Environmental Taxation and International Eco-Industries

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Summary

Environmental policies are discussed when two countries differ in their ability to abate pollution. Northern eco-industries (the industry supplying abatement activities) are more efficient than Southern ones. Segmented environmental markets and a Northern monopoly yield identical second-best taxes in both countries. When markets are global, Southern countries underestimate the market power of eco-industries. Introducing competition creates positive (resp. negative) rent-shifting distortions in South (resp. North). Cooperation could reduce Northern pollution but has ambiguous consequences in South.

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1 Introduction

One cannot deny huge differences in the stringency of environmental policies around the world. There are very good economic explanations to this phenomenon. First, the social value of environmental damage differs among countries, even if the level of pollution is the same. In fact, the environmental damage depends on the citizens' perception of pollution, and it is positively correlated with income. Strategic incentives are also responsible for differences in environmental policies, even when one tackles the same issue. An environmental policy can reflect the relative power of different lobby groups. It can also be justified by imperfect competition in some markets and the need to shift rents toward some of the firms.

To all these very good explanations, we intend in this paper to add another one. The line of argument is straightforward: setting up an environmental policy creates a demand for abatement activities. This demand can be supplied by the own resources of a polluting firm. However, there is a point where it is more efficient for a firm to outsource these activities to an eco-industry sector.[1] Water and waste-water management represents 40% of the activity of this sector, waste management 28% and air pollution control 20% (OECD 1996). On the supply side, the main characteristic concerns the high level of concentration. On each sub-sector, three or four firms often represent more than 80% of the overall turnover. Furthermore, the environmental market size depends on the stringency of environmental policies and these policies appeared sooner and stronger in developed countries, due to an early rise in environmental awareness. It has allowed the emergence of European and North-American firms (Barton 1997). Today, 90% of eco-industry firms come from OECD countries (Kennett & Steenblik 2005).

Meanwhile, a new process has started in less developed countries in order to catch up with European and North-american environmental standards. For instance, new Member States of the European Union need to fulfill an important "acquis communautaire". The environmental standards of the E.U. create considerable needs for those countries. It is likely that they will be supplied by Western European firms. Whether this could act as a brake on the stringency of environmental policies is the first wonder of this article. In other words, when eco-industry firms are foreign-owned, is there an incentive to deviate from the optimal tax rate that would have been chosen in a closed economy? In fact, more stringent environmental policies induce a higher demand in abatement activities and possibly a shift in rents toward foreign firms. However, it is shown that it is not in the interest of developing countries to lower their pollution tax rate when eco-industries are foreign-owned. For instance, when markets are segmented (environmental prices differ according to the country) and eco-industry firms have all Northern assets, no difference appears in second-best environmental policies between Northern and Southern coun-

[1] "Eco-industries may be described as including firms producing goods and services capable of measuring, preventing, limiting or correcting environmental damage such as the pollution of water, air, soil, as well as waste and noise-related problems. They include clean-technologies where pollution and raw-material used is being minimized" (OECD 1999)

tries.[2] Furthermore, when the competition of a local eco-industry is introduced, rent-shifting effects tend to push up the tax in the South. It is only with global environmental markets and one Northern eco-industry that the Southern tax rate should be lower than the tax in North.

It has already been discussed that the eco-industry sector is highly concentrated. Firms of this sector increase their prices above marginal costs, which modifies policy recommendations (David & Sinclair-Desgagné 2005). The authors consider an oligopolistic Cournot competition between eco-industry firms and evaluates the consequences on different environmental policy instruments (taxes, quotas, voluntary approaches, . . .). In particular, the authors show that tax rates should be chosen above marginal damage in order to compensate the lower level of abatement that higher prices induce. Two other papers build on the previous analysis by adding imperfect competition among polluting firms (Nimubona & Sinclair-Desgagné 2005, Canton et al. 2005). Both papers remain focused on pollution taxes. They show that an optimal tax rate is the result of a trade-off between two opposite incentives: lowering the tax in order to compensate the low level of production of polluting firms or increasing it so as to avoid a sub-optimal level of abatement.

