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TRADE LIBERALIZATION, ENVIRONMENTAL REGULATION AND SELF-REGULATION OF MULTINATIONAL FIRMS

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Abstract: Using a monopolistic competition model with mobile capital, where firms may choose between a “dirty” or a “clean” technology, this work explores the relationship between environment, trade liberalization, geographical and technical choices of multinational firms. We show that beside of environmental regulation, the ecological sensitivity of consumers can also be a market mechanism which may urge firms to self-regulate. We show in particular that a local sensitivity of environmental issues amplifies the phenomenon of Pollution Haven induced by an environmental tax, while a more comprehensive environmental awareness attenuates or cancels it gradually as the liberalization progresses.

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1. Introduction

By expanding the territory of economic agents, the globalization process disrupts national economic boundaries and raises the question of geographical choices determinants of multinational corporations (MNC). On the other hand, by accelerating emergent countries' industrialization processes, globalization contributes to increase and internationalize the negative externalities of economic development (resource depletion, pollution, industrial risks, global warming, etc.), and highlights thereby the need for a better understanding of firms' behaviors faced to this strengthening environmental constraints. In this context, if markets proximity, low production costs, attractive taxation or easier access to raw materials are classic arguments steadily advanced in the economic literature to explain the MNC's migrations, some environmental arguments need now to be considered. The objective of this work is to explore the links between economic openness, geographical location and environmental performance of MNCs. The main idea is to show how MNCs can internalize this environmental constraint and how this latter impacts theirs geographical and/or technological choices.

One of the first approaches in economic literature, the Pollution Haven Hypothesis (PHH), emphasizes the links between environmental policies and geographical location of multinational firms[1]. It is based on the idea that differentials of regulatory costs (legislation, norms, fiscality, etc.) can change the traditional comparative advantages among nations. In presence of perfect capital mobility, the increasing openness of economies encourages polluting activities to relocate to less stringent countries where marginal return on capital is higher[2]. In such a theoretical perspective, environmental policies can become a strategic issue of attractiveness between nations (as well as taxation and labor costs) and economic openness can become potentially harmful for environment. During last decade, PHH has been the main subject of many papers which have mostly highlight difficulties to demonstrate empirically this phenomenon. The vast majority of econometric studies reveals at best a small or a partial Pollution Haven effect[3]. Some of them even lead to non intuitive results showing that firms are relocating to countries with more stringent regulation[4]. Besides the technical explanations involving the limits of econometric tools used (imperfect proxies, existence of aggregation bias …), a more general argument has been advanced to explain this difficulties to "unmask" the *Polution Haven*. It is based on the idea that environmental regulation is not the only determinant of the links between openness, location and environmental performance of MNCs. In this spirit, Copeland and Taylor [2004] propose to distinguish the Pollution Haven Effect (PHE) and the Pollution Haven Hypothesis (PHH). If former is hardly debatable, it does not necessarily imply the existence of the latter. In presence of opposing forces, higher costs of regulation may be insufficient to fully determine the location of multinational firms[5].

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[1] Walter [1982], Pearson [1987].

[2] These polluting activities are also more capital intensive (Manni and Wheeler [1998]).

[3] For example, List and Co [2000], Keller and Levinson [2002] or Cole and Elliott [2005] found a moderate abatements costs effect of environmental regulation on FDI in the USA. Eskeland and Harrison [2003] partially confirm the PHH for multinational industries in Mexico, Venezuela, Morocco and Cote d'Ivoire, Hanna [2004] notes that U.S. multinationals respond negatively to the strengthening of environmental regulations (Clean Air Act Amendments) without finding a significant relationship with their location in the South. Dean and al. [2009] validate the PHH in China but only for investors from developing countries and not for those from industrialized countries. See e.g. Jeppesen and al. [2002] for a literature review of empirical studies.

[4] Kalt [1988], Grossman and Krueger [1993], Javorcik and Wei [2005] Raspiller and Riedinger [2008]).

[5] Ederington and al. [2005] show for example that for most industries, reductions in pollution costs are a small component of total costs.

In this spirit, a second line of research has been explored more recently in economic literature: the *Corporate Self-regulation* concept[6]. It starts from the initial finding that, during last years, private voluntary initiatives seem to proliferate in order to improve the environmental performance of firms independently of any coercive regulation: implementation of Environmental Management Systems (EMSs), membership to environmental codes of conduct[7] or international environmental certifications (ISO 14001 or ISO 26000), transfers of clean technology from MNC to their foreign subsidiaries, local sourcing based on minimum environmental standards criteria, etc. If these self-regulatory behaviors of firms may result from ethical or political concern of business managers[8], they seem to be mostly determined by market-based incentives strong enough to be taken into account by firms in the perception of their interest. In this context, environmental self-regulation can be considered as a criterion of good management for firms[9]: as a way to minimize their reputational risk and attract investors[10], as a way to differentiate their product *vis-à-vis* of consumers concerned about ecological issues[11], as a way to win support of employees and to be a real component of the corporate culture[12].

This paper explores simultaneously these previous approaches from a theoretical point of view based on a *Dixit-Stiglitz-Krugman* model of monopolistic competition with capital mobility. In a context of trade liberalization, we examine the effects on geographical and technological choices of MNC both of environmental regulation (*Pollution Haven Hypothesis*) and of market incentives based on a growing ecological sensitivity of consumers (*Corporate Self-regulation concept*). The next section explains the choices made to integrate these two dimensions in the model. The last section shows how simulation of several scenarios may reveal the different impacts of environmental regulations or ecological sensitivity of consumers on geographical and technological firms' choices.

2. The Model

Polluting activities being generally characterized by imperfect competition, increasing returns to scale and high transport costs[13], we use a Chamberlin's monopolistic competition framework for our analysis. To our knowledge, if these models have already led to numerous extensions, there are only few attempts to introduce an environmental dimension[14]. Several points of entry of this dimension are then considered here. The first concerns the firms' possibility to make a choice between a clean or dirty technology which defines thereby their environmental performance. This choice is mainly

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[6] Dasgupta and al. [2000], Khanna (2001), Khanna and Anton (2002), Christmann and Taylor [2001], Mazurkiewicz [2004], Anton and al (2004), Graham and Woods [2006].

[7] See, e.g., Haufler [2001], OECD [2000], Mazurkiewicz [2004] Mironiuc [2008].

[8] Graham and Woods [2006], Ruggie [2003].

[9] O'Rourke [2003], Christmann and Taylor [2001], Anton and alli [2004]). This literature joined the works on the Corporate Social Responsibility (Werhane and Freeman [1999]) where company is supposed to have multiple responsibilities toward its *Stakeholders* (consumers, investors, business partners, employees, NGOs, local communities, publics institutions...).

[10] Some investors, for ethical reasons, take firms' environmental performances as a criterion to invest (*Ethical screened funds*) or as a guideline of action ("*shareholders advocacy*"). See e.g., the Social Investissment Forum 2003 Report.

[11] Haufler [2001], Anton and alli [2004] Mironiuc [2008].

