The effect of trade integration on local and global pollution

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Abstract. This paper shows that trade integration influences the incentives of governments to regulate polluting industries, and that these incentives vary according to the geographical scale of pollution. A two-country model of intra-industry trade in monopolistic competition, in which pollution is modeled as a production externality whose effects can occur from a local to a global scale, is developed. First, unilaterally strengthening a national environmental policy leads to firm relocation accompanied by carbon leakages. Trade integration magnifies the phenomenon. Next, optimal environmental policies are derived in cooperative and non cooperative equilibria. The latter is characterized by suboptimal environmental regulation: it is too strict with regard to local pollution and too lax as far as global pollution is concerned. Finally, trade integration increases the welfare cost of non-cooperation since it is welfare improving only if countries cooperate on environmental regulation.

Keywords
Monopolistic competition, international trade, environmental standards, pollution, co-operation

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1 Introduction

World trade has expanded over the past thirty years, at the same time as environmental concerns have heightened. The comparison of these two trends has given rise to impassioned public debates about the responsibility of trade expansion for the worrying evolution of the environment.
The scale on which the environmental externality takes place, local or global, and its link with international trade, is the key concern of the present paper. It studies how trade integration affects environmental policies, welfare, and both local and global pollution by changing the incentives for governments to regulate polluting industries in the absence of international cooperation.

The paper is motivated by the following stylized fact. In the past twenty years global pollution has increased, or remained constant, while local pollution has decreased. This is illustrated on figure 1 which presents, for OECD countries, the evolution of the ratio of emissions of major greenhouse gases[1] (which are considered as the major source of global air pollution) over emissions of traditional air pollutants[2] (which impact the environment and human health only at the local or regional levels). This paper shows that trade integration can partly explain this trend. Indeed, during this period, trade integration[3] has also increased as can be seen on figure 1.
Although the empirical literature on trade and environmental linkages has not come to a consensus on the methodology to be used and faces a lack of data, it has achieved some results. First, there is no one-to-one relationship between trade and pollution. Since Grossman and Krueger (1992) researchers have broken down the environmental impact of trade liberalization into three effects (scale, composition and technique): each one of these effects can either be beneficial or detrimental to environmental quality, so that the net result is a priori ambiguous. Second, the literature suggests that trade has opposite effects on pollution depending on its geographical scale, local or global. Empirical evaluations of the impact of trade on sulphur dioxide (SO_2) emissions or concentrations are of the same opinion: on average, using panel data, liberalizing trade seems to diminish this kind of pollution whose effects are local (Antweiler et al., 2001; Grether et al., 2007). With increasing preoccupations about climate warming consequences, the same kind of work has recently been carried out on greenhouse gases emissions, mostly on carbon dioxide (CO_2), and has reached opposite results. Cole and Elliott (2003), using panel data, conclude that trade liberalization is likely to increase CO_2 emissions. Frankel and Rose (2005) further improve the method by taking into account endogeneity issues between trade and per capita income. Their cross-country results first reinforce previous studies focusing on local air pollution since they find that more open countries have lower concentrations of SO_2. They also show that, on the contrary, there is a positive relationship between openness and CO_2 emissions.

[1] Carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulfur hexafluoride (SF_6).

[2] Sulfure dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO) and volatile organic compounds (VOC).

[3] Total trade as a percentage of GDP

The aim of this paper is to present a theoretical model to explain the link between trade openness and the nature of pollution. The mechanisms at work in the model are the following. Environmental policies affect negatively polluting firms' operating profits, so that stricter regulations lead to the relocation of polluting activities. As trade is facilitated, firms become more footloose because they easily relocate in one country and reexport to the former: they are therefore more sensitive to any difference in environmental policies between the two countries. These mechanisms generate the following results.

When pollution is local, and in the absence of international cooperation on environmental matters, governments have incentives to impose stricter regulations the more trade is open. Indeed, because the welfare cost of pollution-control in terms of consumption opportunities and pollution leakage abroad is not internalized, trade integration prompts the government to regulate more strictly in order to relocate polluting firms abroad (the "not in my backyard" phenomenon). In the case of global pollution, as climate change for example, the effect of trade integration is opposite. Actually, since local and foreign emitted pollution equally deteriorate domestic consumers' welfare, concerns on domestic firms' competitiveness are the top priority of the government, which sets up too flexible environmental regulations. Trade integration magnifies such an attitude (the "race to the bottom" phenomenon). Hence, trade integration can at the same time encourage stricter regulation on local pollution and looser regulation on global pollution.

As a consequence, the environmental implications of trade integration in this model depend on the scale at which the damage takes place: improvement when pollution is local, deterioration when it is global. This is consistent with the trends observed and discussed above.

Regarding the welfare implications of the model, the analysis first highlights the fact that the welfare loss caused by the absence of international cooperation on environmental regulation is more pronounced when pollution is global than when it is local. Next, whereas the welfare impact of trade integration is positive under cooperation, the outcome is more ambiguous when governments act unilaterally, for all pollution types. As a consequence, the model shows that the welfare cost of the absence of cooperation is larger the more trade is facilitated because it aggravates the incentives for governments to use environmental regulations strategically. The core conclusion of the paper is that trade integration may necessitate, to be welfare improving and therefore politically acceptable, international cooperation on environmental issues.

From a theoretical point of view, interdependencies between the environment and the economic activity have been studied in different frameworks. Initiated by Markusen (1975a, 1975b) with perfectly competitive markets, the literature has recently turned to increasing returns to scale in production, mainly with oligopoly models. In this framework, environmental policies can constitute a strategic instrument to attract mobile capital (Hoel, 1997) or to shift rents toward domestic firms when the factors of production are immobile (Barrett, 1994). Besides, several papers consider new

