DEPOCEN

Working Paper Series No. 2008/02

Globalization, North-South Industrial Location and Environmental Competition

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Abstract

Relying on a North-South model of economic geography, our paper attempts to discuss the management of global pollution issues such as greenhouse gas emissions. As firms are increasingly mobile, they become sensitive to differences in environmental standards across countries and subject the regulatory power of a country to the rule of competition. In this context, we first evaluate the consequences of a passive ecological dumping from the South. We find that the Northern region undergoes a phenomenon of industrial relocation with a fall in its real income. In addition, the outcomes on global pollution abatement appear ambiguous. Globalization of the world economy, by changing the location decisions of firms, can make global pollution even worse. This calls for international cooperation between the North and the South. We then turn to investigate the outcomes of a harmonization of environmental policies. Although better from an ecological point of view, this second scenario harms the South both in terms of industrial relocation and real income.

JEL *classification*: F12 - Q20 - R10
Keywords: Economic geography, global pollution, environmental competition.

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1. Introduction

Along with North-South trade negotiations, concerns with the environment are the issues likely to dominate the international arena in decades to come. In the public debate, it is often claimed that polluting industries are likely to relocate from developed to developing countries in order to take advantage of lax regulations. In the newly globalized economy where firms can freely move across country borders, the North may then fail to upgrade environmental standards to the appropriate levels as stricter regulations may drive industries away. Unless policy harmonization and collective management of common resources are implemented, international competition among individual countries undermine any regulatory efforts of governments. The "ecological dumping"[1] of the South would then be responsible for the regulatory chill in the global context. From the point of view of Southern economies however, the historical responsibility with regards to environmental degradation incontestably lies with the developed countries (*cf.* recent conflicts arisen with China). Along their development process, they face different resource and environmental constraints which impede their efforts to quickly promote people's quality of life, while protecting their natural environment. In this context, environmental regulations are often assumed to hinder their industrialization process and economic development. These contradictory appreciations therefore emphasize the need for a global action on environmental challenges.

In this regard, our paper attempts to develop a theoretical analysis of the eco-dumping assertion by considering environment as a global public good beyond the control of any individual nation. We model the environmental competition debate and the fight against greenhouse gas emissions argument in a two-region model of economic geography (one North, one South)[2]. Our novel contribution here is to extend the traditional analysis of the interaction between trade and environment by taking into account international mobility of capital. In particular, we rely on Martin and Rogers [1995] whose model has been generalized in Baldwin and alii [2003] in the so-called "footloose capital" model. This denomination refers to a process of spatial dynamics which is conducted by capital mobility according to profit differentials across regions[3]. North-South exogenous asymmetry in terms of economic development and environmental regulations will then be faced with the location decisions of firms.

Section 2 presents a description of the model. We then divide our investigation into two parts: first, the effects of a passive environmental policy of the South (the so-called eco-dumping) in terms of global pollution abatement and spatial allocation of industry are assessed in section 3.

[1] The term "ecological dumping" is used here to describe State competition as regards regulation of global environmental issues in order to attract internationally mobile capital and/or to improve competitiveness of domestic industries. In the case of local environmental issues, this definition refers to a social optimum (with internalization of pollution externalities) which theoretically differs among countries. There will be ecological dumping when the environmental regulation of a country in a non-cooperative situation is less strict than the cooperative choice (*cf.* Rauscher, 1994).

[2] Zeng and Zhao [2006] also integrated a model of economic geography with cross-border pollution.

[3] The main advantage of such a framework, compared to the traditional economic geography models with catastrophic agglomeration (Krugman, 1991; Krugman and Venables,1995), is that it affords an analytically tractable solution for the spatial equilibrium. In return, the footloose capital model cuts the circular and cumulative causality that induces a self-reinforcing agglomeration process by assuming that the mobile factor repatriates all of its earnings to its country of origin.

Section 4 then analyzes the outcomes of a cooperative environmental policy between the North and the South. Finally, section 5 summarizes our conclusion.

2. The model

2.1. The analytical framework

We consider two regions: North and South (respectively subscripted N and S). The two regions are endowed with identical total labour supply L[4]. In each economy there are two sectors: a traditional sector (subscripted T) and an industrial sector (subscripted M). The traditional sector is perfectly competitive and produces a homogeneous good under constant returns. It is assumed that this good is costlessly tradable. The location of the traditional activity is predetermined by the location of the immobile factors. The industrial sector produces differentiated goods under increasing returns and monopolistic competition. They are tradable at cost in Samuelson's iceberg form: by denoting τ trade costs, the idea is that only a fraction $1/\tau$ of one unit of an industrial variety arrives on the export market. Trade costs on the global markets are thus proportional to the parameter τ.

Two productive factors are used in the industrial sector: labour L and physical capital K. More specifically, we assume that each industrial variety requires one unit of capital[5]. Hence, the number of differentiated products is determined by the amount of capital available in the two regions. By denoting n_i the number of available varieties in region i (*ie.* the number of industrial firms located in region i)[6] and K_i the capital endowment of region i, we can write that: $n_N + n_S = K_N + K_S$.