[12] For environmental responsibility be not perceived as a communication strategy, it must be clearly defined and the stakeholders must have a complete and reliable information. It's why several initiatives have born in recent years to incent *environmental reporting*. See, e.g., OECD [2000], Mazurkiewicz [2004] Utting [2008], the Global Reporting Initiative (www.globalreporting.org) or Eccles and Krzus [2010].

[13] Zeng and Zhao [2009]

[14] See e.g., Rieber and Tran [2008].

determined by each technology's profitability and may also be induced by spillover effects. The second concerns the presence of an ecological sensitivity of consumers susceptible to be an incentive for firms to reduce the environmental negative externalities of their domestic production or to go abroad. The third concerns the possibility for governments to implement an environmental regulation.

Imperfect competition and international mobility of industrial firms

Consider a world composed of two identical regions (indexed f or h) supposed to have the same factors endowment ($\bar{L}$ and $\bar{K}$). Each region hosts an agricultural sector (A), which uses only labor to produce a homogeneous good under constant returns to scale, and an industrial polluting sector (I), which uses both labor and capital. Labor is supposed to be internationally immobile but perfectly mobile between sectors. With the agricultural homogeneous good chosen as numeraire, we have:

$$\bar{L} = L_{Ah} + L_{Ih} \quad \forall h = 1,2 \text{ with } w_A = w_I = 1 \qquad (1) \text{ and } (2)$$

where L_{Ah} and L_{Ih} are labor used in agriculture and industry in Region h and w_A and w_I are remuneration of labor in the agricultural and industrial sectors in each region.

In the industrial sector, each firm produces a variety of a good differentiated horizontally. As the capital factor is supposed to be perfectly mobile internationally[15], every industrial firm can locate in each region according to the remuneration of this capital. The inter-regional allocation of capital is then:

$$\bar{K} = K_{hh} + K_{hf} \quad \forall h = 1,2 \;\; f = 1,2 \text{ and } h \neq f \qquad (3) \text{ and } (4)$$

where K_{hh} and K_{hf} are capital of Region h remaining in Region h and relocating in Region f

Environmental performances of firms, technology choices and spillover effects in the industrial sector

Industrial pollution is considered as a negative externality, measurable, emitted by each firm and suffered by whole community as it degrades the quality of environment[16]. For each industrial variety, firms may choose to produce either a dirty good, whose production generates high pollution flows, or a clean good obtained with a more environmentally friendly technology whose cost of access is ψ_h. Total cost functions of dirty or clean firms in Region *h* are respectively:

$$CT_{hi}^{d} = \alpha_h \pi_h^{d} + \varphi_h x_{hi}^{d} \quad \forall h = 1,2 \qquad (5) \text{ and } (6)$$

$$CT_{hi}^{c} = \alpha_h \pi_h^{c} + \varphi_h x_{hi}^{c} + \psi_h \quad \forall h = 1,2 \qquad (7) \text{ and } (8)$$

Where α_h and φ_h are capital and labor units used to produce a variety *i*, x_{hi}^{d} (respectively x_{hi}^{c}) is the quantity of dirty (respectively clean) variety *i* produced in Region h, π_h^{d} (respectively π_h^{c}) is the nominal return to capital[17] of dirty (respectively clean) firms and ψ_h the access cost to clean technology. We choose units of capital so that $\alpha_h = 1$.

The access cost to clean technology depends firstly positively on firm's expenditure on R&D ($0 < Q_h \leq 1$). Moreover, assuming that R&D results are not exclusively captured by the firm which finances it, but may also benefit to all competitors, a *technological spillovers effect* is introduced in the

[15] Baldwin and al. [2003]. Industrial firms are supposed to draw their labor factor in the agricultural sector without jeopardize the existence of this sector.
[16] Accordance to traditional approaches (Cropper and Oates [1992]), Environment is here considered as a pure public good whose stock is given but whose quality depends on the pollution level.
[17] The fixed cost depends only of the capital factor even if the sector uses two factors (see Forslid [1999]).

model[18]. Geographically limited, this effect reduces the access cost to clean technology and depends firstly on the number of clean firms located in one region *h* ($n_h^c/(2\bar{K})$). Secondly, it depends on firm's ability to capture, internalize and use the external tacit knowledge from their competitors. This ability is here measured by the parameter θ_h (with $0 \le \theta_h \le 1$) defined as an indicator of technological efficiency or of knowledge permeability. In this framework, assuming that firms of each region make the same environmental effort and that R&D leads always results[19], the access price to clean technology in Region *h* is:

$$\psi_h = v_h Q_h \left[1 - \left(\frac{n_h^c}{2\bar{K}} \theta_h Q_h \right)^k \right] \qquad \forall h = 1,2 \qquad \textit{(9) and (10)}$$

where $0 \le k \le 1$ measures possible effects of congestion in innovation activity[20] and $v_h > 0$ the cost of a unit of R&D.

Ecological sensitivity of consumers

Consumers in Region *h* are supposed to have a Cobb-Douglas utility function between industrial goods and agricultural goods. Consumption of industrial goods is a CES function between the four types of goods existing for each variety ("clean" or "dirty" and "local" or "imported"):

$$U_h = \left[\zeta_{hh}^d \sum_{i=1}^{n_h^d} c_{hhi}^{d\,\frac{\sigma-1}{\sigma}} + \zeta_{hh}^c \sum_{i=1}^{n_h^c} c_{hhi}^{c\,\frac{\sigma-1}{\sigma}} + \zeta_{hf}^d \sum_{i=1}^{n_f^d} c_{hfi}^{d\,\frac{\sigma-1}{\sigma}} + \zeta_{hf}^c \sum_{i=1}^{n_f^c} c_{hfi}^{c\,\frac{\sigma-1}{\sigma}} \right]^{\beta\frac{\sigma}{\sigma-1}} C_{Ah}^{1-\beta}$$

$\forall h = 1,2 \;\; f = 1,2$ and $h \ne f$ *(11) and (12)*

where $0 < \beta < 1$ is the share expenditure on industrial goods, C_{Ah} the total consumption of agricultural good, c_{hhi}^d (respectively c_{hhi}^c) the consumption of a dirty variety *i* (respectively clean) produced in region h, c_{hfi}^d (respectively c_{hfi}^c) the consumption in region *h* of a dirty variety *i* (respectively clean) produced in *f*, $n_h^d, n_h^c, n_f^d, n_f^c$ the number of firms producing clean and dirty varieties in each region and σ, the constant elasticity of substitution[21] between the varieties ($\sigma > 1$) .