trade theory models, derived from the seminal works of Dixit and Stiglitz (1977) and Krugman (1979, 1980). The latter introduced monopolistic competition in the international trade theory, so as to meet observations about the growing importance of intra-industry trade. Researchers have widened this theoretical framework to include environmental matters (see in particular Hung and Phan, 1998; Gürtzgen and Rauscher, 2000; Pflüger, 2001; Haupt, 2006).
The present paper fits into the scheme of this last part of the literature. It introduces pollution and environmental policies into a basic framework of the new trade theory (see Helpman and Krugman, 1985) with two countries and an endogenous location of economic activity. Polluting emissions are released during the production of varieties of a differentiated good; they negatively contribute to consumers' utility. The government intervention to internalize this social cost into firms' choices takes the form of a process standard imposed to polluters, as in Haupt (2006). The reason for this choice of command-and-control policy is twofold: first, standards are traditional instruments of environmental policies and are still widely used; next, they are simpler to model than taxes since they generate no revenues and distributional issues. The strategic game between countries as far as standards are concerned is explicitly analyzed and compared to the political scenario in which governments coordinate on environmental matters. Except Gürtzgen and Rauscher (2000), papers mentioned above developing monopolistic competition models only consider local pollution issues; keeping in mind the climate warming phenomenon the model here includes a parameter which allows considering pollution from a local to a global scale. Also, rather than just comparing autarky and free trade, the introduction of trade costs enhances the analysis of the environmental and economic impacts of trade integration, which takes the form here of a bilateral reduction in transport costs. Finally, this paper complements Burguet and Sempere (2003) and Baksi and Chaudhuri (2008), whose questionings are similar to that developed here but in a different framework: ours is one of intra-industry trade with monopolistic competition rather than Brander-Spencer reciprocal dumping model of trade, it endogenizes the location decision of polluting firms, explicitly develops the cooperative solution, and considers different policy variables (an environmental standard instead of a tax, and a bilateral reduction in transport costs rather than a bilateral reduction in a tariff).

The rest of the work is organized as follows. Section 2 further develops the model: consumption, production and the environmental policy. Section 3 solves the market equilibrium. Section 4 first explores the choice of the environmental policy under two political approaches, cooperation and unilateralism, next compares the two equilibria and discusses the effects of trade integration according to the type of pollution. Section 5 concludes.

2 The model

There are two countries, Home and Foreign, which are identical in size, tastes and technologies. The analysis focuses on Home; Foreign results are perfectly symmetric and marked by an asterisk.

2.1 Consumption

The Home representative consumer has a utility function, U, additively separable in consumption of goods, C, and environmental damage, E:

$$U = \ln C - \frac{E^2}{2} \tag{1}$$

The damage function has traditional properties: it is increasing and convex in E, which is a combination of domestic (e) and Foreign (e^*) emitted pollution:

$$E = (1-\alpha)\, e + \alpha e^* \qquad 0 \leq \alpha \leq 0,5 \tag{2}$$

This specification allows to cover a whole set of environmental issues: from perfectly local pollutions ($\alpha = 0$) to global ones ($\alpha = 0,5$), going through transboundary environmental phenomena ($0 < \alpha < 0,5$). Home's consumption index is defined over the consumption of a homogeneous good, H, and the consumption of a basket of all existing varieties of a differentiated product, D:

$$C = H^{1-\mu} D^{\mu} \qquad 0 < \mu < 1 \tag{3}$$

As he supplies one unit of labor and only receives labor income, the Home representative consumer faces the following budget constraint:

$$w = H + PD \tag{4}$$

w is the wage rate in the Home country and P the price index of the basket of varieties of the differentiated good. The homogeneous good is assumed to be freely traded, which ensures it has a unique world price, set to one: this good is the numeraire. Individual demands are derived from the maximization of the consumption index under this constraint:

$$H = (1-\mu)\, w \qquad \text{and} \qquad D = \frac{\mu w}{P} \tag{5}$$

The budget shares spent on the homogeneous and the differentiated goods are constant, due to a unitary elasticity of substitution between the two types of product. The second stage of demands' determination consists in allocating the expenditure on the differentiated good between every available variety worldwide, according to consumers' preferences of the love-of-variety type. The differentiated good consumption index is therefore defined as:

$$D = \left[n d_h^{\frac{\sigma-1}{\sigma}} + n^* d_f^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}} \tag{6}$$

n is the number of varieties produced by Home and d_h the consumption of each of them, n^* is the number of varieties imported from Foreign and d_f the consumption of each of them. The elasticity of substitution between any two varieties, σ, is constant and strictly superior to 1: in other words, every pair of varieties is equally well substitutable for each other. The corresponding price index for the differentiated good consumed in the Home country is:

$$P = \left[np^{1-\sigma} + n^* \left(\tau p^*\right)^{1-\sigma}\right]^{\frac{1}{1-\sigma}} \tag{7}$$

p is the production price of Home varieties, p^* the production price of Foreign varieties, and τ bilateral symmetric transport costs. Foreign varieties can be consumed at Home, but their trade occurs at a cost assumed to be of the iceberg type: for one unit of product shipped, only the fraction $1/\tau$ arrives, with $\tau > 1$; the rest is lost in transit. These iceberg trade costs raise the consumer price of imported varieties, whereas domestic varieties are available at production prices. This difference in consumption prices results in a difference in the demands for each sort of variety. Home per capita demands for the two kinds of varieties are:

$$d_h = \mu w p^{-\sigma} P^{\sigma-1} \qquad \text{and} \qquad d_f = \mu w \left(\tau p^*\right)^{-\sigma} P^{\sigma-1} \tag{8}$$

2.2 Production

Two industries in each economy relate to either type of consumption goods: the first one produces the homogeneous product and the second one deals with varieties of the differentiated good. Labor is the sole factor of production, perfectly mobile within but not between countries.

Production of the homogeneous good is characterized by perfect competition, which ensures its price equals the marginal cost of production. It is produced with only one unit of labor in each country after perfectly free trade: since this good is the numeraire, the wage rate is equal to one in both sectors and countries.

All varieties of the differentiated good are produced with the same cost function. Scale economies occur at the firm level, which means that as the output expands the average cost of production declines. A fixed set-up cost (f) and a constant marginal cost of production (m), both expressed in labor terms, reflect it. The total cost associated to the production of q units, whatever the Home variety considered, can be written as:

$$l = f + mq \tag{9}$$

l is the amount of labor needed to produce q units of the variety; returns to scale intensity is f/m. Thanks to symmetric production costs and processes, all varieties are produced in the same quantity and at the same price within a country. The Home representative firm's profits are:

$$\pi = (p - m)\, q - f \tag{10}$$

The two usual equilibrium conditions for production price and output in the context of monopolistic competition naturally apply here. On the one hand, marginal revenue must be equal to marginal cost, which leads to:

$$p = \frac{\sigma}{\sigma - 1} m \tag{11}$$

On the other hand, free entry on the market generates zero profits for all existing firms, which results in:

$$q = (\sigma - 1)\, \frac{f}{m} \tag{12}$$

Using these equilibrium values, the price index and individual demands can be rewritten as:

$$P = \frac{\sigma}{\sigma - 1} \left[n m^{1-\sigma} + \phi n^* m^{*1-\sigma} \right]^{\frac{1}{1-\sigma}} \tag{13}$$

and

$$\begin{aligned} d_h &= \mu \frac{\sigma - 1}{\sigma} \frac{m^{-\sigma}}{n m^{1-\sigma} + \phi n^* m^{*1-\sigma}} \\ d_f &= \mu \frac{\sigma - 1}{\sigma} \frac{\tau^{-\sigma} m^{*-\sigma}}{n m^{1-\sigma} + \phi n^* m^{*1-\sigma}} \end{aligned} \tag{14}$$

Where ϕ represents the freeness of trade, the degree of trade integration between countries, defined as $\phi = \tau^{1-\sigma}$. Since both transport costs and the elasticity of substitution between every pair of varieties exceed one, ϕ is in a value range of 0 to 1: for $\phi = 0$ each country lives in autarky, whereas for $\phi = 1$ trade is perfectly free between them.