Contrary to the traditional sector, industrial firms can move freely across regions. Spatial dynamics in the model is then driven by capital mobility in response to profit differentials across regions. By contrast, labour is nationally mobile but internationally immobile. By denoting s_n North's share of industry ($s_n = n_N / \left(n_N + n_S\right)$) and π_i the reward to capital in region i, the spatial dynamics is described in the following way:

$$\dot{s}_n = \left(\pi_N - \pi_S\right)\ \left(1 - s_n\right)\ s_n \tag{1}$$

where, in addition to a core-periphery solution ($s_n = 0$ or $s_n = 1$), an interior solution will result from an arbitrage condition that equalizes capital's rates of return across regions. The industrial structure of our two regions N and S is consequently endogenous and, because physical capital can be separated from its owners, we must therefore distinguish the capital endowment of a region from the number of industrial firms located in this region. For example, we must distinguish the share of world capital owned by North (we denote this as $s_K = K_N / \left(K_N + K_S\right)$)

[4]This assumption aims to abstract from the traditional comparative advantage approach. By doing this, we seek to focus exclusively on the trade flows generated by the agglomeration forces and their influence on industrial location.
[5]Since each unit of capital can be used to produce one industrial variety, the reward to capital would be bid up to the point where it equals operating profit (see Baldwin and *alii*, 2003).
[6]Because of increasing returns to scale, each variety of the differentiated good is supplied in only one location by a single firm.

from the share of industrial firms located in North or the share of all varieties made in North (s_n).

Manufacturing generates cross-border pollution by an emission coefficient a. Every firm can cut its polluting emissions but it incurs an abatement cost. Indeed, any emission standard $\beta_i a$ imposed by the authorities of region i (with $0 < \beta_i < 1$) requires an additional fixed cost v_i (the environmental cost v_i is measured in labour units). Moreover, we assume that this additional fixed cost is inversely proportional to the effort of pollution abatement, so that:

$$v_i = v(\beta_i) \quad with\ v' < 0\ and\ v(1) = 0 \tag{2}$$

To describe the government's pollution abatement policy, we make the assumption that it seeks to reach an exogenous level of polluting emissions[7] resulting from local and international agreements. Moreover, as our main focus here is not to compare the efficiency of various policy instruments of environmental regulation[8], we will restrict our discussion on environmental competition to the case of emission standards which, in contrast to other policy instruments such as emission taxes, does not generate budget revenue. Indeed, the efficiency of environmental tax policy depends upon the distribution of tax revenue (Rauscher, 1995; Wilson, 1996). Environmental regulation through emission standards therefore circumvents the redistribution policy issue which might strongly condition the outcomes of our analysis and would move us away from our main focus.

In the model, two assumptions describe North-South asymmetry:
1) differences in incomes. We assume that capital is more abundant in N ($s_K > 1/2$), which means, as we will see henceforth, that North's income is higher than the Southern one.
2) asymmetry in environmental regulations. Initially, environmental regulation is more stringent in N[9]: $\beta_N < \beta_S$. According to relation (2), this implies that the environmental cost supported by the Northern firms is higher than the one prevailing in S, $v_N > v_S$.

The technology used by a typical firm located in region i is described by its cost function (CT_i):

$$CT_i = \pi_i + w_i c x_i + w_i v_i \quad \forall i = N,\ S \tag{3}$$

where c measures units of labour per unit of output, x_i is firm-level output in region i and w_i the nominal reward to labour in region i.
Industrial activity generates global pollution at the level:

$$P = \int_0^{n_N + n_S} e_j\, dj = a\left(n_N \beta_N x_N + n_S \beta_S x_S\right) \tag{4}$$

The representative consumer in each region has Cobb-Douglas tastes and preferences given by:

$$U = C_M^{\mu} C_T^{1-\mu} \quad with\ \ 0 < \mu < 1 \tag{5}$$

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[7]In response to the difficulty in determining the optimal level of pollution, we assume as in Baumol and Oates [1971] an exogenous environmental policy. By this, we choose to ignore the strategic dimension of environmental policy under imperfect competition (*cf.* Ulph 1996ab, 1997).
[8]For a discussion on the efficiency of the various policy instruments of environmental regulation under monopolistic competition, see Chiroleu-Assouline and *alii* [2003].
[9]This assumption becomes an outcome in the case of local pollution issues when the environmental policy is endogenous: as environmental quality is a normal good, the richer region will apply stricter environmental standards (Copeland and Taylor, 1994,1995).

where C_T and C_M are respectively consumption of the traditional good and consumption of the composite industrial good defined over a continuum of varieties of differentiated goods. By denoting C_j the consumption of each available variety j and assuming that the representative consumer has a preference for variety in industrial goods, C_M is defined by a constant-elasticity-substitution (CES) function:

$$C_M = \left(\int_{j=0}^{n_N+n_S} C_j^{1-1/\sigma} dj \right)^{\left(\frac{\sigma}{\sigma-1}\right)} \tag{6}$$

where $\sigma > 1$ represents the constant elasticity of substitution between any two varieties.
Combining relations (5) and (6), we can express the indirect utility function of the representative consumer in region i:

$$V_i = \frac{E_i}{G_i} \quad G_i = p_{iT}^{1-\mu} \left(\int_{j=0}^{n_N+n_S} p_{ij}^{1-\sigma} dj \right)^{\left(\frac{-\mu}{1-\sigma}\right)} \quad \forall i = N,\ S \tag{7}$$

where E_i is the region-specific expenditure (*ie*. income, as there is no taxation and no savings in this model), G_i is the price index in region i, p_{iT} is the price of the traditional good in region i, p_{ij} is the consumer price of industrial variety j in region i.
The level of income in region i is the sum of labour and capital income:

$$E_i = \pi_i K_i + w_i L \quad \forall i = N,\ S \tag{8}$$

Utility maximization yields a constant division of expenditure between the consumption of traditional and composite industrial goods:

$$C_{iT} = (1-\mu) E_i \quad C_{iM} = \mu E_i \quad \forall i = N,\ S \tag{9}$$

μ is the expenditure share on industrial varieties (*ie*. $(1-\mu)$ is the expenditure share on traditional goods).
Utility maximization also implies that the demand function for industrial variety j in region i is:

$$C_{ij} = \frac{p_{ij}^{-\sigma} \mu E_i}{\int_{j=0}^{n_N+n_S} p_{ij}^{1-\sigma} dj} \quad \forall i = N,\ S \tag{10}$$