This structure reveals an environmental quality preference of consumers in favor of the type clean of each variety (the environmental characteristics are assumed measurable and well known by

[18] Audresch [1998], Jaffe and al [1993]; Autant-Bernard [1999].
[19] Even if an activity of R&D is uncertain, we assume that the probability that at less a project leads to an innovation is close to 1 Indeed, if probability to see a project fail is $(1-\gamma)$, probability that there are at least an R & D leading an innovation is $1-(1-\gamma)^n$ with $0 < \gamma < 1$. When concentration of firms is high, i.e. when the number n of firms is large, which is precisely one of the characteristics of Chamberlin's monopolistic competition, this probability is then close to 1.
[20] Function is concave. See Boschma [2005].
[21] For simplicity, we assume that all varieties have the same degree of substitution between them.

consumers)[22]. ζ_{hh}^{c} (respectively ζ_{hh}^{d}) represents indeed an inverse indicator of ecological sensitivity of a consumer[23] in Region *h* for a clean variety (respectively dirty) produced in *h*:

$$\zeta_{hh}^{d} = 1 - S_h^{-1}\left(\mu_h e_h^d \sum_{i=1}^{n_h^d} x_{hi}^d\right) \qquad \forall h = 1,2 \qquad (13) \text{ and } (14)$$

$$\zeta_{hh}^{c} = 1 - S_h^{-1}\left(\mu_h e_h^c \sum_{i=1}^{n_h^c} x_{hi}^c\right) \qquad \forall h = 1,2 \qquad (15) \text{ and } (16)$$

$$\zeta_{hf}^{d} = 1 - S_h^{-1}\left(\upsilon_h e_f^d \sum_{i=1}^{n_f^d} x_{fi}^d\right) \qquad \forall h = 1,2 \;\; f = 1,2 \text{ and } h \neq f \qquad (17) \text{ and } (18)$$

$$\zeta_{hf}^{c} = 1 - S_h^{-1}\left(\upsilon_h e_f^c \sum_{i=1}^{n_f^c} x_{fi}^c\right) \qquad \forall h = 1,2 \;\; f = 1,2 \text{ and } h \neq f \qquad (19) \text{ and } (20)$$

This inverse indicator of sensitivity depends first on the maximum level of tolerance to environmental degradation in the region of residence of the consumer (S_h). It depends secondly on pollution flows generated by each type of varieties (e_h^d and e_h^c per unit produced, with $e_h^d > e_h^c$). The parameters μ_h and υ_h indicate that the perception of this pollution is different if it is emitted locally or abroad. Assuming that consumers attach more importance to local pollution (which affects them directly) rather to foreign pollution, we have $\upsilon_h \leq \mu_h \;\; \forall h$. Thereby, when the pollution level is equal to the perceived maximum tolerable threshold, sensitivity of consumers is high and they do not get any utility by consuming the relevant category of industrial goods. Conversely, when they are indifferent to pollution (μ_h and υ_h zero), their sensitivity is null and not affects their choices.

Trade costs and variable of trade or environmental policies

If trade of Agricultural goods is assumed to be free, industrial goods face iceberg intra- and inter-regional trade costs. The former are considered as potential instruments of national environmental policies. They differ according to environmental performance of goods. When a dirty variety (respectively clean) produced in Region *h* is consumed locally, its transport cost is equal to τ_h^d (respectively τ_h^c). Inter-regional trade costs are determined by trade policy but may also be environmental policies instruments if they are distinct between clean or dirty goods of each variety. τ_{hf}^d (respectively τ_{hf}^c) represents trade cost when Region *h* imports a dirty variety (respectively clean) produced in Region *f*. All these trade costs are assumed to be greater than unity and intra-regional costs assumed to be lower than inter-regional costs.

Characterization of equilibrium: supply, demand, prices and factor returns

In a monopolistic competition framework, price equals marginal cost plus a *mark-up*[24] representing the producer's monopoly power. Profit maximization of each firm gives the equilibrium

[22] Determinants of consumers' preference for environment may be multiple (adherence to community values, search for meaning, moral responsibility, etc.). In the tradition of the theory of revealed preference, we assume that consumption choices are enough to reveal the induced environmental rationality provided that consumers are fully informed. Only industrial products are concerned here.

[23] This modeling is based on Beaumais and Schubert [1994, 1996.1999] or Chiroleu-Assouline and al. [2004].

price of a variety in each region[25]. For simplicity, we assume that production processes are identical in both countries and choose $\varphi_h = \varphi_f = (\sigma-1)/\sigma$, which allows us to write that $p_h^c = p_h^d = 1$ ∀h = 1,2

In equilibrium, supply equals demand for each type of variety in each region

$$x_h^d = \left(\frac{\tau_h^d}{G_h}\right)^{1-\sigma} \left(\zeta_{hh}^d\right)^{\sigma} \beta Y_h + \left(\frac{\tau_{fh}^d}{G_f}\right)^{1-\sigma} \left(\zeta_{fh}^d\right)^{\sigma} \beta Y_f \qquad \forall h = 1,2 \;\; f = 1,2 \text{ and } h \neq f \qquad \textit{(21) and (22)}$$

$$x_h^c = \left(\frac{\tau_h^c}{G_h}\right)^{1-\sigma} \left(\zeta_{hh}^c\right)^{\sigma} \beta Y_h + \left(\frac{\tau_{fh}^c}{G_f}\right)^{1-\sigma} \left(\zeta_{fh}^c\right)^{\sigma} \beta Y_f \qquad \forall h = 1,2 \;\; f = 1,2 \text{ and } h \neq f \qquad \textit{(23) and (24)}$$

On the demand side, quantities are obtained by aggregating the individual demand functions, which are themselves determined by the constrained maximization of utility. Demand value is therefore composed of local demand and foreign demand. It depends on consumers' ecological sensitivities, on transport costs, on price indices for each region (G_h and G_f) measuring the purchase cost of the composite manufactured in each region, defined by[26]:

$$G_h = \left[n_h^d \left(\zeta_{hh}^d\right)^{\sigma} \left(\tau_h^d\right)^{1-\sigma} + n_h^c \left(\zeta_{hh}^c\right)^{\sigma} \left(\tau_h^c\right)^{1-\sigma} + n_f^d \left(\zeta_{hf}^d\right)^{\sigma} \left(\tau_{hf}^d\right)^{1-\sigma} + n_f^c \left(\zeta_{hf}^c\right)^{\sigma} \left(\tau_{hf}^c\right)^{1-\sigma} \right]^{\frac{1}{1-\sigma}}$$

∀h = 1,2 f = 1,2 and h ≠ f *(25) and (26)*

and on consumers' income (Y_h *and* Y_f) in each region[27] defined by :

$$Y_h = \bar{L} + \pi_h K_{hh} + \pi_f K_{hf} \qquad \forall h = 1,2 \;\; f = 1,2 \text{ and } h \neq f \qquad \textit{(27) and (28)}$$

where π_h is the nominal return of capital in the region h

Since the capital is restricted to the fixed costs, this short term nominal return is the Ricardian surplus of a firm, i.e. the operating profit related to the production of a variety. For each type of firm it is:

$$\pi_h^d = \frac{x_h^d}{\sigma} \quad \forall h = 1,2 \qquad \textit{(29) to (30)}$$

$$\pi_h^c = \frac{x_h^c}{\sigma} - \psi_h \quad \forall h = 1,2 \qquad \textit{(31) to (32)}$$

Spatial dynamics of firms

Each industrial firm faces two choices (location and production technology) determined endogenously and simultaneously in the model. The geographical distribution of firms is based on the capital

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[24] Subjectivity introduced by ζ in the utility function does not affect the mark-up.