2.3 Pollution and environmental policy

Consumers are adversely affected by an environmental damage arising from polluting emissions, which are by-products of the production of varieties: firms' activity generates a social cost that the environmental policy aims at internalizing into producers' choices. Actually, national governments can impose a standard on production processes in order to achieve a greater environmental quality. Both the level of the strictness of policy and the control of standard compliance are assumed to be costless activities the government undertakes. The standard specifies the way varieties have to be produced with regard to their impact on the environment. Several techniques allow to control and reduce emissions, but they are more expensive to implement than more polluting ones: complying with standards is costly. All firms use the same techniques to cut emissions and thus face up to identical pollution abatement costs.

The emission rate defines the amount of pollutants released per unit of output. Total pollution produced by a country is therefore a function of three variables: the output level (q) and the emission rate (noted τ_e), which together define the environmental damage at the level of the firm, and the number of firms (n):

$$e = q\tau_e n \qquad \text{and} \qquad e^* = q^*\tau_e^* n^* \tag{15}$$

The environmental policy sets a standard which defines the maximum emission rate. The relation between this rate and production costs is the abatement function, which is assumed to be identical for all firms throughout the world: the higher pollution-control efforts, the higher the amount of labor devoted to environment-friendly activities, and the lower the polluting emission rate. Regulations can affect alternately the fixed or the marginal cost of production. Thus, each type of cost can be split up into two parts: the first one is the minimum amount of labor needed to produce; the second part represents the additional amount of labor to employ in order to cope with the environmental standard imposed by national governments. The countries have access to the same technologies, and therefore face identical minimum costs of production.

The first way to cut the amount of pollutants released during the production of varieties is to impose a standard which forces the firms to enhance their environmental performance by increasing expenses to set-up and design a cleaner production process: this raises the fixed cost from the minimum needed to enter the market and start production. In that case the abatement function is:

$$\tau_e = 1/f \tag{16}$$

The more environment-friendly the country, the lower the emission rate, the higher the fixed cost. The environmental policy part of the marginal cost of production is equal to zero in both countries. As a consequence, in that scenario, the production price of every single variety is the same wherever the manufacturing location. Moreover this price is constant and independent of the standard as it affects the fixed cost only. On the contrary, outputs can differ between countries due to possible dissimilar regulations. A stricter environmental policy not only strengthens the monopolistic structure of the market but also boosts domestic firms' size: with a constant price, firms have to produce more in order to be able to cope with the higher fixed cost.

The other possibility to lessen polluting emissions released during production is to force the firms to allocate more labor to the manufacturing process. The production process itself is unchanged, but a proportion of the labor force is diverted from production to abatement activities. The emission rate is now related to the marginal cost of production; the abatement function is:

$$\tau_e = 1/m \tag{17}$$

Contrary to the previous scenario, the environmental policy has now an influence on both the production price and the representative firm's size. Tightening up the national environmental regulation penalizes firms on two sides: first, their products are less competitive since there are more expensive. Second, firms experience lower returns to scale, their size and operating profits diminish.

As following results are qualitatively similar for both scenarios, the analysis is developed for the fixed cost case, which is more representative of a regulatory policy, and the results of the marginal cost case are only presented in the appendix. The only difference between the two scenarios is that the parameter σ can influence the magnitude of the phenomena in the marginal cost case.

3 The market equilibrium

3.1 The equilibrium number of firms

The equilibrium number of firms is the one that solves the differentiated good market clearing condition: for each variety, output must be equal to the sum of all individual consumptions, taking into account iceberg transport costs which represent an indirect demand. For Home varieties, the market equilibrium is reached when $q = Ld_h + L^*\tau d_h^*$, with L and L^* the respective sizes of Home and Foreign. The symmetric for Foreign varieties is $q^* = L\tau d_f + L^* d_f^*$. Equilibrium values of outputs given by the free entry condition (12), of per capita demands (14), and the assumption of identical country size ($L = L^*$) are used to get a two-equation system of two unknowns, n and n^*:

$$\begin{cases} \frac{\sigma}{\mu L} = \left(\frac{1}{nm^{1-\sigma}+\phi n^* m^{*1-\sigma}} + \frac{\phi}{\phi n m^{1-\sigma}+n^* m^{*1-\sigma}}\right)\frac{v^{1-\sigma}}{f} \\ \frac{\sigma}{\mu L} = \left(\frac{\phi}{nm^{1-\sigma}+\phi n^* m^{*1-\sigma}} + \frac{1}{\phi n m^{1-\sigma}+n^* m^{*1-\sigma}}\right)\frac{m^{*1-\sigma}}{f^*} \end{cases} \tag{18}$$

When the environmental policy applies to the fixed cost of production, the system resolution generates the following equilibrium numbers of Home and Foreign firms[4]:

$$n = \frac{\mu L}{\sigma}\frac{\left(1+\phi^2\right)f^* - 2\phi f}{\left(f-\phi f^*\right)\left(f^*-\phi f\right)} \quad \text{and} \quad n^* = \frac{\mu L}{\sigma}\frac{\left(1+\phi^2\right)f - 2\phi f^*}{\left(f-\phi f^*\right)\left(f^*-\phi f\right)} \tag{19}$$

The world number of firms (n^w) is therefore:

$$n^w = n + n^* = \frac{\mu L}{\sigma}\frac{\left(1-\phi\right)^2\left(f+f^*\right)}{\left(f-\phi f^*\right)\left(f^*-\phi f\right)} \tag{20}$$

[4]In the general case, both the fixed and the marginal costs of production can differ between countries, and the equilibrium numbers of Home and Foreign are :

$$n = \frac{\mu L m^{\sigma-1}}{\sigma}\frac{\left(1+\phi^2\right)m^{*\sigma-1}f^* - 2\phi m^{\sigma-1}f}{\left(m^{\sigma-1}f-\phi m^{*\sigma-1}f^*\right)\left(m^{*\sigma-1}f^*-\phi m^{\sigma-1}f\right)}$$

$$n^* = \frac{\mu L m^{*\sigma-1}}{\sigma}\frac{\left(1+\phi^2\right)m^{\sigma-1}f - 2\phi m^{*\sigma-1}f^*}{\left(m^{\sigma-1}f-\phi m^{*\sigma-1}f^*\right)\left(m^{*\sigma-1}f^*-\phi m^{\sigma-1}f\right)}$$

The first comment on these results is that when the analysis is limited to non zero solutions, having both n and n^* non negative imposes the following condition on the relative level of production costs:

$$\frac{2\phi}{1+\phi^2} \leq F \leq \frac{1+\phi^2}{2\phi} \qquad \text{with } F = f/f^* \tag{21}$$

For both countries to have an industrial productive sector, national environmental policies cannot be too different from each other. If a large difference exists, all firms disappear in the strictest country and relocate in the laxest one.

