produced in South.[6] Mirror image holds for South. σ in the CES function for differentiated varieties denotes the constant elasticity of substitution between two varieties.

The disutility caused by local emissions is expressed as an increasingly monotonic function of the total emissions of M-sector varieties, $g(\chi)$, where χ is the total emissions in North (χ^* is for South).[7] 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 the consumption decisions.[8]

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

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[6] 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.

[7] The case in which the disutility is caused by "global" emissions is dealt with in Section 4.1.

[8] There is another modelling in which consumers care about environmental damage when making the 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.

North's share of initial capital and labor endowments are given by $s_K \equiv K/K^W$ = $L/L^W \equiv s_L$, where "*W*" stands for values pertaining to the world. However, after firm relocation, 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, 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 expenditure, *E*, is defined as $s_E \equiv E/E^W$, 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.[9]

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 product variety of a North-based M-sector firm are given by:

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

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

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

where "a" is the unit labor requirement and w^* (<1) is the South wage rate, which are exogenously given as a constant. North (South) consumers pay *p* (p_S^*) for local

[9] 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.

variety and p_S (p^*) for imported variety. Consumption per local variety and imported (foreign) variety in North are respectively given by:

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

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 $\overline{\Delta^*}(n) \equiv [n\tau^{1-\sigma} + (1-n)w^{*1-\sigma}]a^{1-\sigma}$.[10] Noting the South 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 firm shares, n_0 (we let a subscript "0" denote the initial equilibrium):

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

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

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

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 $0 < n_0 < 1$,

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[10] Note that each firm's profit is 1/σ times firm revenue. The (1 – 1/σ) terms cancel out in the price of a variety and in CES composition.

which holds only if $1-(\tau w^*)^{1-\sigma} > 0$, and investigate the impact of environmental standards on firm location.[11] However, we also discuss 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 $\tau_S^{1-\sigma} = \dfrac{w^{*1-\sigma} - \sqrt{w^{*2(1-\sigma)} - 4s(1-s)}}{2(1-s)}$.[12] When $\tau < \tau_S$, all firms concentrate in South. We differentiate τ_S with respect to w^* to obtain $\dfrac{\partial \tau_S}{\partial w^*} < 0$. A lower w^* enhances cost advantage in South and attracts more firms to South. Hence full agglomeration in South is more likely. This means an increase in τ_S.

Proposition 1: The larger the North-South wage gap (i.e., the lower the South wage rate), the more firms are attracted to South. Sufficiently small trade costs and/or a substantially low South wage rate lead 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. It is assumed that emissions never negatively affect production in both sectors but affect each consumer's utility as seen in (1). The quantity consumed by the North (South) residents for a local variety 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 variety 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

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[11] $1-(\tau w^*)^{1-\sigma} > 0$ implies that trade costs are relatively high and the South wage rate is close to unity.

[12] The numerator of (6) equals zero with $\tau = \tau_S$.

$\gamma \equiv (1-1/\sigma)$. It follows that the total emissions in North and South in the initial equilibrium are respectively:

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

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

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 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 and South emissions are given by

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

This implies that the smaller trade costs and lower South wage increase North emissions. The lower consumption prices in North due to the smaller trade costs and lower South wage rate increase North consumption and hence North emissions.

3. ENVIRONMENTAL PRODUCT STANDARDS AND COMPLIANCE COSTS

3.1. *Compliance costs*

Now the North government unilaterally introduces a product standard in terms of emissions during 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), it can be sold in the North market. However, if it does not (that is, if it is a "dirty" product), it cannot be sold in North. Thus, North firms producing dirty products stop their operation in North and relocate to South. South firms producing dirty products cannot export to North.

In response to the North 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 $N_C + N_D = 1$.[13] We assume that firm types never change even if firms change location. The compliance needs additional labor forces per unit of production and thus 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 additional units of labor per output 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 to equalize the profits. Although all D-firms locate in South due to the standard, C-firms are able to choose their location which could be diversified between 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

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

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 but *m* is endogenously determined by $\pi_C - \pi_C^* = 0$. The profits of a North-based C-firm and a South-based C-firm are given by:

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

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[13] 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.