In the present paper, we extend the framework of David & Sinclair-Desgagné (2005) in an international context, focusing on environmental tax rates only. As eco-industry firms come from different countries, regulators tend to internalize the externality but also to shift rents toward local firms. Regulators behaving so as to shift rents refers to the traditional analysis of strategic trade policies (Brander & Spencer 1985) and even more to strategic environmental policies when trade instruments are not available (Barrett 1994, Ulph 1996). In this literature, it is shown that it can be in the interest of a regulator maximizing local welfare to use environmental policies so as to give a competitive advantage to local polluting firms. Most of the time, this gives rise to lower levels of taxation than what would have happened without strategic incentives. Compared to the previous literature, the regulator behaves in our context so as to shift rents at an upstream level. The implications of imperfect competition in intermediate goods supply on strategic trade policy have first been examined by Ishikawa & Spencer (1999). They show that a subsidy aimed at shifting rents from foreign to domestic final-good producers is lowered by the presence of foreign intermediate-good producers.

Environmental taxation in the presence of an international eco-industry mixes both strands of literature. First, Fees & Muehlheusser (2002) consider two polluting firms competing à la Cournot on a third market, and buying environmental goods to an eco-industry, based in North, supplying both markets and characterized by a learning-by-doing cost function. Environmental policies are set up in two countries on two periods. The authors show that North tends to increase the environmental policy in the first period in order to benefit from economies of scale in the second period. Building on this framework, Greaker (2006) adds the possibility of foreign competition (both on local and international markets) and endogenizes the price of envi-

[2] In this work, the terminology "North" and "South" is used so as to differentiate countries according to the efficiency of their eco-industries.

ronmental inputs. The author shows that a strong environmental policy may benefit industrial competitiveness through its effect on the price of pollution abatement. However, the author only studies emission quotas and maintains imperfect competition among polluting firms. We have chosen to focus on the environmental market and on taxation. Therefore, the analysis is simplified by assuming perfect competition among polluting firms. It allows us to present different environmental market structures and to test the robustness of our results to various assumptions. Another way to model the abatement services market would have been to follow Copeland (2005) and model this market with monopolistic competition. The author notably shows that optimal pollution taxes for a uniformly mixed pollutant such as carbon emissions may not be uniform across sectors. However, we are more interested in the way profits shift from one country to another.

We first present the simplest case: two countries without any interactions. In each country, a regulator endogenizes the externality of a polluting industry by setting up an environmental tax. Thus, polluting firms have an incentive to purchase environmental goods and services. Abatement activities are supplied by a monopoly. This monopoly belongs to Northern consumers and is made up by two autonomous centers of decisions, one based in North, the other one based in South. These centers are assumed autonomous for two reasons. First, markets are segmented so prices differ according to the country where products are sold.[3] Second, constant average costs are assumed, so there are no economies of scale. Even though the monopoly returns profits to its Northern shareholders, which makes welfare lower in South, it is shown that the optimal environmental tax rate is identical. The result does not hold in the presence of a single world market. In this context, the Southern regulator underestimates the overall mark-up that a Northern eco-industry firm makes. The result is a lower tax rate in the South than in North.

Afterward, an eco-industry with Southern shareholders enters the market. First, environmental markets are supposed segmented. In each country a domestic and a foreign firm compete via two decision centers, the Southern firm having higher production costs. In this context, the asymmetric Cournot-Nash competition induces a higher level of taxation in South. Furthermore, if the difference in production costs is high enough, the Southern regulator can even choose a higher tax than in the monopoly case. Rent-shifting incentives overcompensate the benefits of increased competition. Second, we study a model of tax competition when the environmental market is international. In this case, non-cooperative behaviors lead to lower taxes in both countries than without any competition. Introducing cooperative behavior (as in Greaker (2003)) allows to increase the environmental performance in North, but gives ambiguous results as far as South is concerned.