[25] Varieties clean and "dirty" are assumed to have the same price and are distinguished only by the level of pollution they generate. There is no willingness from consumers to pay extra for clean products.

[26] This price index is partly subjective. *Ceteris paribus*, when perceptions of pollution *(ζ)* tend towards unity, G_h decreases and standard of living increases qualitatively.

[27] Consumers owning all the factors of production, they receive the whole remuneration of these factors. The profits of exported capital are fully repatriated in their home country.

profitability differential between regions[28]. The technological distribution is based on the profit differential between non-polluting and polluting firms. Thereby, equalization of capital returns determines the distribution of four types of firms in the world. Assuming that fixed capital cost per firm is unitary, the respective number of clean and dirty firms in each region is limited by the capital endowment:

$$n_h^d + n_h^c = K_{hh} + K_{fh} \qquad \forall h = 1,2 \;\; f = 1,2 \text{ and } h \neq f \qquad \textit{(33) and (34)}$$

Moreover, assuming full employment in each region, the number of workers employed in the industrial sector is:

$$L_{Ih} = \frac{\sigma - 1}{\sigma}\left(n_h^d x_h^d + n_h^c x_h^c\right) \quad \forall h = 1,2 \qquad \textit{(35) and (36)}$$

The perfect mobility of capital allows the intersectoral and international equalization of capital return. Thus, in the long-run equilibrium, we assume that $\pi_h^d = \pi_h^c = \pi_h = \tilde{\pi} \quad \forall h = 1,2$ *(37) and (38)*

Combination of equations (29) to (32) gives the long-run capital return value[29]:

$$\tilde{\pi} = \frac{\beta Y}{2\sigma \bar{K}} - \Psi \qquad \textit{(39)}$$

where Ψ is the average cost of the environmental efforts of firms :

$$\Psi = \psi_1 \frac{n_1^c}{2\bar{K}} + \psi_2 \frac{n_2^c}{2\bar{K}} \qquad \textit{(40)}$$

and βY the share of world income devoted to the acquisition of the industrial good. Y is given by the sum of equations (27) and (28):

$$Y = 2\bar{L} + 2\tilde{\pi}\bar{K} \qquad \textit{(41)}$$

Combination of equations (39) and (41) determines the value of long-run capital return[30]:

$$\tilde{\pi} = \frac{\sigma \bar{K}\Psi - \beta \bar{L}}{(\beta - \sigma)\bar{K}} \qquad \textit{(42)}$$

3. Simulations

We can now examine the interactions between trade liberalization's intensity (through the level of exogenous variables of interregional transports costs τ_{hf}^c and τ_{hf}^d)) and strategic choices of firms in terms of location and technology (through the endogenous variables n_1^d, n_1^c, n_2^d and n_2^c). The nonlinearity of the model prevents any analytical resolution. Thus we have to simulate numerically the equilibrium reached after a change of an exogenous variable. Initial reference equilibrium is obtained

[28] See Baldwin and al. [2003] for more details.

[29] See e.g. Rieber and Tran [2008].

[30] As the capital return cannot be negative or zero, we will ensure that the values of parameters and exogenous variables satisfy condition : $\Psi < (\bar{L}\beta)/(\sigma\bar{K})$

by calibration of key model parameters[31]. It is perfectly symmetrical between each region, with the same number of clean or dirty firms. The later are assumed to be majority in the world (65%).

Simulation 1 – Testing *the "Pollution Haven Hypothesis"*: trade liberalization with an unilateral environmental tax in one region

The first simulation considers a trade liberalization process when one region (arbitrarily Region 1) imposes an unilateral tax t* (e.g. a carbon tax) on intra-national and international transport of polluting goods produced in this region[32].This tax causes a reduction of short-term profitability of capital employed in the dirty industry located in Region 1. It alters the initial technological distribution of firms by inducing polluting ones to adopt a clean technology (Table 1). This effect is proportional to the level of tax considered (low t *= 5% and high t *= 20%)[33]. For high transport costs, the effects in terms of relocation are negligible.

Table 1 - Effects on the initials equilibrium characteristics of the introduction of an environmental tax in Region 1

	n_1^c	n_1^d	n_2^c	n_2^d
Share of each firms in initial equilibrium [(1)]	17,5	32,5	17,5	32,5
Change compare to initial equilibrium [(1)]				
t=5%*	+29,1	-17,5	-0,6	+2,2
t=20%*	+116,9	-69,1	-0,3	+6,3

(1) Per cent

Whatever the level of tax, trade liberalization causes a partial polarization of firms in Region 2 and a declining share of polluting firms in the world (Graphs 1a and 1b). These movements are consistent with the traditional results of monopolistic competition models with capital mobility, where the presence of an asymmetry between the regions is sufficient to cause an endogenous dynamics of firms' agglomeration[34]. In this case, polluting firms are incited to move where the transport is not taxed. This "*Pollution haven effect*" reflects a change in comparatives advantages induced by the tax. When dirty firms choose to locate where environmental constraints are less strict, Region 2 tends to "specialize" in the production of dirty varieties and Region 1 in the production of clean varieties. The simulation shows that this "*Pollution haven effect*" is proportional to the level of tax and that there is a critical threshold level of transport costs (τ_{hf}^c and τ_{hf}^d = 2) below which it accelerates. Moreover, the slight increase of clean firms observed in Region 2 (growing after the threshold level of transport costs) shows that some dirty firms of Region 1, induced to change technology, prefer to locate in region 2. The explanation lies in the emergence of a "*home market effect*" in this latter region. Indeed, polarization of dirty firms in one region increases its asymmetry with the other region beyond the simple effect of the tax. By holding progressively a larger share of global production activities, Region 2 knows an increase of its domestic market and, thus, of its relative attractiveness. When transport costs are sufficiently low to overcome the inertia of the labor factor, it encourages firms, including

[31] $\forall h = 1,2$: $\beta = 0.8$; $\sigma = 3$; $\bar{K} = 1$; $\bar{L} = 100$; $S_h = 40$; $e^d = 0.8$; $e^c = 0.4$, $\mu_h = \nu_h = 0.1$, $Q_h = Q_f = 1$, $\theta_h = \theta_f = 0.5$ and $\psi_h = 25$.

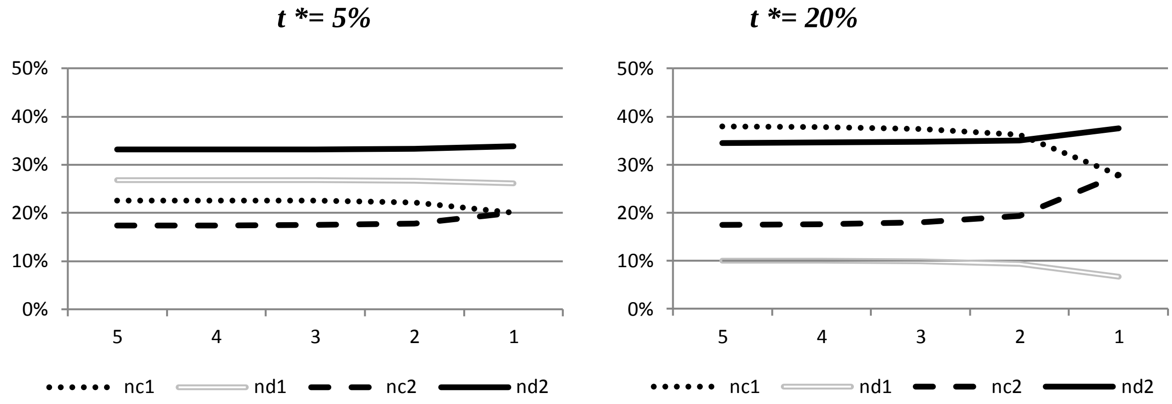
[32] The redistribution effect of tax revenue is ignored here (partial equilibrium).