Second, intensifying national pollution-control has important consequences in terms of economic activity: slowdown at home and growth abroad. Let's consider for instance that the Home country raises the strictness of its standard whereas Foreign keeps its own regulation unchanged. From a firm point of view, a tougher environmental policy means additional fixed costs; a competitiveness effect occurs which creates incentives for domestic firms to relocate abroad. As a consequence, the number of firms decreases in the Home country, and increases in the Foreign one. Given that prices are constant in the case of a regulation that only affects fixed costs of production, remaining domestic firms have to produce more in order to cope with higher fixed costs. Eventually, there are fewer domestic firms facing a stricter environmental regulation but they are larger in order to be able to pay the extra fixed cost; the number of foreign firms, of unchanged size, increases.

As the less stringent country in terms of pollution-control efforts experiences firms creations through relocations, it becomes more specialized in the differentiated good production. As often in this literature, to ensure a unitary and uniform wage rate across countries, no full specialization is assumed so that the homogeneous good sector exists in both countries. Using the full employment condition, which divides the workers among the two sectors of the economy, this assumption is reflected in the following inequality for Home:

$$\frac{\mu f\left[\left(1+\phi^2\right)f^* - 2\phi f\right]}{\left(f-\phi f^*\right)\left(f^*-\phi f\right)} < 1 \tag{22}$$

The share of the labor force working in the differentiated good industry must be strictly inferior to one.

Trade integration in the model takes the form of a bilateral reduction in transport costs, reflected in a rise in ϕ. As trade is facilitated, firms become more footloose because they easily relocate in one country and reexport to the former. As a consequence, for given levels of environmental policies f and f^*, the outcome of an increase in ϕ on the number of firms in each country depends on the comparison of national environmental policies: the economic activity expands in the laxest country and declines in the other. At the end, firms' creations exceed firms' destructions and the world number of firms increases.

3.2 The environmental damage

Now that the description of the market equilibrium is complete, this section discusses the environmental consequences of production. For each polluting emission released in a country, a part $1-\alpha$ remains within the borders and affects domestic consumers, whereas the rest crosses the frontier and damages the environment abroad. The level of pollution produced by a country depends on three variables: the output of the representative firm, the emission rate and the number of firms. To cover an increase in the fixed cost of production, competition needs to fall and the size of surviving domestic firms needs to increase. This size effect automatically generates additional emissions that offset exactly the reduction of pollution due to the reduction in the emission rate. Eventually, the effects of pollution-control regulations on the size of the representative firm and on its emission rate cancel each other, and emissions per firm are simply $\sigma-1$. The Home environmental damage can thus be written as:

$$E=\frac{(\sigma-1)}{m}\left[(1-\alpha)\,n+\alpha n^{*}\right] \tag{23}$$

It happens that the environmental outcome of increased unilateral national efforts to control pollution is ambiguous.
When the government faces a purely local pollution ($\alpha=0$) the environmental damage the country suffers from only depends on the domestic number of polluting firms. As the implementation of a more stringent environmental policy has a depressing effect on this number, it always succeeds in improving the local environmental quality.
When the externality is global ($\alpha=0,5$) the foreign number of firms is as important as the domestic one to determine the level of pollution national consumers suffer from. A more environment-friendly national regulation therefore has two opposite effects on the environmental quality. On the one hand it lowers the number of domestic firms and, as a result, domestically emitted pollution. But on the other hand it increases, through relocations, the number of foreign firms and, consequently, foreign emissions: this is commonly called the leakage effect. The overall impact of a modification of a national environmental policy is a priori ambiguous. A more advanced analysis shows that the derivative of the Home environmental damage with respect to the Home environmental policy can be either positive or negative; the sign is determined by a critical value for the relative level of environmental standards:

$$\begin{cases} \frac{\delta E}{\delta f}\leq 0 & \text{if } \; F\leq\frac{(1+\phi)\sqrt{\phi}-\phi}{\phi} \\ \frac{\delta E}{\delta f}>0 & \text{otherwise} \end{cases} \tag{24}$$

The equivalent for Foreign is:

$$\begin{cases} \frac{\delta E^{*}}{\delta f^{*}}\leq 0 & \text{if } \; F\geq\frac{(1+\phi)\sqrt{\phi}+\phi}{1+\phi+\phi^{2}} \\ \frac{\delta E^{*}}{\delta f^{*}}>0 & \text{otherwise} \end{cases} \tag{25}$$

According to these results, if national policies are too different from each other, the pro-environmental impact of the reduction in the number of domestic firms can be offset by the worsening of foreign pollution induced by relocations. Furthermore, trade integration (a rise in ϕ) amplifies the leakages, and thus reduces the probability that a national regulation actually improves the domestic environmental quality.
For intermediate cases of pollution dispersion ($0 < \alpha < 0,5$), the environmental outcome of an increase in the stringency of a national regulation is even more complicated. It is going to depend on both the scale of the damage (α) and the relative level of environmental standards (F).

Even if the result is not guaranteed, the objective of the implementation of pollution-control measures is to prevent environmental deteriorations. Nevertheless, it also reduces private consumption: the domestic price index rises due to the reduction in the number of domestic varieties and the increase in the number of varieties to be imported, subject to transportation costs. The Home representative consumer utility can be expressed as a function of environmental policies, where the first expression in brackets is consumption and the second one is the environmental damage:

$$\begin{aligned} U &= \ln\left[\kappa\left(\frac{\mu L\left(1-\phi^2\right)}{\sigma m^{\sigma-1}\left(f-\phi f^*\right)}\right)^{\frac{\mu}{\sigma-1}}\right] \\ &- \frac{1}{2}\left[\frac{\mu L\left(\sigma-1\right)}{\sigma m}\frac{\left(1-\alpha\right)\left[\left(1+\phi^2\right)f^*-2\phi f\right]+\alpha\left[\left(1+\phi^2\right)f-2\phi f^*\right]}{\left(f-\phi f^*\right)\left(f^*-\phi f\right)}\right]^2 \end{aligned} \tag{26}$$

with $\kappa = \left(1-\mu\right)^{1-\mu}\mu^{\mu}\left(\frac{\sigma-1}{\sigma}\right)^{\mu} > 0$ a positive constant. The symmetric applies to the Foreign country. When setting environmental standards, governments face a trade-off between pollution control and consumption opportunities.