[3]There are many good reasons to assume that eco-firms locate in the country rather than exporting. First, these markets depend on local regulation, that can differ greatly from one country to another. Second, they also depend on local technical characteristics, such as the geography of a region. Therefore, it is one of the main issues that entrepreneurs from the sector raised when asked by governments (Numeri & R.D.I. 2004).

The rest of the paper proceeds as follows. Section 2 considers the monopoly case and sets up a neutrality condition. Section 3 examines environmental taxation when markets are segmented and two asymmetric firms compete in each country. Section 4 introduces a world market of environmental goods and services and studies the robustness of the previous results whether countries cooperate or not. Section 5 sums up our work.

2 Environmental taxation when the eco-industry is a monopoly

In this section, a second-best environmental taxation is chosen by two regulators, each one facing a polluting industry purchasing abatement technologies to a monopolistic eco-industry. The eco-industry firm is assumed to belong to Northern shareholders and discriminates among countries via two plants (or decision centers), one based in each country. Everything else being identical, we can focus on the specific consequences of the ownership pattern of an eco-industry on environmental taxation . First, both environmental markets are segmented, so there is no interaction. Second, we allow for an international market and show that market segmentation is a crucial assumption of the model.

This is a three stage game. In the first stage, the regulator chooses the tax so as to maximize its country's welfare. Welfare depends on consumers' surplus, on firms' profits and on the environmental damage. In a second stage, the environmental industry determines the level of production and the price of environmental goods, anticipating downstream demand. In a third stage, polluting firms compete so as to maximize their profits. They are assumed to be price-takers in the final good market. As usual, this game is solved by backward induction.

2.1 Optimal decision by polluting firms

Polluting firms maximize their profits, given prices of final and environmental goods. They also consider as given the pollution tax chosen by the regulator. We assume that in each country, there exists a continuum of firms, included between 0 and 1. Thus, a single firm can represent the overall market. So, in country $j = s, n$, its profit function can be written as follows:

$$\Pi_j(x_j, a_j) = P_j x_j - c(x_j) - p_j a_j - t_j(\epsilon(x_j) - w(a_j)) \tag{1}$$

where in each country, P_j is the final good market price,[4] $c(x_j)$ is an increasing and convex cost function, p_j the price of environmental goods, a_j the quantities purchased of environmental goods and $\epsilon(x_j) - w(a_j)$ the net emission function. We consider an end-of-pipe pollution, where $\epsilon(x_j)$ measures the link between production and polluted waste ($\epsilon'(x_j) > 0$, $\epsilon''(x_j) \geq 0$) and $w(a_j)$ expresses the abatement activities due to the purchase of a_j environmental goods. This

[4] $P(x_j)$ is the inverse demand function and determines the market price equilibrium.

function tends to reflect the growing difficulty in cleaning up polluted waste, i.e. the marginal efficiency of abatement activities is decreasing in a_j ($w'(a_j) > 0$ but $w''(a_j) < 0$). Each polluting firm maximizes its profits considering two variables, x_j and a_j. As production and pollution are additively separable, we first investigate the optimal level of production.

2.1.1 Production in final goods

First order conditions of profit maximization are, $\forall\ j = s, n$.

$$\frac{\partial \Pi_j}{\partial x_j} = P_j - c'(x_j) - t_j \epsilon'(x_j) = 0 \tag{2}$$

Second order conditions are:

$$\frac{\partial^2 \Pi_j}{\partial x_j^2} = -c''(x_j) - t_j \epsilon''(x_j) < 0 \tag{3}$$

First order conditions yield the optimal inverse supply function of polluting goods. At the market price equilibrium, supply equals demand ($P(x_j^*) = c'(x_j^*) + t_j \epsilon'(x_j^*)$). We assume that $x_j^*(t_j)$ exists and is unique.