[33] We can recognize here, by a different way, the "*Porter hypothesis*" where strict environmental regulations may, ceteris *paribus*, encourage firms to adopt a cleaner technology (Porter and Van Linde [1995]).

[34] Models based on capital mobility show that trade liberalization is neutral in terms of location of firms when both regions are identical (e.g. Baldwin and al. [2003]).

clean ones, to locate in the larger market. When the level of tax is high and the liberalization process is completed, Region 2 holds about 65% of firms, 43% of which are clean.

Graphs 1a and 1b - Effects of trade liberalization on the distribution of firms with an environmental tax in Region 1 (1)



(1) Abscissa: $n_h^{c,d}$; Ordinate: $n_h^{c,d}$ (% of global firms)

Whatever the tax level, trade liberalization is positive on environment for Region 1, negative for Region 2 and slightly positive at the global level (Graphs 1c and 1d). We recognize here, by different ways, the combination of three effects already described in the economic literature[35]. A *composition effect* is related to the change of specialization of each region according to their new comparative advantages. In this case, it promotes the environment of Region 1, which sees its polluting activities move outside, and penalizes Region 2, which attracts them. *A scale effect* is related to the size of production and determines the intensity of pollution flows. In the simulations, it is positive on the environment for region 1 and negative for region 2. A *technique effect* which reflects that trade liberalization promotes the adoption of an environmentally friendly technology[36]. In this case, it goes through the *spillovers effect*, which facilitates technology diffusion during the agglomeration process. It goes also through the pressure of environmental regulations on costs production (*Porter Hypothsesis*)[37]. These effects are proportional to the level of tax. Theory predicts moreover that their intensity depends also on the degree of trade liberalization. It is the case here, where a sharp acceleration can be observed at the end process, after the critical threshold of transport costs (τ_{hf}^{c} and τ_{hf}^{d} = 2). Indeed, the reduction of transport costs intensifies the *composition effect* as far as each region accelerates its specialization. It also intensifies the *scale effect* by expanding the production possibilities frontier[38] and by decreasing world income (and therefore world production) as far as the relative share of clean firms increases in the economy[39].

[35] Grossman and Krueger [1993]; Copeland and Taylor [1994, 2004]; Antweiler and al. [2001]; Cole and Eliot [2003]; Wagner and Timmings [2009]; McAusland [2010].

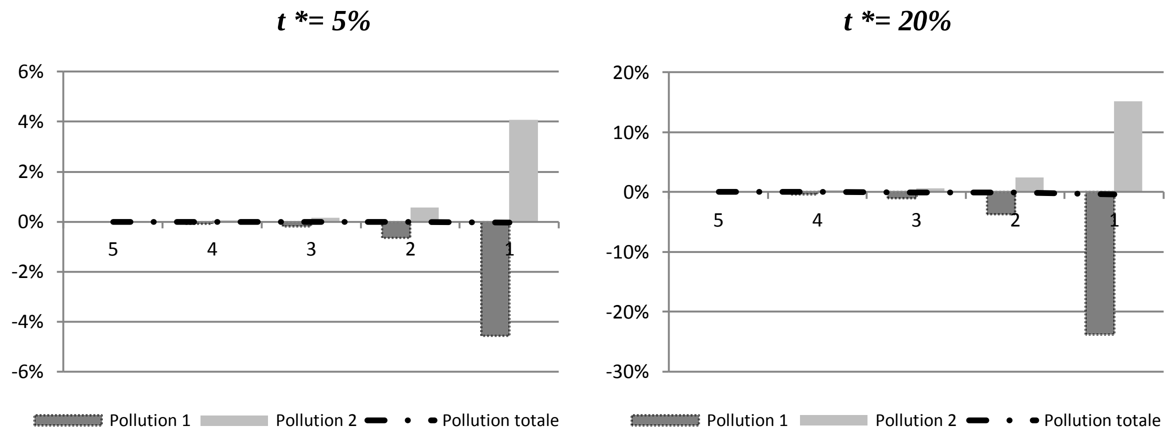
[36] Eskeland and Harrison [2003] show that multinationals are more environmentally friendly than local firms.

[37] Porter and Van der Linde [1995]

[38] Equations 24-27 are decreasing functions of transports costs.

[39] Clean technology access costs reduces equilibrium return of capital (equation 42) and thus the world's income.

Graphs 1c and 1d - Effects of trade liberalization on environment with an environmental tax in Region 1 (1)



(1) Abscissa: $\tau_{hf}^{c,d}$; Ordinate: ΔPollution (in %)

Simulation 2 - "*Not In My BackYard*": Trade liberalization in presence of a local ecological sensitivity of consumers in one region

The second simulation assesses the impact of trade liberalization on firm's choices when consumers of one region (arbitrarily Region 1) are sensitive about environmental issues that affect them locally[40]. The model has been built to offer the possibility of measuring the impact of a change in the ecological sensitivity of consumers through the parameters μ and υ which weigh respectively on pollution emitted locally and abroad in their utility function (equations 12-19). When $\mu_h \neq 0$ and $\upsilon_h = 0$, consumers in the region h are supposed selfish[41], only concerned with the quality of their local environment and indifferent to any degradation of the environment in the other region. In this simulation, we consider two levels of local environmental sensitivity (medium, μ_1 = 0.5) and maximum μ_1 = 1), ν_1, μ_2 and ν_2 remaining low. This local sensitivity alters the initial technological and geographical distribution of firms by encouraging polluting enterprises of Region 1 to modify their technology (Table 2). When it becomes strong enough, it incites all the firms to leave Region 1 because consumers have developed an aversion to local pollution generated by clean firms as well as by dirty ones.