Turning to p_i, the producer price for an industrial variety j in region i, it results from profit maximization under monopolistic competition which sets prices as constant mark-ups on marginal costs. Moreover, recall that Samuelson's iceberg trade costs imply that prices on the export market k are proportional to the parameter τ. Thus:

$$p_i = \frac{\sigma w_i c}{\sigma - 1} \quad p_k = \frac{\tau \sigma w_i c}{\sigma - 1} \quad \forall i,\ k = N,\ S \ \ with\ i \neq k \tag{11}$$

Technology in the traditional sector is characterized by two simplifying assumptions without loss of generality: first, producing traditional goods requires only labour and second, it takes one unit of labour to make one unit of the traditional good. With those simplifying assumptions and choosing the traditional good to be the numeraire, profit maximization in the constant-returns sector combined with intersectoral mobility of labour imply that $w_i = 1$. In addition, if we assume

that the traditional good is produced in both regions[10], its costless trade ensures that $w_N = w_S = w = 1$.
Thereafter, by normalizing the marginal cost of the increasing-returns sector to $c = 1 - 1/\sigma$ and replacing $w_i = 1$, the pricing equation (11) becomes $p_i = 1$ and $p_k = \tau$.

2.2. Spatial allocation equilibrium and global pollution

Using relations (3) and (11), we can derive the reward to capital in region i: $\pi_i = \left(p_i x_i / \sigma \right) - v_i$.
Since total world spending on industrial varieties equals μE_w and since an interior solution ($0 < s_n < 1$) is defined by equalizing capital's rates of return across regions, the long-run reward to capital will be: $\pi^* = \alpha E_w - v_N s_n - v_S (1 - s_n)$ with $\alpha = \mu / \sigma < 1$.
In addition, by normalizing the world capital endowment K_w to 1, we derive the expression for world income: $E_w = 2L + \pi^*$. This can be also rewritten as:

$$E_w = \frac{2L - v_N s_n - v_S (1 - s_n)}{(1 - \alpha)} \tag{12}$$

Employing relation (12), we can define the long-run equilibrium expression of capital's reward as:

$$\pi^* = \frac{2\alpha L - v_N s_n - v_S (1 - s_n)}{(1 - \alpha)} \tag{13}$$

Condition $\pi^* \geq 0$ implies that:

$$v_N s_n + v_S (1 - s_n) \leq 2\alpha L \tag{14}$$

This is assumed to hold henceforth and says the following: in order to keep the reward to capital positive in the long run, the global cost of environmental regulation must be bounded. More specifically, the sum of environmental fixed costs in the two regions weighted by their respective industrial development does not exceed an upper bound equal to $2\alpha L$.
Defining $s_E = E_N / E_w$ as North's share of world expenditure, we can use relations (8), (12) and (13) to get:

$$s_E = \frac{(1 - \alpha)}{2L - v_N s_n - v_S (1 - s_n)} \left(L - v_N s_n s_K - v_S s_K (1 - s_n) \right) + \alpha s_K \tag{15}$$

The above "market-size condition" describes the impact of endowment shares of world capital (s_K) on the relative market size (s_E)[11]. In contrast to Baldwin and alii [2003], expression (15) implies that the spatial distribution of industry (namely s_n) also affects the spatial distribution of

[10]This condition, called "non-full specialization" by Baldwin and *alii* [2003], is written as $(1 - \mu)(E_N + E_S) > L$. It implies that total world spending on traditional goods is greater than the maximum value of traditional production that is possible by either region.
[11]In contrast to Baldwin and *alii* [2003], we assume this expression to hold only in the long run where capital's rewards are equalized across regions. Although relation (15) is unaffected by this temporal restriction, it allows us to abstract from their assumption that the spatial distribution of industry in the short run must depend upon endowment shares of the world capital stock.

expenditure (namely s_E) *via* differences in environmental policy (v_N, v_S). Indeed, differences in environmental constraints determine capital's reward (relation (13)) and thus the spatial distribution of income.

On the industrial goods market, firm production in each region depends on foreign and domestic demands. From relation (10), that defines the demand function in region i, we can deduce the scale of production of a firm located in N and S respectively:

$$x_N = \mu\left(\frac{E_N}{n_N + n_S\tau^{1-\sigma}} + \frac{E_S\tau^{1-\sigma}}{n_S + n_N\tau^{1-\sigma}}\right)$$
$$x_S = \mu\left(\frac{E_S}{n_S + n_N\tau^{1-\sigma}} + \frac{E_N\tau^{1-\sigma}}{n_N + n_S\tau^{1-\sigma}}\right) \qquad (16)$$

The first term in brackets describes domestic demand whereas the second one describes foreign demand.

From this, we can derive the expressions of capital's short-run reward in each region:

$$\pi_N = \alpha\left(\frac{Ew}{Kw}\right)\left(\frac{s_E}{s_n + (1-s_n)\ \phi} + \frac{(1-s_E)\ \phi}{(1-s_n) + s_n\phi}\right) - v_N$$
$$\pi_S = \alpha\left(\frac{Ew}{Kw}\right)\left(\frac{(1-s_E)}{(1-s_n) + s_n\phi} + \frac{s_E\phi}{s_n + (1-s_n)\ \phi}\right) - v_S \qquad (17)$$

with $\phi = \tau^{1-\sigma}$ between 0 and 1 which is inversely proportional to trade costs τ ($\phi = 0$ represents no trade and $\phi = 1$ represents free trade).