2.1.2 Demand in environmental goods

Each polluting firm chooses the optimal level of environmental goods purchased, according to the tax and the price of environmental input. Thus, first and second order conditions are, $\forall\ j = s, n$:

$$\frac{\partial \Pi_j}{\partial a_j} = -p_j + t_j w'(a_j) = 0 \tag{4}$$

$$\frac{\partial^2 \Pi_j}{\partial a_j^2} = t_j w''(a_j) < 0 \tag{5}$$

Assuming an interior solution will be chosen, i.e. $\frac{p_j}{t_j} \in]0; \lim_{a_j \to 0} w'(a_j)[$, the downstream demand in environmental goods is given by $a_j = w'^{-1}(\frac{p_j}{t_j})$.

2.2 The eco-industry's decision

The eco-industry firm l[5] acts, via its two decision centers, as a monopoly in each local market. It anticipates the demand of downstream firms and chooses the optimal supply and the price equilibrium in environmental goods. Therefore, $\forall\ j = s, n$, its profit function Π_{lj}^{up} is such that:

$$\Pi_{lj}^{up} = \left(t_j w'(a_j)\right) a_j - c_l(a_j) \tag{6}$$

[5] As opposed to h for the Southern firm in the next section

where $t_j w'(a_j) = p_j(a_j)$ is the inverse demand function in environmental goods, a_j is the production of environmental goods in country j, and $c_l(a_j)$ the cost function of the eco-industry, identical in both countries. First and second order conditions are:

$$\frac{\partial \Pi_{lj}^{up}}{\partial a_j} = \left(t_j w''(a_j)\right) a_j + t_j w'(a_j) - c_l'(a_j) = 0 \tag{7}$$

$$\frac{\partial^2 \Pi_{lj}^{up}}{\partial a_j^2} = 2t_j w''(a_j) + t_j w'''(a_j) a_j - c_l''(a_j) < 0 \tag{8}$$

Equalizing supply and demand yields $a_j^*(t_j)$, the optimal level of environmental goods produced, according to the country's level of taxation. As the standard analysis of monopolies tells us, the price is fixed above marginal cost.

2.3 Welfare and optimal tax rates

Both welfare functions take account of the profits of polluting firms and consider the environmental damage. The only difference comes from the fact that in North, the regulator considers profits of the eco-industry[6] whereas in South, buying environmental goods and services only appears as costs for polluting firms.

$$\begin{aligned} W_n(t_n) &= \int_0^{x_n^*(t_n)} P(u)du - c\left(x_n^*(t_n)\right) - p_n a_n^*(t_n) + p_n a_n^*(t_n) \\ &- c_l\left(a_n^*(t_n)\right) + p_s a_s^*(t_s) - c_l\left(a_s^*(t_s)\right) - \nu\Big(\epsilon\left(x_n^*(t_n)\right) - w\left(a_n^*(t_n)\right)\Big) \end{aligned} \tag{9}$$

$$W_s(t_s) = \int_0^{x_s^*(t_s)} P(u)du - c(x_s^*(t_s)) - p_s a_s^*(t_s) - \nu\Big(\epsilon(x_s^*(t_s)) - w(a_s^*(t_s))\Big) \tag{10}$$

where ν is the marginal environmental damage, assumed constant. Totally differentiating these functions with respect to the tax rate gives the first order condition of welfare maximization.[7]

2.3.1 The regulator's decision in North

The welfare maximization condition in North is:

[6] As markets are segmented, profits made in South by the eco-industry are not influenced by the Northern regulator's decision. Therefore, they only appear as a constant in the Northern welfare function.