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

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

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

Appendix 1 shows that compared to the initial equilibrium, m_1 is always greater than the North firm share in the initial equilibrium (i.e., $m_1 > n_0$) as long as both $m_1 > 0$ and $n_0 > 0$ hold. Moreover, the share of available varieties in North increases by the standard, i.e., $n_1 = m_1 N_C > n_0$.[15] 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 in North reduce competition in North, which attracts more C-firms to North. Since prices (marginal costs) of C-firms are higher than those of D-firms and have less impact on the market

[15] See Appendix 1 for proof.

[17] 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.

competition in North, more C-firms can locate in North. Therefore, standards could increase the North firm share.

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

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

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

The North consumption of a local variety (C-firms) is given by $c_C = \frac{\mu\gamma s}{\Delta b^\sigma}$ and that of an imported variety is $c_{CS} = \frac{\mu\gamma s}{\Delta(bw^*\tau)^\sigma}$. The South 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 emissions*

We compare North 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.[17]

Appendix 2 proves that $\chi_1 > \chi_0$ if $a \cong b$ and $z \cong 1$ hold, or more precisely $1/a \cong z/b$ 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 raises North emissions, $\chi_1 > \chi_0$.[19] 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.[20]

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, the North standards perfectly work and can effectively reduce emissions.

Proposition 3: Unless all firms concentrate in South, North environmental product standards could worsen North environment. This is more likely when compliance costs are low and standards are lax. If all firms concentrate in South, on the other hand, North product standards necessarily improve environment in North.

3.4. *Why do the North environmental standards increase emissions? Location effect and import embargo effect*

The reasons why emissions increase by an environmental product standard are as follows. First, North enforces the regulations and 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, the North market potential increases through less competition (a fall of Δ). On the other hand, all D-firms locate in South, which charge lower prices. The South market potential decreases through tougher market competition (a rise of Δ*). North can attract more C-firms by the standard. Since domestic varieties of C-firms increase, North consumers pay less trade costs and can consume more. Thus, North emissions increase. This stems from an increase in the number of C-firms in North, which is called the "location" effect.

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[19] North standards could decrease South emissions. See Section 4.1.

[20] Recall that our basic model assumes that both South 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.

Second, 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 in the CES function. 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 the South 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. 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 emissions are given by (18) and South emissions are given by

(19)

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

Suppose $1/a \cong z/b$. Standards always increase North emissions and always decrease South emissions, $\chi_0 - \chi_1 < 0$ and $\chi_0^* - \chi_1^* > 0$ (see Appendixes 2 and 3). Thus, 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.

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

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

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

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

Proposition 4: When compliance costs are sufficiently low and emission standards are sufficiently lax, 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 $\tilde{N}_C$, as N_C rises, the share of the North firms m_1 decreases, because some C-firms choose to locate in South, $\frac{dm_1}{dN_C} < 0$.[22] The threshold value, $\tilde{N}_C$, is derived by setting $m_1 = 0$ in (14):

[22] Appendix 1 shows $\frac{dm_1}{dN_C} < 0$ when $m_1 < 1$.

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

At extreme when almost all firms are C-firms with a moderate wage gap and trade costs, their locations are diversified between North and South.

We now investigate North emissions with ("1") and without ("0") standard when N_C increases. North emissions in the initial equilibrium are independent of N_C as shown in (7). Under the standard, North 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

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

Thus, an increase in N_C decreases m_1 as well as χ_1. If N_C is large, 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 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

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

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

In general, however, both conditions are not simultaneously binding in the equilibrium.[23] 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) $\pi_C - \pi_C^* = 0$ $\pi_C^* - \pi_D^* > 0$. 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)

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 emissions are written as $\chi_3 = \frac{z\mu\gamma s}{b}$. Thus, North emissions under standards may or may not be less than the initial emission level. In this case, North may worsen environment. With smaller b (smaller compliance costs) and/or larger z

[23] See Appendix 4 for proof.