4 The environmental policy

This section addresses the issue of the endogenous choice of environmental standards. This government decision is based on maximizing the representative consumers' welfare given by (26) for Home and its symmetric for Foreign, since all consumers are identical within each country. In doing so, governments take into account the reactions of economic activity to environmental regulations, insofar as these expressions incorporate market equilibrium results.
Two policy options are considered. The two countries cooperation in the fight against pollution is examined first. However, this is not the attitude that prevails today, particularly as far as global warming is concerned. Therefore, the second part of this section deals with the simultaneous and non-cooperative choice of a pollution-control policy by each government: the Nash equilibrium in environmental standards. The two equilibria are then compared.

4.1 The cooperative equilibrium

In the first policy scenario, the two governments give up autonomy on the environmental policy and agree to rely on a supranational authority specially designed to deal with pollution issues. This organization sets the cooperative environmental standard, f_{coop}, common to both countries since they are perfectly identical, in such a way as to maximize the world representative consumer's utility. The optimal policy, obtained from the first order condition[5], is:

$$f_{coop} = \frac{L\mu^{1/2}(\sigma-1)^{3/2}}{\sigma m} \tag{27}$$

To this standard corresponds the following level of welfare:

$$U_{coop} = \ln\left[\kappa\left(\frac{\mu^{1/2}(1+\phi)}{m^{\sigma-2}(\sigma-1)^{3/2}}\right)^{\frac{\mu}{\sigma-1}}\right] - \frac{\mu}{2(\sigma-1)} \tag{28}$$

When governments cooperate, the optimal standard neither depends on the intensity of trade linkages between the countries (ϕ) nor on the scale of the environmental damage (α): from an aggregate point of view, since countries are perfectly identical, it does not matter whether pollution crosses borders or not. This ensures an invariable world number of firms whatever the value of α or ϕ: indeed $n^w_{coop} = \mu L/\sigma f_{coop}$, with f_{coop} constant with respect to these variables.

A modification of the parameter α, representing the share of a country's emissions that affect consumers abroad, has absolutely no impact on the cooperative welfare since it does not affect the standard in this policy scenario.

The fact that n^w_{coop} is constant with respect to ϕ has two implications for the welfare consequences of trade integration. First, the environmental quality is unchanged as trade is facilitated, in each country and at the aggregate level. Next, the range of varieties to be consumed does not expand with trade integration. Nevertheless, consumers benefit from freer trade since imported varieties are cheaper: the consumption index then unambiguously rises. In sum, when a supranational authority is in charge of the international environmental policy, strengthening trade relations between countries undoubtedly benefits consumers.

4.2 The Nash equilibrium

When the two countries retain authority over environmental matters instead of cooperating, governments simultaneously choose their standard as the one which maximizes their own representative consumer's utility, considering the environmental policy

[5]The first order condition here is: $\frac{\delta U}{\delta f}\mid_{f=f^*} = 0$.

abroad as given. This is the Nash equilibrium. Due to symmetric behaviors, the environmental standard ends up being the same in both countries despite the lack of coordination. Labeled f_{nash} it is equal to[6]:

$$f_{nash} = \frac{L\mu^{1/2}(\sigma-1)^{3/2}\left[1+\phi^2-\alpha(1+\phi)^2\right]^{1/2}}{\sigma m(1-\phi)^{1/2}} \tag{29}$$

The corresponding level of utility is:

$$\begin{aligned} U_{nash} &= \ln\left[\kappa\left(\frac{\mu^{1/2}(1+\phi)(1-\phi)^{1/2}}{m^{\sigma-2}(\sigma-1)^{3/2}\left[1+\phi^2-\alpha(1+\phi)^2\right]^{1/2}}\right)^{\frac{\mu}{\sigma-1}}\right] \\ &- \frac{\mu(1-\phi)}{2(\sigma-1)\left[1+\phi^2-\alpha(1+\phi)^2\right]} \end{aligned} \tag{30}$$

Equilibrium values for the standard and welfare now depend on α, the pollution dispersal parameter, and on ϕ, the trade integration variable.

An increase in α indicates that a country exports a greater share of its own emissions, but that, in return, it receives a larger part of pollution produced abroad. The pollution externality becomes more global. As a consequence, since countries do not cooperate, the welfare cost of locally produced emissions is less internalized by each government, whose consistent attitude then is to relax the strictness of their environmental policy. Thus, f_{nash} is a decreasing function of α.
This fall in the strictness of the environmental regulation when the emissions dispersal becomes more pronounced obviously causes additional pollution. Indeed, a lower fixed cost of production makes market entry easier: the world number of polluting firms increases[7]. This expansion in the range of varieties is detrimental to the environment, but it has a positive impact on consumption since consumers are better off with a larger choice of goods. The overall effect on welfare of an increase in α is therefore ambiguous: consumption gains on the one hand, more damaged environment on the other hand. The final outcome depends on a critical value of the pollution dispersal parameter:

$$\begin{cases} \frac{\delta U_{nash}}{\delta\alpha} \geq 0 & \text{if } 0 \leq \alpha \leq \overline{\alpha} \text{ with } \overline{\alpha} = \frac{\phi}{1+\phi} \\ \frac{\delta U_{nash}}{\delta\alpha} < 0 & \text{otherwise} \end{cases} \tag{31}$$

Up to $\overline{\alpha}$, consumption gains more than compensate additional environmental deterioration, and welfare rises with α. The threshold is an increasing function of the freeness of trade: the more integrated the countries, the greater the consumption effect since imported varieties are cheaper; the probability to have welfare gains is thus higher.

[6]It solves the first-order conditions $\frac{\delta U}{\delta f}|_{f^*} = 0$ and $\frac{\delta U^*}{\delta f^*}|_{f} = 0$.

[7]Indeed, the world number of firms, $n^w_{nash} = \mu L/\sigma f_{nash}$, is a decreasing function of the strictness of the environmental policy, which decreases with α.