[7] In order to simplify the expressions, we drop the superscript * and the fact that optimal values of production depend on t_j. However, each time a regulator takes its decision, one must recall that it is given the equilibrium values of production that it anticipates.

$$\begin{aligned}\frac{dW_n(t_n)}{dt_n} &= P(x_n)\frac{dx_n}{dt_n} - c'(x_n)\frac{dx_n}{dt_n} \\ &- c_l'(a_n)\frac{da_n}{dt_n} - \nu\left(\epsilon'(x_n)\frac{dx_n}{dt_n} - w'(a_n)\frac{da_n}{dt_n}\right) = 0 \end{aligned} \tag{11}$$

Using Equations 2 and 7, this condition can be rewritten as follows:

$$(t_n - \nu)\epsilon'(x_n)\frac{dx_n}{dt_n} = (t_n - \nu)w'(a_n)\frac{da_n}{dt_n} + t_n w''(a_n)a_n\frac{da_n}{dt_n} \tag{12}$$

which yields, recalling that $t_n w''(a_n) = p_n'(a_n)$

$$t_n = \nu + \frac{p_n'(a_n)a_n\frac{da_n}{dt_n}}{\epsilon'(x_n)\frac{dx_n}{dt_n} - w'(a_n)\frac{da_n}{dt_n}} \tag{13}$$

Before giving a few comments, let us present the sense of direction of production and depollution according to variations in the tax rate. By totally differentiating first order conditions of polluting and environmental firms, and recalling that supply must equal demand in the final good market, we get: $\forall j = s, n$

$$\frac{dx_j}{dt_j} = \frac{\epsilon'(x_j)}{P'(x_j) - c''(x_j) - \epsilon''(x_j)} < 0 \tag{14}$$

$$\frac{da_j}{dt_j} = \frac{-(w''(a_j)a_j + w'(a_j))}{t_j w'''(a_j)a_j + 2t_j w''(a_j) - c_l''(a_j)} > 0 \tag{15}$$

So, as the denominator and numerator of the second term on the RHS of Equation 13 are always negative, a second best solution leads to $t_n^* > \nu$. We find again the results already presented by David & Sinclair-Desgagné (2005). There exists an incentive for the regulator to increase the tax above marginal damage so as to reach an optimal trade-off between abatement activities and downstream production levels.

2.3.2 The decision in South

Using the same methodology, the condition on welfare maximization in South is:

$$\begin{aligned}\frac{dW_s(t_s)}{dt_s} &= P(x_s)\frac{dx_s}{dt_s} - c'(x_s)\frac{dx_s}{dt_s} - p_s(a_s)\frac{da_s}{dt_s} - p_s'(a_s)a_s\frac{da_s}{dt_s} \\ &- \nu\left(\epsilon'(x_s)\frac{dx_s}{dt_s} - w'(a_s)\frac{da_s}{dt_s}\right) = 0 \end{aligned} \tag{16}$$

Rewriting this condition using Equation 2, 4 and 7 yields:

$$t_s = \nu + \frac{p_s'(a_s)a_s\frac{da_s}{dt_s}}{\epsilon'(x_s)\frac{dx_s}{dt_s} - w'(a_s)\frac{da_s}{dt_s}} \tag{17}$$

In other words, the optimality condition is the same in both countries. Even though welfares differ (in South, what matters is what polluting firms pay whereas in North it is only the costs to produce abatement activities), the optimal tax rate is identical.

When the eco-industry monopoly maximizes its profits, it chooses a level of production such as marginal benefit equals marginal cost. In the welfare maximization condition, what matters in North is the marginal cost of the eco-industry whereas in the South, it is the marginal benefit. In the same vein than what was found by Lee (1990) and Long & Soubeyran (2001*b*) in different contexts, a neutrality condition is given:

Proposition 1 *The nationality of a monopoly selling environmental goods and services to polluting industries does not influence the choice of an optimal second-best tax rate. Even though welfares differ, the tax rate chosen is independent of the ownership pattern.*

It is almost immediate to see that the neutrality condition holds if the monopoly is partially owned by domestic investors or if Northern eco-industry's profits are taxed in South. The result remains also true if there is competition among eco-industry firms under the condition that they all come from the same country. However, the neutrality condition does not encompass all possible cases, especially when environmental markets are not segmented.