From relations (12) and (17), the long run equilibrium condition (solving $\pi_N = \pi_S$) can be written as:

$$s_E = \frac{\left[(1-\phi)\ \left(2\alpha L - (v_N - v_S)\ s_n\right) + v_N(1-\alpha) - v_S(1-\alpha\phi)\right]\ \left[s_n + (1-s_n)\ \phi\right]}{\alpha\left(1-\phi^2\right)\ \left[2L - v_N s_n - v_S(1-s_n)\right]} \qquad (18)$$

Finally, we turn to the long run interaction between the global pollution level (P) and the spatial distribution of industry (s_n). For this, we retain that $x_i = \sigma(\pi_i + v_i) \quad \forall i = N,\ S$ in the development of relation (4) and we rely on the definition of the long run reward to capital (expression (13)). Thus, we get:

$$P = \frac{\sigma a\left[2L\alpha - v_N s_n - v_S(1-s_N)\right]}{(1-\alpha)}\left[\beta_N s_n + \beta_S(1-s_N)\right] + a\sigma\left[\beta_N v_N s_n + \beta_S v_S(1-s_N)\right] \qquad (19)$$

The long run equilibrium of the model results from a system of 3 equations (15, 18, 19) with 3 endogenous variables (s_E, s_n, P). Unfortunately, the combination of relations (15) and (18) leads to a quadratic equation which is inconvenient to induce a simple solution of spatial allocation equilibrium (s_n) and international distribution of income across regions (s_E). For this reason, we will carry out throughout the following sections an analysis in comparative statics which takes as a starting point the observation that the environmental standards in N are stricter than in S ($\beta_N < \beta_S$). We shall see specifically that trade costs (ϕ) and environmental policy of the two regions (β_N, β_S) may affect spatial interactions at work and the nature of the long run equilibrium.

3. Ecological dumping, industrial location and global pollution

This section evaluates the consequences of a passive ecological dumping from the Southern region. We assume that N unilaterally reinforces its environmental regulation by constraining firms located in its area to reduce their level of greenhouse gas emissions. By contrast, S does not modify anything concerning its environmental regulation. To keep things simple, we define a base scenario with total environmental laxism of South: that is to say, firms located in S face no pollution constraint ($\beta_S = 1 \Rightarrow v_S = 0$). North's environmental policy is then evaluated through comparative statics on the impact of a reduction in β_N. The firms located in N are then confronted with a dual choice: either meet this new environmental standard, thereby incurring an increase in their environmental fixed cost, or avoid the tough environmental policy by relocating their productive activity in S. In addition to its effects on the spatial distribution of industrial activities, we will measure the efficiency of this non-cooperative policy in terms of global pollution abatement and the impact of globalization process on the various interactions at work.

3.1. Relocation of industrial activities

With $\beta_S = 1$, relation (15) describing the market size condition is rewritten as:

$$s_E = \frac{(1-\alpha)}{2L - v_n s_n}\left(L - v_n s_n s_K\right) + \alpha s_K \tag{20}$$

Given differences in incomes between N and S ($s_K > 1/2$), we show in *Appendix 1* that this relation is negatively sloped in a diagram (s_n, s_E) (*Figure 1*). Indeed, with growing spatial agglomeration in North more firms are subject to strict environmental standards ($\beta_N > 0$), thereby eroding capital profitability internationally through firm mobility. Assuming that N is abundant in capital ($s_K > 1/2$), it will be more affected by this change in factor rewards, thus explaining decrease in North's income with spatial concentration in that region. We also show that a more stringent environmental policy (reduction in β_N) shifts the curve (20) downward to the left. Such a displacement is explained as follows: a reduction of the emission coefficient β_N implies an increase in the environmental fixed cost (v_N), which in turn lowers capital's reward in N (π_N). As capital is mobile, this phenomenon spreads internationally. But under the assumption that N is more abundant in capital, for an unchanged spatial distribution of industry ($ds_n = 0$), this region will be more concerned by the lower reward to capital so that its relative income (s_E) will decrease.

With $\beta_S = 1$, the long run locational equilibrium condition (relation (18)) becomes:

$$s_E = \frac{\left[(1-\phi)\ \ (2\alpha L - v_N s_n) + v_N (1-\alpha)\right]\ \left[s_n + (1-s_n)\ \ \phi\right]}{\alpha(1-\phi^2)\ \ [2L - v_N s_n]} \tag{21}$$

It is shown in *Appendix 2* that this relation is an upward curve in a diagram (s_n, s_E) (*Figure 1*), describing the traditional "home market effect" of new economic geography models: spatial agglomeration in N (s_n) is increasing with the North's share of world expenditure (s_E). We also show in *Appendix 2* that a reduction in β_N moves the curve upward to the left. Such a displacement is explained by the fact that, for a given distribution of income s_E, a stringency of North's environmental standards encourages relocation of industry into South.

Insert Figure 1

Figure 1 shows graphically that the reduction in β_N, leads to a jump from equilibrium 0 to equilibrium 1. The outcome is unambiguously a reduction in s_n. Recall that the introduction of more stringent environmental standards causes an immediate increase of production costs for firms located in N. The region becomes less attractive and industrial firms choose to circumvent the environmental constraints by moving away (lower s_n). The extent of the phenomenon should however be downplayed by the fact that the relocation incentive is partly moderated by privileged access to a large market once a firm is located in N.
At the same time, the reduction of capital's reward in N spreads internationally *via* firm mobility. This in turn decreases nominal income in both regions (E_N, E_S) while affecting, as we showed, North more because of its capital endowment. To complete the welfare analysis, we have to consider the impact of North's unilateral environmental policy on the cost of living in the two regions (relation (7)): $G_N = \left[s_n^{1-\sigma} + \phi(1-s_n)^{1-\sigma}\right]^{-\mu/(\sigma-1)}$ and $G_S = \left[(1-s_n)^{1-\sigma} + \phi s_n^{1-\sigma}\right]^{-\mu/(\sigma-1)}$.
Relocation of productive activities to S implies an increase in North's price index (G_N) because more goods have to be imported, implying a higher trade cost than the one faced if the good was produced locally. By contrast, the price index decreases in S (G_S) since it imports a narrower range of industrial goods. In addition, we saw that nominal income decreases in the two regions, thereby resulting unambiguously in a reduction of real income in N. The net effect on South's real income remains ambiguous. The impact depends on the extent of industrial relocation: if this phenomenon is extensive, the price index in S will drop strongly, thereby increasing the likehood of real income improvement.