Turning to the influence of trade integration on the non-cooperative standard, we find that:

$$\begin{cases} \frac{\delta f_{nash}}{\delta \phi} \leq 0 & \text{if} \quad 0 \leq \phi \leq \overline{\phi} \quad \text{with} \quad \overline{\phi} = 1 - \frac{\sqrt{2(1-\alpha)(1-2\alpha)}}{1-\alpha} \\ \frac{\delta f_{nash}}{\delta \phi} > 0 & \text{otherwise} \end{cases} \tag{32}$$

As explained above, lower transport costs encourage polluting industries to relocate to the country with the least severe environmental policy. Since there is no specific policy instrument to address this issue, governments are inclined to strategically use the environmental regulation in order to protect the domestic industry. This attitude is reflected in downward pressure on the standard as trade is facilitated. A decrease in the strictness of the environmental policy aggravates pollution by increasing the world number of polluting firms since market entry is easier. This expansion in the range of varieties benefits consumers, as well as the access to cheaper foreign varieties. Eventually, a decrease in transport costs has a direct positive effect on consumption by making imports less expensive, but it generates competitive concerns that can induce a relaxation of pollution-control efforts, creating additional consumption opportunities but also aggravating damage to the environment. The comparison of these two opposite effects determines the direction of the evolution of the non-cooperative environmental standard in trade integration. Up to $\overline{\phi}$, the strategic use of the environmental policy predominates; beyond this threshold value, it gets weaker and environmental regulation becomes positively associated with ϕ.

The threshold $\overline{\phi}$ is an increasing function of α: the greater the pollution dispersal, the more likely it is that trade integration results in a less stringent environmental policy. Indeed, as α increases, the externality becomes more global, which means that the government control over the domestic environmental quality weakens. It encourages free-rider behavior about environmental issues, which results in a more strategic use of the pollution-control regulation. At extreme cases:

$$\begin{cases} \frac{\delta f_{nash}}{\delta \phi} > 0 & \text{if} \quad \alpha = 0 \\ \frac{\delta f_{nash}}{\delta \phi} < 0 & \text{if} \quad \alpha = 0,5 \end{cases} \tag{33}$$

When pollution is purely local ($\alpha = 0$), all emissions produced by a country exclusively affect domestic consumers. As a consequence, changes in the quality of the local environment perfectly match that of the number of domestic firms. Since the government control over pollution affecting domestic consumers is maximum, the strategic dimension of its intervention disappears in favor of environmental concerns. Trade integration therefore generates a rise in the strictness of the environmental standard. This policy succeeds in mitigating the local environmental damage, but it also reduces the world number of varieties. Thus, facilitating trade between non-cooperative countries facing local pollution has, on the one hand, positive effects on the environmental quality and on consumption through cheaper imports, but, on the other hand, it negatively impacts the number of varieties to be consumed. Finally, the net effect of a bilateral reduction in transport costs is positive for low values of trade integration.

When the freeness of trade exceeds the rough critical value of 0,448 this is no more the case and trade integration becomes welfare depressing.
When the externality is global ($\alpha = 0,5$), domestic and foreign emissions equally damage a country's environment. The government control over pollution affecting domestic consumers is low, and the internalization of the environment cost of emissions released by the country is minimum. Concerns on domestic firms' competitiveness play a predominant role in the standard setting. As trade is facilitated, non-cooperative governments behave like free-riders on environmental matters, and continuously relax their environmental regulation. It makes market entry to polluting firms easier, which is obviously detrimental to the environment, but also good for consumption. Eventually, the net effect of trade integration on welfare is positive when openness is limited (ϕ below 0.172, approximately), and negative otherwise.
To conclude on this question, reducing bilateral trade costs between non-cooperative countries facing purely local or global pollution improves welfare only for low levels of openness. Gaining advantage of freer trade is more rare when pollution is global than when it is local.

4.3 The comparison of equilibria

This section compares cooperative and non-cooperative standards, environmental damages and utilities, when pollution is either perfectly local, or perfectly global. The geographical scale of the externality generates very different results.

As far as standards are concerned, the Nash environmental policy is always suboptimal. It is too strict when pollution is local, whereas it is too lax when countries face global pollution:

$$\begin{cases} f_{coop} \leq f_{nash} & \text{if} \quad \alpha = 0 \\ f_{coop} > f_{nash} & \text{if} \quad \alpha = 0,5 \end{cases} \tag{34}$$

The first result refers to the "not in my backyard" phenomenon. As discussed above, when pollution is perfectly local, the government's ability to control pollution harmful for domestic consumers' utility is maximum. By giving priority to strict regulation of polluting firms, a non-cooperative government does not take into account the negative spillovers it generates on foreign consumers, both by worsening pollution abroad and reducing consumption opportunities. As a consequence, it over internalizes the cost of the production externality, and sets up a too stringent environmental standard. At the opposite, when pollution is perfectly global, non-cooperative governments adopt a free-rider behavior since their control over the domestic environment quality is weak. They give priority to the protection of the domestic industry from international competition. Indeed, cooperation ensures that production costs are identical for all firms worldwide, whereas concerns about competitiveness losses arise when countries act unilaterally. Sub optimality arises here because non-cooperative governments do not take into account the negative impact of a relaxation of their environmental policy

on global environment. They under internalize the cost of the externality generated by their polluting industry, and implement an insufficiently strict environmental standard.
A decrease in trade costs worsens the sub optimality of non-cooperative environmental policies. With cooperation on environmental issues, the common standard is unchanged when trade is facilitated. With unilateralism, making trade freer encourages the relocation of polluting firms, and therefore exacerbates the concerns responsible for the sub optimality of environmental policies. Indeed, when pollution is perfectly local, any increase in the number of domestic firms mean additional emissions. That is why non-cooperative governments increase the stringency of their policy in order to preserve their environment, at the expense of economic activity. The "not in my backyard" effect is reinforced when trade becomes freer. At the opposite, when pollution is global, non-cooperative governments further relax the environmental regulation when trade costs decline, in order to avoid the flight of firms abroad. They go into a race to lower standards.

As far as the local externality is concerned, the model shows that the environmental damage a country suffers from is larger when there is international cooperation than when there is not, due to the "not in my backyard" phenomenon. Trade integration amplifies this gap: indeed, local pollution is unchanged when trade costs decline and cooperation exists, whereas it is reduced by more stringent environmental policies when non-cooperative countries reduce bilateral transport costs. At the opposite, when pollution is global, international coordination of pollution-control efforts permits to achieve a greater environmental quality than with unilateralism. Here also the gap increases with integration: the expansion of the freeness of trade aggravates global pollution under Nash due to the "race to the bottom" phenomenon, whereas it maintains the cooperative one. The model then predicts that trade integration can at the same time generates lower local pollution and higher global pollution when countries do not coordinate environmental efforts. From an environmental point of view, there are strong incentives to cooperate when pollution is global.