Table 2 - Effects on the initials equilibrium caracteritics of the introduction of a local environmental sensitivity in Region 1

	n_1^c	n_1^d	n_2^c	n_2^d
Share of each firms in initial equilibrium (1)	17,5	32,5	17,5	32,5
Change compare to initial equilibrium (1)				
$\mu_1 = 0{,}5$	+48,9	-39,8	+14,3	+6,0
$\mu_1 = 1$	+16,3	-55,7	+62,0	+13,5

(1) Per cent

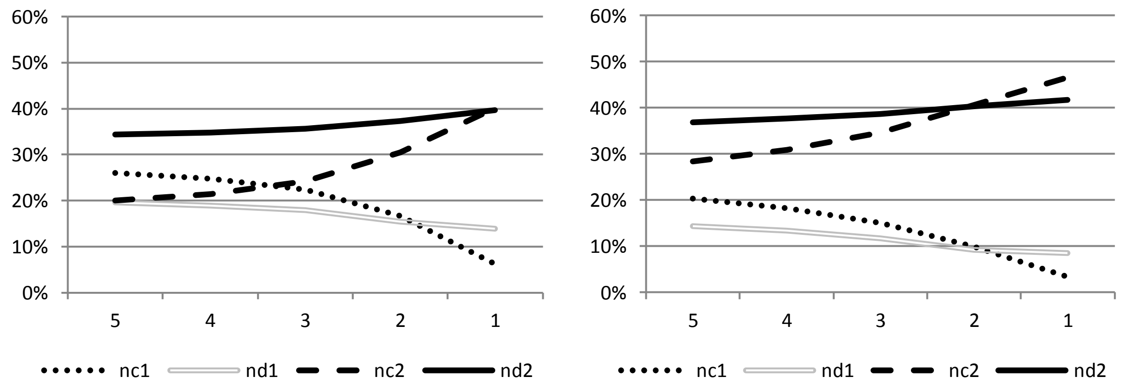
[40] See e.g. McAusland [2010] for a literature review of the relationship between environmental behavior of consumers and income.

[41] When $\mu_1 = \upsilon_1 = 1$, consumers of Region 1 do not derive any utility from the consumption of goods concerned.

Reduced transport costs determine a new technological and geographical distribution of firms (Graphs 2a and 2b). As trade liberalization makes gradually less expensive the industrial varieties imported, both dirty firms and clean firms are incited to leave Region 1 because of consumers' aversion to local pollution. These movements are proportional to the level of environmental sensitivity. At the end of the process, firms are majority in Region 2: 90% of firms when sensitivity is maximum, 80% for a medium sensitivity. Because incentives to invest in clean technology plays here both on demand side (through consumers' sensitivity) and supply side (through technological spillovers), 53% (respectively 50%) of these firms are clean at the end of liberalization process for $\mu_1 = 1$ (respectively $\mu_1 = 0{,}5$).

Graphs 2a and 2b - Effects of trade liberalization on the distribution of firms with a local environmental sensitivity in Region 1 [(1)]

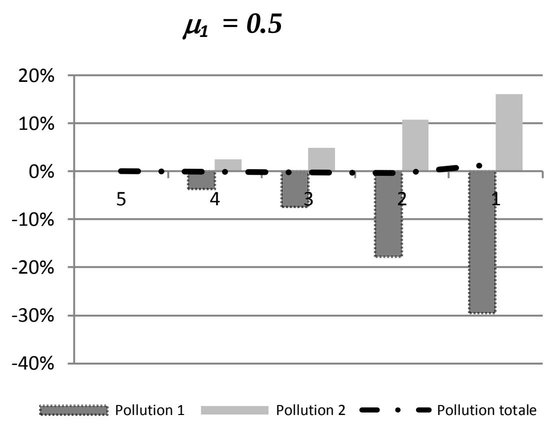
μ_1 = 0.5 ***μ_1 = 1***

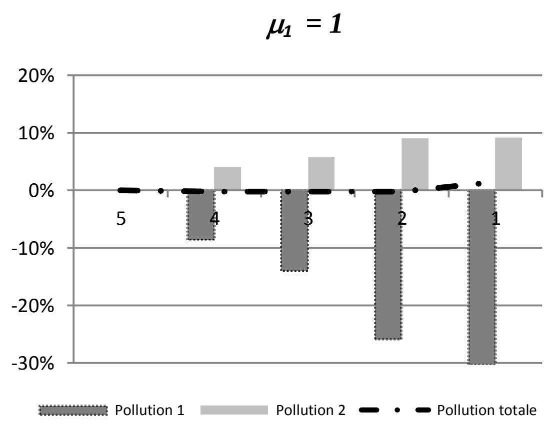


(1) Abscissa: $n_h^{c,d}$; Ordinate: $n_h^{c,d}$ (% of global firms)

Region 1, where the number of firms declines significantly, knows an improvement of its environmental conditions (graphs 2c and 2d). Region 2, on the other hand, sees its environment deteriorate because of the agglomeration of dirty firms. The global environmental impact, initially weakly positive, becomes significantly negative when transport costs are low. We recognize here the combination of the effects already described in the previous simulation: i) the *scale effect* linked to the production level and determined both by the decline of transport costs and a lower capital remuneration of clean firms ii) the *technical effect*, linked to incentives to change technology (via consumers' behavior and technological spillovers). For a low level of transport costs, agglomeration forces in Region 2 are such that pollution in this region offsets the environmental benefits recorded in Region 1.

Graphs 2c and 2d - Effects of trade liberalization on environment with a local environmental sensitivity in Region 1 (1)





(1) Abscissa: $\tau_{hf}^{c,d}$; Ordinate: ΔPollution (in%)

Simulation 3 - The environment as a *global public good*: Trade liberalization in presence of a global ecological sensitivity of consumers in one region

This simulation extends the previous one considering that consumers in region 1 are not only concerned about their local environment but also by environmental issues in region 2. Their local environmental sensitivity is assumed maximum (μ_1 = 1) and their perception of the pollution emitted in the other region is now assumed to increase: medium (ν_1 = 0,5) and high (ν_1 = 1). The new initial equilibrium shows that a global environmental sensitivity encourages polluting firms in Region 1 to change their technology and to become environmentally responsible (Table 3). Compared to the previous simulation, this effect also extends to the dirty firms in Region 2. When the environmental sensitivity is medium it encourages a reallocation of firms to region 2. This phenomenon lessens when global sensitivity is stronger.

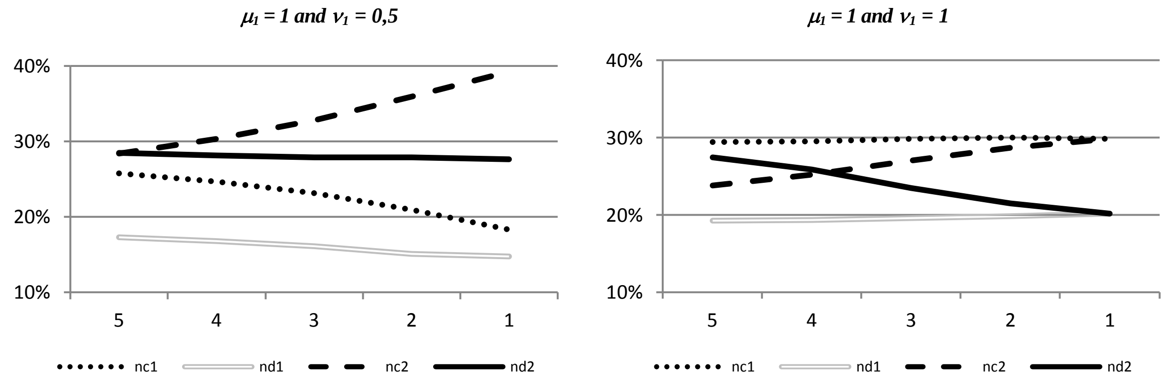
Table 3 - Effects on initials equilibrium characteristics of the introduction of a global environmental sensitivity in Region 1

	n_1^c	n_1^d	n_2^c	n_2^d
Share of each firms in initial equilibrium (1)	17,5	32,5	17,5	32,5
Change compare to initial equilibrium (1)				
ν_1= 0,5	+47,1	-46,6	+62,6	-12,3
ν_1= 1	+68,3	-40,8	+36,0	-15,5