3.2. The efficiency on global pollution control

As an intermediate result, we showed that unilateral pollution abatement policy is very expensive for the richer region, since it undergoes a phenomenon of industrial relocation with a fall in its real income. What about its consequences in terms of global pollution abatement?
With $\beta_S = 1$, relation (19) defining the long run global pollution level becomes:

$$P=\frac{\sigma a\left(2L\alpha-v_N s_n\right)}{\left(1-\alpha\right)}\left[\beta_N s_n+\left(1-s_n\right)\right]+\sigma v_N a\beta_N s_n \tag{22}$$

We show in *Appendix 3* that this relation is a downward curve in a diagram (s_n, P): a higher s_n increases the number of firms forced to exploit a cleaner technology, which will result in a reduction of global pollution. In the same way, we also show that a lower β_N shifts the curve (22) leftwards: regardless of what happens to industry location (unchanged s_n), stricter environmental standards in N reduce transboundary pollution (P).

As drawn in *Figure 1*, North's environmental policy has ambiguous effect on global pollution control: in particular, there's an inherent conflict between relocation of firms ($\triangle s_n$) and the shift in the global pollution schedule (curve (22)). Relying on relation (22), we can show analytically that the change in P with respect to a small change in β_N is decomposed into three contradictory elements denoted respectively the technology effect, the scale effect and the relocation effect.

$$\frac{dP}{d\beta_N}=\underbrace{\left.\frac{\partial P}{\partial \beta_N}\right|_{ds_n=dv_N=0}}_{\text{technology effect}}+\underbrace{v_N^{'}\times\left.\frac{\partial P}{\partial v_N}\right|_{ds_n=d\beta_N=0}}_{\text{scale effect}}+\underbrace{\frac{\partial s_n}{\partial \beta_N}\times\frac{dP}{ds_n}}_{\text{relocation effect}} \tag{23}$$

The technology effect:

This effect simply describes the favourable impact on environment of cleaner industrial processes. Relying on relation (14), we show that the first partial derivative is positive:

$$\left.\frac{\partial P}{\partial \beta_N}\right|_{ds_n=dv_N=0}=\sigma a s_n\left[\left(\frac{2L\alpha-v_N s_n}{\left(1-\alpha\right)}\right)+v_N\right]>0 \tag{24}$$

Cleaner technology used in N implies all other things equal (*ie.* for a given spatial distribution of industry and a given environmental fixed cost) a lower level of global pollution.

The scale effect:

This effect measures the impact of the environmental policy on firm scale which in turn determines the level of pollution. According to relation (23), the scale effect is decomposed into two terms. The first one asserts that a lower β_N raises the environmental fixed cost of firms located in N ($v_N^{'}<0$). But, according to the second term, this higher fixed cost affects firm scale and therefore the level of pollution. Relying on relation (4) and assuming that $\beta_S=1$, we can decompose this second term further:

$$\left.\frac{\partial P}{\partial v_N}\right|_{ds_n=d\beta_N=0}=a\left[s_n\beta_N\left.\frac{\partial x_N}{\partial v_N}\right|_{ds_n=0}+\left(1-s_n\right)\left.\frac{\partial x_s}{\partial v_N}\right|_{ds_n=0}\right] \tag{25}$$

To study this derivative in more detail, we have to distinguish the scale of firms located in N and S. After rewriting relations (3) and (11), we can observe that $x_N=\sigma\left(\pi_N+v_N\right)$ and $x_S=\sigma\pi_S$. In the long run, capital's rewards are equalized across regions and relation (13) indicates that $\pi_N=\pi_S=\pi^*=\left(2L\alpha-v_N s_n\right)/\left(1-\alpha\right)$. Thus, in the long run, we have $x_N>x_S$, as firms located in N seek to cover the environmental fixed cost by producing at larger scale (we will name this the "paying off" effect). At the same time, the higher environmental fixed cost in N burdens capital profitability on the global markets (*via* capital mobility) and consequently encourages firms in both regions to reduce their scale of production (we refer to this as the "capital profitability" effect). These two effects induced by the increase in v_N have a contradictory impact on the scale of firms located in N:

$$\left.\frac{\partial x_N}{\partial v_N}\right|_{ds_n=0} = \sigma\left[\left.\frac{\partial \pi_N}{\partial v_N}\right|_{ds_n=0} + 1\right] = \frac{\sigma}{1-\alpha}\left[(1-s_n)-\alpha\right] \qquad (26)$$

In the first expression of equation (26) we find our two above effects in square brackets: the first term refers to the capital profitability effect (the sign of the partial derivative is negative) whereas the second, of positive sign, refers to the paying off effect. The second expression on the right-hand side of relation (26) shows that the interaction between these two effects renders the sign of the partial derivative (26) ambiguous.

In contrast, such ambiguity disappears for the firms located in S. As they are not affected directly by the environmental constraint, only the capital profitability effect prevails (*via* the international mobility of capital) so that the impact of v_N on their scale of production is negative.

$$\left.\frac{\partial x_s}{\partial v_N}\right|_{ds_n=0} = \sigma\left.\frac{\partial \pi_N}{\partial v_N}\right|_{ds_n=0} = -\frac{\sigma s_n}{1-\alpha} < 0 \qquad (27)$$

For completeness, we can replace expressions (26) and (27) into (25):

$$\left.\frac{\partial P}{\partial v_N}\right|_{ds_n=d\beta_N=0} = \frac{\sigma a}{1-\alpha}\left[s_n(1-s_n)\ \ (\beta_N-1)-\alpha s_n\beta_N\right] < 0$$

In other words, the increase of the environmental fixed cost in North involves, all things being equal, a reduction in the level of global pollution *via* a negative supply effect. That is to say, because of capital mobility, firms in both regions are affected by the capital profitability effect[12] and lower their scale of production. In contrast, only firms located in North are subject to the paying off effect, which induces production at larger scale. We can see that the capital profitability effect dominates this interacting process.