Concerning welfare, consumers are better off when international cooperation prevails, whatever the scale on which pollution takes place. This result is quite obvious when pollution is global since global issues naturally call for supranational answers. It also applies to local-type environmental externalities because non-cooperation generates a shortfall in the world number of varieties. The gap between cooperative and Nash utilities is larger when pollution is global than when it is local, and it increases with trade openness: indeed, cooperative welfare always improves with freer trade, whereas the non-cooperative one deteriorates as soon as the freeness of trade reaches intermediate values. According to the model, trade integration may necessitate, to be welfare improving, international cooperation on environmental issues.

5 Conclusion

This paper has explored interactions between trade and environment, in a framework of monopolistic competition with endogenous firm location, a negative production externality whose dispersal varies, and intra-industry trade between two countries.

First of all, the analysis highlights that a national environmental policy, which takes the form of a process standard, affects not only the domestic economy and environment, but also exerts spillovers abroad. On the one hand, making the standard stricter in a country has adverse effects on domestic economic activity through the destruction of some polluting firms, which reduces national polluting emissions. On the other hand, such a regulation favors the relocation of firms, and, as a consequence, expands economic activity and pollution abroad. This leakage effect can undermine the effectiveness of a national environmental policy.
Next, a non-cooperative environmental regulation proves to be always suboptimal when no other policy instrument is available. Indeed, environmental concerns, exacerbated by the lack of international cooperation, result in a too strict standard when pollution is local. At the opposite, when pollution is global, competitiveness concerns prompt non-cooperative governments to strategically use the environmental policy by applying a too lax standard. Furthermore, the model shows that trade integration magnifies the sub optimality of environmental standards. As a consequence, when there is no cooperation on environmental matters, a decrease in bilateral transport costs can at the same time reduce local pollution, and increase global pollution, results which are consistent with the stylized fact presented in the introduction of the paper.
Finally, the model shows that a decrease in bilateral transport costs is always welfare improving when a supranational authority is in charge of pollution-control efforts, whereas the outcome is more ambiguous when cooperation is absent.

To conclude, the main results of the paper are as follows. First, from an environmental point of view, the coordination of trade and environmental policies should all the more be a priority that pollution is global. Next, to be welfare improving and therefore politically acceptable, trade facilitation should not be carried on as long as the harmonization of international environmental efforts is not real.

6 Appendixes - Results for the marginal cost scenario

6.1 The market equilibrium

When the environmental policy goes through an action on the marginal cost of production, the fixed cost is minimum and identical throughout the world, whereas the marginal cost can differ between countries. In this case the equilibrium numbers of firms in each country are:

$$n = \frac{\mu L m^{\sigma-1}}{\sigma f} \frac{\left(1+\phi^2\right) m^{*\sigma-1} - 2\phi m^{\sigma-1}}{(m^{\sigma-1} - \phi m^{*\sigma-1})(m^{*\sigma-1} - \phi m^{\sigma-1})}$$
$$n^* = \frac{\mu L m^{*\sigma-1}}{\sigma f} \frac{\left(1+\phi^2\right) m^{\sigma-1} - 2\phi m^{*\sigma-1}}{(m^{\sigma-1} - \phi m^{*\sigma-1})(m^{*\sigma-1} - \phi m^{\sigma-1})}$$

These numbers are decreasing functions of the strictness of the domestic environmental policy, and increasing functions of environmental efforts abroad. The Home environmental damage can be written as:

$$E = (\sigma - 1) f \left[(1 - \alpha) \frac{n}{m^2} + \alpha \frac{n^*}{m^{*2}} \right]$$

As opposed to the fixed cost case, the action of a stricter national policy on E occurs via four channels: on the one hand a decrease in the domestic number of polluting firms, in their output and emission rate; on the other hand an increase in the number of polluting firms abroad. The overall effect of a rise in the strictness of a national pollution-control regulation turns out to be ambiguous: it improves the domestic environmental quality but deteriorates the neighbor's one. The Home representative consumer's welfare can be expressed as a function of national environmental policies:

$$\begin{aligned} U &= \ln \left[\kappa \left(\frac{\mu L (1 - \phi^2)}{\sigma f (m^{\sigma-1} - \phi m^{*\sigma-1})} \right)^{\frac{\mu}{\sigma-1}} \right] \\ &- \frac{1}{2} \left[\frac{\mu L (\sigma - 1)}{\sigma} \frac{\left(\begin{array}{c} (1-\alpha) m^{\sigma-3} ((1+\phi^2) m^{*\sigma-1} - 2\phi m^{\sigma-1}) \\ + \alpha m^{*\sigma-3} ((1+\phi^2) m^{\sigma-1} - 2\phi m^{*\sigma-1}) \end{array} \right)}{(m^{\sigma-1} - \phi m^{*\sigma-1})(m^{*\sigma-1} - \phi m^{\sigma-1})} \right]^2 \end{aligned}$$

6.2 The environmental policy

6.2.1 The cooperative equilibrium

The coordination of environmental efforts results in a common standard for the two countries, which maximizes the world representative consumer's utility:

$$m_{coop} = \left[\frac{2^{1/2} L \mu^{1/2} (\sigma - 1)}{\sigma} \right]^{1/2}$$

To this standard corresponds the following level of welfare:

$$U_{coop} = \ln \left[\kappa \left(\frac{L\mu (1 + \phi)}{\sigma f} \right)^{\frac{\mu}{\sigma-1}} \left(\frac{\sigma}{2^{1/2} L \mu^{1/2} (\sigma - 1)} \right)^{\frac{\mu}{2}} \right] - \frac{\mu}{4}$$

Cooperative results are independent of α: the localization of pollution does not matter from an aggregate point of view. The standard is also independent of ϕ, and utility increases when trade becomes freer since importing varieties is less expensive.