(1) per cent

The decrease of transport costs enhances the intensity of these phenomena (Graphs 3a and 3b). For a medium level of global sensitivity, firms tend to polarize in Region 2 (which holds 67% of firms, 60% of which clean). We can recognize here some mechanisms at work in previous simulation. Indeed, even if they are concerned by environmental issues in Region 2, consumers of region 1 maintain a relatively greater vigilance on their local environment. In this context, firms are encouraged to move to Region 2 (where environmental pressure is lower in relative terms) but also to accelerate their technological innovation. When consumers' sensitivity is maximal, we can also see a rising number of clean firms in Region 2. But, spurred by demand effects (environmental sensitivity) and supply effects (technological spillovers), this movement comes now at the detriment of the dirty firms of Region 2. We can also see that firms come back gradually in Region 1 when transport costs decrease. Indeed, combination of lower transport costs and of a global environmental sensitivity in Region 1, contribute to generate an integrated space where location choices are less important. At the end of the liberalization process, the geographical and intersectoral distributions of firms tend to equilibrate. 50% of firms (60% of which clean) are located in each region.

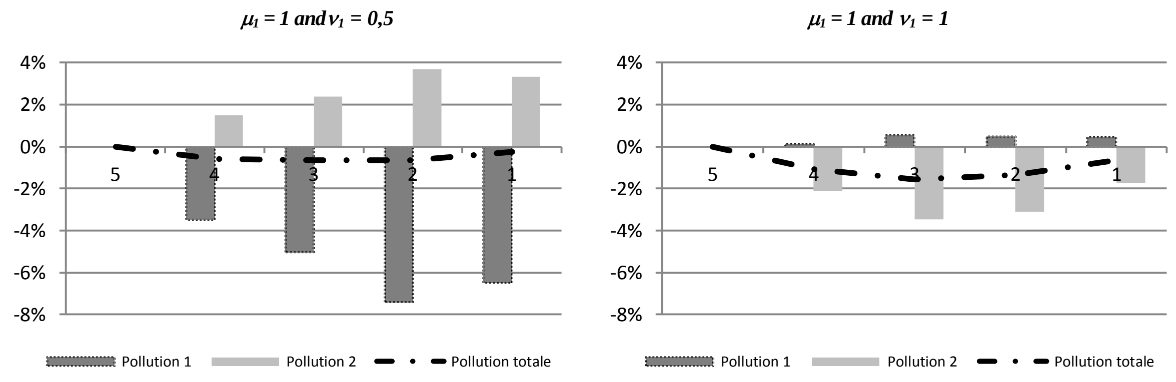
Graphs 3a and 3b - Effects of trade liberalization on the distribution of firms with a global environmental sensitivity in Region 1 (1)



(1) Abscissa: $n_h^{c,d}$; Ordinate: $n_h^{c,d}$ (% of global firms)

The two simulations are not equivalent in terms of environmental degradations (Graphs 3c and 3d). With a medium sensitivity level, Region 1 knows an improvement of its environment due to a *scale effect* (the decrease of its local production offsets the increase of its clean firms). In Region 2, the same *scale effect* offsets the *technical effect* and contributes to environmental degradation. As the total number of clean firms increases in the world, the global impact on environment is positive but attenuates at the end of the liberalization process. When sensitivity is high, environmental effects are less marked. Region 2, on one part, sees its environment improve significantly due to the *technical effect* and the increase of its clean firms. Region 1, on the other part, attracts more firms as far as liberalization intensifies, which contributes, even if this firms are clean, to degrade its environment. At the end of the liberalization process, global pollution tends to decrease as the *technical* and *scale effects* decline.

Graphs 3c and 3d - Effects of trade liberalization on environment with a global environmental sensitivity in Region 1 (1)



(1) Abscissa: $\tau_{hf}^{c,d}$; Ordinate: ΔPollution (in%)

Simulation 4 - Trade Liberalization, environmental regulation and self-regulation of firms

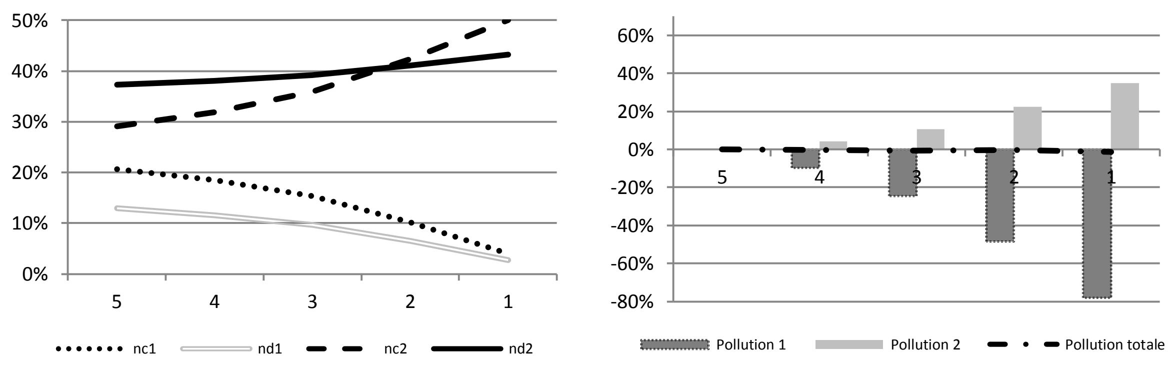
Now, it's time to combine all the effects obtained separately in previous simulations. Two simulations are considered here. In the first one, an environmental tax is implemented in Region 1 in presence of consumers with high local ecological sensitivity. In the second one, the tax level is maintained and consumers in Region 1 are now supposed to be concerned by global environmental issues.

4.1 Local ecological sensitivity and national environmental tax in Region 1

The simulation of trade liberalization in presence of a high local ecological sensitivity and a carbon tax in Region 1 shows that the pressure from consumers on their local environment intensifies the *Pollution Haven* phenomenon generated by the tax (Graphs 4a and 4b). Compared to simulation 1, trade liberalization generates here a greater polarization of dirty firms in Region 2 at the end of process (94% against 85% in the case where only the tax was taken into account as in simulation 1). As in simulation 2, this polarization also concerns the clean firms since the first steps of trade liberalization revealing the mechanisms at work in Region 2 (consumers' incitation to invest in clean technology, technological spillovers linked to agglomeration and "home market effect"). The global benefit on environment is weakly positive. Favorable for Region 1, which sees its firms moving to the other region, it penalizes Region 2 which attracts them. Unlike the simulation 1, where a threshold level of transport costs could be observed, this phenomenon is here more progressive, showing that *scale*, *specialization* and *technological effects*, are at work immediately after the first reduction of transport costs and intensify progressively as trade liberalization progresses.