The relocation effect:

The relocation effect illustrates the consequences of environmental regulation on firms' choice of location. We have partly described this effect in the previous section: in comparative statics, more stringent environmental standards in N involve inevitably a relocation of firms ($\partial s_n / \partial \beta_N > 0$). In addition, we show in *Appendix 3* that $dP/ds_n < 0$, *ie.* the relative share of industrial firms in N, with its more constraining environmental regulation, reduces the level of global emissions. Hence:

$$\frac{\partial s_n}{\partial \beta_N} \times \frac{dP}{ds_n} < 0 \qquad (28)$$

Contrary to the two former effects (the technology effect and the scale effect), the relocation effect therefore affects negatively expression (23). More generally, the efficiency of a unilateral environmental policy can be cancelled by firm mobility: instead of applying a cleaner production process which by nature is more expensive, firms located in the richer region can move to the region with laxer environmental standards.

[12]More precisely, as shown by relation (25), the capital profitability effect is weighted in each region by its respective emission coefficient and share of industrial firms.

3.3. The consequences of globalization

By reducing barriers to trade in industrial goods, globalization of the world economy may affect the interaction between the three forces at work. This process is captured in our model by the parameter ϕ $(0<\phi<1)$ which measures the freeness of trade. We observe that ϕ intervenes in the locational equilibrium condition (relation (21)) and influences both spatial allocation and global pollution[13].

Looking at the impact of ϕ on the spatial dynamics, we can observe from relation (21) that:

$$\left.\frac{\partial^2 s_E}{\partial\beta_N\partial\phi}\right|_{ds_n=0} = v_N' \left.\frac{\partial^2 s_E}{\partial v_N\partial\phi}\right|_{ds_n=0} < 0 \quad (29)$$

Expression (29) is drawn in *Figure 1* as follows: the globalization process, illustrated by a higher ϕ, magnifies the shift of the curve (21) onto the left corresponding to a reduction in β_N. The new equilibrium (equilibrium 2) is characterized *inter alia* by a stronger reduction in s_n, *ie.* a larger relocation in comparison with equilibrium 1.

Globalization, by reducing barriers to trade in industrial goods, makes access to the Northern market easier and hence firms more sensitive in their location choice to the induced pollution abatement overcost. As spatial agglomeration in the larger region in order to take advantage of its market size will be reduced, it becomes more profitable for firms to relocate in S and export to N instead of complying with its local environmental standards. In other words, the globalization process enhances firm sensitivity to ecological dumping. In addition, by magnifying the relocation effect (relation (23)), it increases the probability that North's stricter environmental policy paradoxically harms environment.

4. International cooperation on environmental policy

Previous results obviously argue in favour of global action on the environmental standards. To analyze the consequences of such a policy, we reformulate our model in comparative statics. Departing from the base scenario where $\beta_S = 1$, $0<\beta_N<1$, we constrain the Southern region to adopt the same stringent environmental standards as North ($\beta_S = \beta_N$). For an analysis of the locational equilibrium under harmonized environmental regulation, we rewrite the model by holding: $\beta_S = \beta_N = \beta$ and $v_S = v_N = v$.

Relation (15) describing the market size condition is then rewritten as:

$$s_E = \frac{(1-\alpha)}{2L-v}\left(L - v s_K\right) + \alpha s_K \quad (30)$$

In contrast to relations (15) and (20), we can see that the relative distribution of world income (s_E) becomes now invariant to the spatial distribution of industry (s_n) (*Figure 2*). This outcome can be explained by the fact that harmonization of the environmental standards cancels short run differences in capital's rates of return across regions. Hence, as capital's reward is repatriated to

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[13]More precisely, in relation (23) detailed above, the parameter ϕ intervenes in the definition of the relocation effect.

the country of origin, relocation of industry induces no income change in the two regions[14]. Spatial equilibrium condition (18) becomes:

$$s_E = \frac{s_n + (1-s_n)\ \phi}{(1+\phi)} \tag{31}$$

In comparison with the base scenario ($\beta_S = 1,\ \ 0 < \beta_N < 1$), the outcome of environmental harmonization is a shift downward onto the right of the spatial equilibrium schedule (*Figure 2*)[15]. In a global context of harmonized environmental standards, the level of transboundary pollution is by nature independent from the location decisions of firms. Indeed, relation (19) is rewritten with $\beta_S = \beta_N = \beta$:

$$P = \frac{\sigma a \alpha \beta (2L - v)}{(1-\alpha)} \tag{32}$$

As drawn in *Figure 2*, relation (32) determines minimal pollution in a non-cooperative situation where all industrial activities would be agglomerated in North (relation (32) corresponds to relation (22) with $s_n = 1$).

Insert Figure 2

Figure 2 shows that harmonization of the environmental standards, by the jump from equilibrium 0 to equilibrium 3, may be efficient in terms of global pollution abatement[16]. But it induces simultaneously a relocation of industry into N: as the environmental fixed cost is identical in both regions, firms will prefer to benefit from a better access to the North's larger market.
Finally, turning to the welfare effects, we first observe that the higher environmental fixed cost in S reduces reward to capital internationally *via* capital mobility. As we showed, this reduction affects more the Northern region because of its higher capital endowment. However, its price index tends to decrease with the attraction of industrial activities, implying an ambiguous outcome on its real income: the decrease in the price index (G_N) may prevail over the reduction of nominal income (E_N). By contrast, South's disindustrialization affects its price index in the opposite direction: as a wide range of industrial goods are now imported, it bears higher trade costs. Accordingly, harmonization of the environmental standards implies unambiguously a reduction of real income in S: the increase of the price index (G_S) in accordance with the disindustrialization process adds further to the reduction of its nominal income (E_S).
To summarize, world harmonization of the environmental standards hurts South through a disindustrialization process and a loss of real income. This outcome is of interest because it points out that Southern countries bear the burden of efficiency for global action on environmental regulation.