6.2.2 The Nash equilibrium

The Nash standard is the result of the strategic game on the environmental policy between the two governments:

$$m_{nash} = \left[\frac{2^{1/2} L \mu^{1/2} (\sigma - 1) \left[(1-\alpha)(1-\phi)^2 + \phi (\sigma - 1)(1 - 2\alpha) \right]^{1/2}}{\sigma (1-\phi)^{1/2}} \right]^{1/2}$$

The corresponding level of welfare is:

$$\begin{aligned} U_{nash} &= \ln \left[\kappa \left(\frac{L\mu (1+\phi)}{\sigma f} \right)^{\frac{\mu}{\sigma-1}} \left(\frac{\sigma (1-\phi)^{1/2}}{2^{1/2} L \mu^{1/2} (\sigma-1) \left[(1-\alpha)(1-\phi)^2 + \phi(\sigma-1)(1-2\alpha) \right]^{1/2}} \right)^{\frac{\mu}{2}} \right] \\ &- \frac{\mu (1-\phi)}{4 \left[(1-\alpha)(1-\phi)^2 + \phi (\sigma-1)(1-2\alpha) \right]} \end{aligned}$$

The results are very similar to the fixed cost case. First, the standard is a decreasing function of the pollution dispersal parameter since a loss of control over the domestic environmental quality encourages non-cooperative governments to relax the strictness of the standard:

$$\frac{\delta m_{nash}}{\delta \alpha} < 0$$

Next, this behavior has a positive impact on consumption. But, contrary to the fixed cost case, the world number of varieties is constant, independent of the environmental policy:

$$n^w_{nash} = \mu L / \sigma f$$

Then, the favorable effect on consumption occurs via a reduction in the production price of varieties. This attitude has a major drawback since it further deteriorates the environment: firms' output and emission rate both increase. The comparison between these two opposite effects depends on a threshold value of the dispersal parameter:

$$\begin{cases} \frac{\delta U_{nash}}{\delta \alpha} \geq 0 & \text{if} \quad 0 \leq \alpha \leq \frac{\phi(\sigma+\phi-2)}{(1-\phi)^2 + 2\phi(\sigma-1)} \\ \frac{\delta U_{nash}}{\delta \alpha} < 0 & \text{otherwise} \end{cases}$$

In this present case, the threshold not only depends on ϕ, but also on the value of the elasticity of substitution between every pair of varieties (σ). Thus, a rise in σ makes it more likely that a greater dispersal of pollution results in a higher welfare, because it exacerbates competition and decreases the production price.

Like in the fixed cost case, the response of the non-cooperative standard to freer trade is also subject to a threshold:

$$\begin{cases} \frac{\delta m_{nash}}{\delta \phi} \leq 0 & \text{if} \ \ 0 \leq \phi \leq 1 - \sqrt{\frac{(\sigma-1)(1-2\alpha)}{1-\alpha}} \\ \frac{\delta m_{nash}}{\delta \phi} > 0 & \text{otherwise} \end{cases}$$

The critical value here is a decreasing function of σ: the higher is the elasticity of substitution between every pair of varieties, the higher is the firms' output, and the more important is the amount of pollution released. This phenomenon makes it more likely that environmental concerns dominate strategic considerations, and therefore that the standard increases with trade integration. At the two extreme cases:

$$\begin{cases} \frac{\delta m_{nash}}{\delta \phi} > 0 & \text{if } \alpha = 0 \text{ and } \sigma \geq 2 \\ \frac{\delta m_{nash}}{\delta \phi} < 0 & \text{if } \alpha = 0,5 \end{cases}$$

The only difference with the fixed cost case is that when pollution is local, the standard is a decreasing function of trade integration provided that the elasticity of substitution exceeds 2. Below this value, competition is very weak and prices are high: making trade freer gives incentives to governments to attract firms in order to intensify domestic competition.

As far as welfare is concerned, consumers benefit from trade integration only for small values of openness: up to a certain point, consumption gains more than compensate the environmental deterioration. This critical level of openness depends on the intensity of varieties substitutability: the higher σ, the lower the production price, and the lower the consumption gains from trade integration. Thus, a high elasticity of substitution between varieties makes it more likely that trade integration is welfare depressing.

6.2.3 Comparison of equilibria

In the marginal cost case also the Nash equilibrium is suboptimal:

$$\begin{cases} m_{coop} \leq m_{nash} & \text{if } \alpha = 0 \text{ and } \sigma \geq 2 \\ m_{coop} < m_{nash} & \text{if } \alpha = 0,5 \end{cases}$$

Non-cooperative environmental standards differ from the cooperative ones, and as a consequence, consumers are worse off when unilateralism prevails than when pollution-control efforts are coordinated. The explanations about these results are the same than the ones exposed for the fixed cost scenario. Trade integration also makes the sub optimality of non-cooperative environmental policies and welfare worse.

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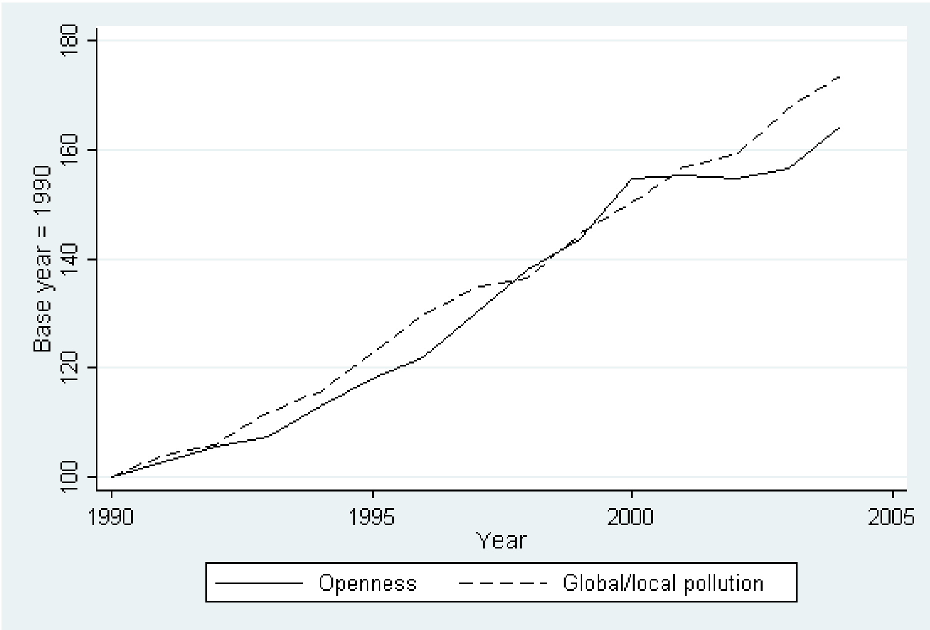

Figure 1: Evolution of openness and of the ratio of global over local air pollutions, for OECD countries, from 1990 to 2005. *Data: OECD Environmental Data Compendium (2007) - Alan Heston, Robert Summers and Bettina Aten, Penn World Table Version 6.2, Center for International Comparisons of Production, Income and Prices at the University of Pennsylvania, September 2006.*