Graphs 4a and 4b - Effects of trade liberalization on firms distribution and environment quality in presence of an environmental tax and a local ecological sensitivity in Region 1 (1) (2)

μ_1 = 1 and t = 20%*



(1) Abscissa: $\tau_{hf}^{c,d}$; Ordinate: $n_h^{c,d}$ (% of global firms)

(2) Abscissa: $\tau_{hf}^{c,d}$; Ordinate: ΔPollution (in %)

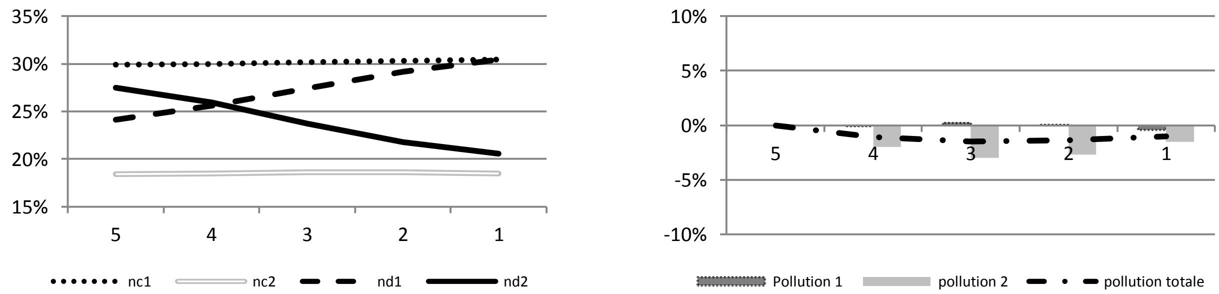
4.2 Global ecological sensitivity and national environmental tax in Region 1

The simulation of trade liberalization in presence of a high global ecological sensitivity and a carbon tax in Region 1 (graph 4c) allows recognizing the distinction made by Copeland and Taylor [2004] between the *Pollution Haven Effect* (PHE) and the *Pollution Haven Hypothesis* (PHH). In simulation 1, trade liberalization and a unilateral tax generated a Pollution haven phenomenon (see Graph 1b). This latter now disappears due to the opposite force caused by the incentive to self-regulate induced by consumers' behavior. When this incentive is maximal, it overtakes the tax effect. The results of this simulation are here quasi similar to those of simulation 3 (see Graph 3b), the tax keeping only a marginal influence on the number of polluting firms in Regions 1 and 2. At the end of liberalization process, 61% of firms are clean and 51% are located in Region 2. Region 1 holds 49% of firms 62% of which are clean. A sensitivity test results shows that for a trade liberalization completed, the pollution haven hypothesis is verified until a threshold level of ecological sensitivity of μ_1 = 0,6 (Graph 4e). Beyond that threshold level, incentives of self-regulation overtakes the constraints of regulation, and technological choices prevail on geographical ones. In other words, the Pollution Haven Effect (PHE) generated by the tax is not sufficient to validate the Pollution Haven Hypothesis (PHH).

The global environmental impact is very positive because the number of polluting firms drops sharply in the world (Graph 4d). Region 1 knows a double dividend situation. It benefits both of the decrease in pollution in its territory and of neutrality of the tax on the number of companies it hosts.

Graphs 4c and 4d - Effects of trade liberalization on firms distribution and environment quality with of an environmental tax and a global ecological sensitivity in Region 1 (1) (2)

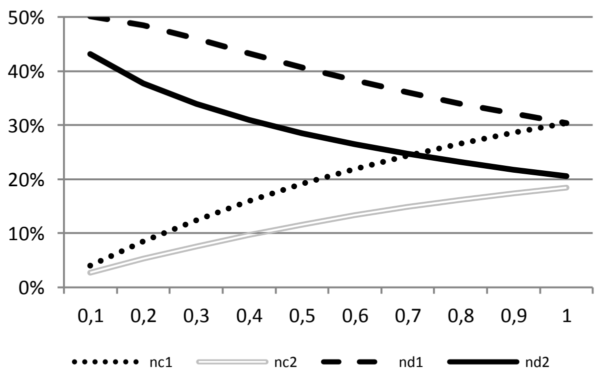
μ_1 = ν_1= 1 and t = 20%*



(1) Abscissa: $\tau_{hf}^{c,d}$; Ordinate: $n_h^{c,d}$ (% of global firms) (2) Abscissa: $\tau_{hf}^{c,d}$; Ordinate: ΔPollution (in%)

Graphs 4e- Sensitivity test results on firms' distribution for different levels of global ecological sensitivity in Region 1 in presence of environmental tax and low transports costs (1)

μ_1 = 1, $\tau_{hf}^{c,d} = 1$ and t = 20%*



(1) Abscissa: ν_1 ; Ordinate: $n_h^{c,d}$ (% of global firms)

Conclusion

Given the growing importance of environmental issues in the globalization process, it seems appropriate to introduce this dimension in order to explain the determinants of geographical and technological choices of multinational firms. Starting from the point of views that these choices are determined both by regulation constraints and by self-regulation incentives, we try to introduce parts of theses dimensions in a DSK model of imperfect competition : firms' possibility to choose between a clean or dirty technology, presence of an ecological sensitivity of consumers and possibility for governments to implement an environmental regulation.

Our first results confirm the validity of the *pollution haven hypothesis*, showing that trade liberalization in presence of an unilateral environmental regulation, generates, *ceteris paribus*, an agglomeration process of polluting firms in the most lax region. Our second results reveal that corporate environmental self-regulation can be induced by market mechanisms. We show that a presence of an ecological sensitivity of consumers also leads firms to integrate environmental restrictions in their behaviors. When consumers in one region are only sensitive to local environmental issues, trade liberalization leads to an agglomeration process in the other region and to a global incentive to adopt cleaner technology. When this ecological sensitivity is gradually expanding from local to global level, the simulations show that, from a threshold level, only technological choices remain important for firms. They become predominantly environmentally responsible and divide equally between the two regions as far as trade liberalization progresses. Our third results show how these different incentives (fiscality and consumers sensitivity) reinforce each other or cancel each other when they are combined. A local ecological sensitivity with a high national environmental tax amplifies the pollution haven phenomenon. In contrast, a global ecological sensitivity reduces or overtakes the pollution haven effect induced by the tax. This last result indicates thereby some ways to best understand the difficulties to identify econometrically the pollution haven hypothesis.

Ultimately, we show how trade liberalization is not neutral in environmental terms when there are these sorts of incentives given the *composition*, *scale* and *technique* effects that it entails. Our simulations reveal in particular the importance of a global ecological sensitivity which encourages firms of both countries to adopt cleaner technologies, but which are not economically costly for the country. This result argues for any measure to strengthen the environmental reporting of companies and ecological education of consumers.

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