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[14] Relation (30) refers to the case $s_n = 1$ in expression (20), *ie.* all industrial activities are fully agglomerated in the region adopting clean technology.
[15] We find the same locational equilibrium condition as in Baldwin and *alii* [2003]. In the base scenario, relation (31) would correspond to the particular case $v_N = 0$.
[16] We carry out this point in detail in Rieber and Tran [2007].

5. Conclusion

Under the new globalized economy, competitiveness concerns have gained raising interest in all governments. Environmentalists are then afraid that the individual pursuit of this objective can enter in conflict with the safeguarding of environmental resources. As firms become increasingly mobile in the global markets, the environmental regulatory power of a country in terms of taxes and standards is subject to the rule of competition. The management of global or transboundary pollution issues such as greenhouse gas emissions may then result on "free rider" behaviour which can involve irreversible environmental damages.

In this paper, we have attempted to develop a theoretical analysis of the eco-dumping assertion in an economic geography model. Such a framework allows us to evaluate environmental policy in a context of international capital mobility and growing interdependence between individual nations. Relying on a two-region model, the North-South tension at work has been confronted with transboundary pollution issues. We have first considered a passive ecological dumping from the Southern region. It is shown in particular that the North undergoes a phenomenon of industrial relocation with a fall in its real income, as firms initially located in the North are incited to avoid its stringent environmental policy by relocating their productive activity in the South. However, the ecological dumping argument has only found partial evidence because the North still remains attractive for firms which take advantage of the market size effect. In addition, the total effect on global pollution control is ambiguous as three effects work in opposite directions. It is shown that globalization (*i*e. freer trade and capital mobility) enhances firm sensitivity to ecological dumping (namely differences in environmental standards across countries). Accordingly, the Northern environmental policy may paradoxically harm the environment.

These results provide quite natural arguments for international cooperation. However, the outcomes remain uneven: environmental harmonization hurts specifically the South both in terms of spatial distribution of industry and real income. In other words, the Southern region would "unilaterally" incur the burden of a successful harmonized environmental policy. Our results therefore bring theoretical support to the so-called principle of "common but differentiated responsibilities". More specifically, it raises the urgent challenge of financial and technological compensations that developed countries should grant to developing countries under multilateral environmental agreements.

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Appendices

Appendix 1: The properties of the market size condition

$$s_E = \frac{(1-\alpha)}{2L - v_n s_n}\left(L - v_n s_n s_K\right) + \alpha s_K \tag{20}$$

We demonstrate that relation (20) is negatively sloped in a diagram (s_n, s_E):

$$\frac{ds_E}{ds_n} = \frac{v_N\,(1-\alpha)\ \left[L\left(-2s_K + 1\right)\right]}{\left(2L - v_N s_n\right)^2} < 0 \quad for \quad s_K > 1/2$$

We also demonstrate that a more stringent environmental policy in North (reduction in β_N) shifts the curve (20) downward to the left. Indeed, for $s_K > 1/2$, we have:

$$\left.\frac{\partial s_E}{\partial \beta_N}\right|_{ds_n=0} = \frac{v_N'\,(1-\alpha)\ \overline{s_n}\left[L\left(-2s_K + 1\right)\right]}{\left(2L - v_N\,\overline{s_n}\right)^2} > 0$$

Appendix 2: The properties of the locational equilibrium condition

$$s_E = \frac{\left[(1-\phi)\ \left(2\alpha L - v_N s_n\right) + v_N\,(1-\alpha)\right]\ \left[s_n + (1-s_n)\ \ \phi\right]}{\alpha\left(1-\phi^2\right)\ \left[2L - v_N s_n\right]} \tag{21}$$

We then have:

$$\frac{ds_E}{ds_n} = \frac{(1-\phi)}{\alpha(1+\phi)} + \frac{(1-\phi)^2(1-\alpha)\ \ 2L(v-2L) + \phi v_N^2\,(1-\alpha)}{\alpha\left(v_N s_n - 2L\right)^2\left(1-\phi^2\right)}$$

$$\frac{d^2 s_E}{ds_n^2} = \frac{-2\alpha v_N\left(1-\phi^2\right)\ \left(v_N s_n - 2L\right)\ \left[(1-\phi)^2(1-\alpha)\ \ 2L(v-2L) + \phi v_N^2\,(1-\alpha)\right]}{\alpha^2\left(v_N s_n - 2L\right)^4\left(1-\phi^2\right)^2}$$

Therefore, we consider two situations:

1) if $(1-\phi)^2(1-\alpha)\ \ 2L(v-2L) + \phi v_N^2\,(1-\alpha) > 0$ then following relation (14): $ds_E / ds_n > 0$ and $d^2 s_E / ds_n^2 > 0$

2) if $(1-\phi)^2(1-\alpha)\ \ 2L(v-2L) + \phi v_N^2\,(1-\alpha) < 0$ then we solve $\overline{s_n}$ such as $ds_E / ds_n = 0$

$$\overline{s_n} = \frac{\left[-(1-\phi)^2(1-\alpha)\ \ 2L(v-2L) - \phi v_N^2\,(1-\alpha)\right]^{1/2}}{(1-\phi)\ \ v_N} + \frac{2L}{v_N}$$

With (14) and $0 < \alpha < 1$, we can deduce that $2L \geq v_N$, so that $\overline{s_n} > 1 \ \ \forall \ \ 0 \leq s_n \leq 1$

As $\overline{s_n} > 1$ and $d^2 s_E / ds_n^2 < 0$ we have demonstrated that $ds_E / ds_n > 0 \ \ \forall \ \ 0 \leq s_n \leq 1$.