(lax environmental regulations), North emissions are more likely to exceed the initial emission level.

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 determines N_C.[24] Solving the type condition, we obtain $N_C = \frac{s\alpha}{\alpha - \beta}$. North emissions can be written as $\chi_4 = \frac{z\mu\gamma s}{b\tau w^*}$. Obviously this is always less than the initial level.[25]

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

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

Note that firm share is the same as the initial equilibrium, $n_0 = n_6$. North 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 environment product standards. Then, in a range of parameterizations, all firms become C-firms and locate in North. In this case, North environment deteriorates if the compliance costs are sufficiently low and the environmental product standard is sufficiently lax.

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

[25] In this case, all firms locate in South in the initial equilibrium.

5. CONCLUDING REMARKS

We have explored the effects of environmental product standards on 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 the North market. Our model has uncovered a possibility that such environmental product standards worsen North environment and improve South environment. In particular, we have found that small compliance costs and lax emission standards tend to generate such a paradoxical result. It is expected that the laxer the environmental standard is, the smaller the costs to comply with the standard. Thus, no environmental standard is likely to be better than a lax standard from the viewpoint of environmental protection in North. Even if environmental damage is not local but global, North environmental product standards could worsen global environment.

Our model is on the basis of monopolistic competition. We do not claim that monopolistic competition is the best market structure to investigate the issue. Our focus is on the effects of environmental product standards on environment through firm location choices. Firm location choices have extensively been studied in the NEG framework which heavily depends on monopolistic competition. Thus, it seems like the natural starting point to build a monopolistically competitive model based on the NEG framework to analyze how firm location choices led by environmental standards affect environment. However, it is certainly worthwhile to examine the same issue in alternative market structures.

Furthermore, we can extend our model in many ways to analyze various situations in the real world. A possible extension of our model is to consider type switch involving environmental R&D activities. Firms may invest in R&D to comply with standards. Also, it would be possible to incorporate entry and exit into the model. For example, D-firms may choose exit rather than relocation. However, the model would become much more complex and may not provide analytical solutions. In this case, we need to 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 and permissive. In the real world governments tend to subsidize firms so that products meet standards. However, our model does not capture this issue. To study the policy in this viewpoint, we may have to use 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 $n_1 > n_0$:

$n_1 = \left[\dfrac{sN_D \alpha (1-(\tau w^*)^{1-\sigma})}{\beta} + (\tau^{2(1-\sigma)} - s\tau^{2(1-\sigma)} + s - (\tau w^*)^{1-\sigma}) \right] \Gamma > n_0$, because $\dfrac{sN_D \alpha (1-(\tau w^*)^{1-\sigma})}{\beta} > 0$. 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 $1/a \cong z/b$ 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:

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

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

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

APPENDIX 3: SOUTH EMISSIONS

We first derive South 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*:

$\Omega(x) \equiv \dfrac{xw^{*\sigma} + (1-x)\tau^\sigma}{x\tau^{1-\sigma} + (1-x)w^{*1-\sigma}}$. We differentiate it with respect to *x* and obtain

$\dfrac{d\Omega(x)}{dx} \equiv \dfrac{w^* - \tau}{(x\tau^{1-\sigma} + (1-x)w^{*1-\sigma})^2} < 0$. Using $n_1 = m_1N_C > n_0$, we have $\Omega(n_0) > \Omega(n_1)$,

i.e., $\dfrac{n_0w^{*\sigma} + (1-n_0)\tau^\sigma}{n_0\tau^{1-\sigma} + (1-n_0)w^{*1-\sigma}} - \dfrac{n_1w^{*\sigma} + (1-n_1)\tau^\sigma}{n_1\tau^{1-\sigma} + (1-n_1)w^{*1-\sigma}} > 0$. Thus, $\chi_0^* - \chi_1^* > 0$. We can conclude that as n_1 (namely, m_1) rises by more stringent North standards, South 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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