A reduction in β_N moves the curve (21) leftwards:

$$\left.\frac{\partial s_E}{\partial \beta_N}\right|_{ds_n=0} = \frac{2L(1-\alpha)\ \ v_N'\left[s_n+\left(1-\overline{s_n}\right)\ \ \phi\right]\ \left[1-s_n(1-\phi)\right]}{\alpha\left(v_N s_n-2L\right)^2\left(1-\phi^2\right)}>0$$

Appendix 3: The properties of the global pollution level

$$P=\frac{\sigma a\left(2L\alpha-v_N s_n\right)}{(1-\alpha)}\left[\beta_N s_n+\left(1-s_n\right)\right]+\sigma v_N a\beta_N s_n \tag{22}$$

We demonstrate that relation (22) is a downward curve in a diagram (s_n, P):

$$\frac{dP}{ds_n}=\frac{-a\sigma\left(1-\beta_N\right)\ \left[v_N\left(1-s_n\right)+\left(2l\alpha-v_N s_n\right)\right]-\alpha\sigma v_N a\beta_N}{(1-\alpha)}<0$$

A more stringent environmental policy in North (reduction in β_N) shifts the curve (22) leftwards:

$$\left.\frac{\partial P}{\partial \beta_N}\right|_{ds_n=0} = \frac{a\sigma v_N' s_n\left[\left(1-\beta_N\right)\ \left(s_n-1\right)-\beta_N\alpha\right]+a\sigma s_n\left[\left(2l\alpha-v_N s_n\right)+v_N\left(1-\alpha\right)\right]}{(1-\alpha)}>0$$

Figure 1

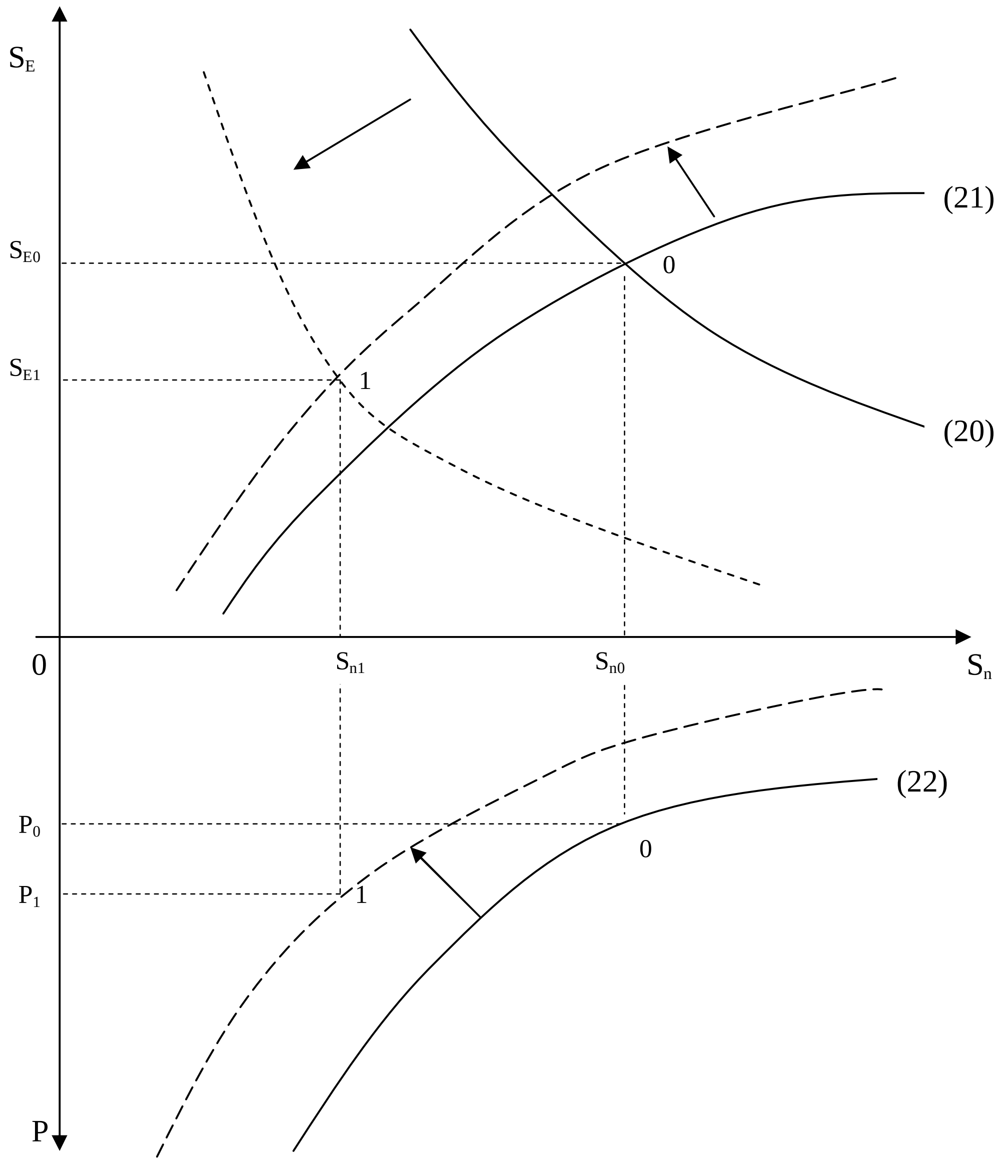

Figure 2