2.4 Global market and environmental policies

We keep the same framework except that polluting firms can now buy environmental goods in both countries, without any further costs. Therefore, the price p of environmental goods is unique across countries, the result of the confrontation of global demand and global supply. First order conditions of welfare maximization become:

$$\begin{aligned}\frac{dW_s(t_s)}{dt_s} &= P(x_s)\frac{dx_s}{dt_s} - c'(x_s)\frac{dx_s}{dt_s} - p(a_s+a_n)\frac{da_s}{dt_s} - p'(a_s+a_n)a_s\frac{da_s}{dt_s} \\ &- p'(a_s+a_n)a_s\frac{da_n}{dt_s} - \nu\left(\epsilon'(x_s)\frac{dx_s}{dt_s} - w'(a_s)\frac{da_s}{dt_s}\right) = 0 \end{aligned} \tag{18}$$

$$\begin{aligned}\frac{dW_n(t_n)}{dt_n} &= P(x_n)\frac{dx_n}{dt_n} - c'(x_n)\frac{dx_n}{dt_n} - c_l'(a_n+a_s)\frac{da_n}{dt_n} - c_l'(a_n+a_s)\frac{da_s}{dt_n} \\ &- \nu\left(\epsilon'(x_n)\frac{dx_n}{dt_n} - w'(a_n)\frac{da_n}{dt_n}\right) = 0 \end{aligned} \tag{19}$$

Compared to the previous analysis, regulators consider the influence of a change in their policy on foreign demand and therefore on the new price equilibrium. Rewriting previous conditions yields:

$$t_s = \nu + \frac{p'(a_s + a_n) a_s \frac{dA}{dt_s}}{\epsilon'(x_s) \frac{dx_s}{dt_s} - w'(a_s) \frac{da_s}{dt_s}} \tag{20}$$

$$t_n = \nu + \frac{p'(a_s + a_n) A \frac{dA}{dt_n}}{\epsilon'(x_n) \frac{dx_n}{dt_n} - w'(a_n) \frac{da_n}{dt_n}} \tag{21}$$

where $A = a_s + a_n$. Both countries distort positively their environmental tax rate compared to the first best situation. However, in order to choose the optimal level of distortion, the Southern regulator only considers its country's demand (a_s) whereas the Northern regulator considers the world production (A). In other words, the second-best trade-off of the Southern regulator leads to a lower level of abatement than the one chosen by the country holding the eco-industry. In that country, the regulator considers the profit function of the eco-industry, and therefore its overall production.

In terms of policy recommendations, the environmental performance would be increased by decisions taken at a global level. Cooperation is useful, not because of a risk of tax competition but because some countries do not consider the overall supply of environmental goods and therefore do not endogenize the true mark-up that imperfect competition may create in the eco-industry market. Kirkspatrick et al. (2006) discuss some of the reasons that could explain that so little progress has been made in the trade liberalization in environmental services. Among them, they recall that Southern countries are quite reluctant to ask foreign firms to supply their local markets, especially when it has to do with such a sensitive sector as the water and sanitation one. From our analysis, one can understand that indeed, it would be in the interest of a Southern regulator to reduce its environmental taxation when subject to a world price of environmental goods and services and foreign firms only.

3 Pollution tax and asymmetric Cournot duopolies

In the previous section, when all eco-industry firms come from the same country and markets are segmented, environmental taxation does not differ according to the ownership pattern. Here, we study the consequences of competition among firms coming from different countries. A Southern firm, with higher production costs, enters the market. The asymmetric competition among foreign and local eco-industries justifies differences in environmental policies. However, the reasons differ from the previous section. Strategic rent-shifting effects appear as the main incentive to distort pollution tax rates.

3.1 Asymmetric Cournot competition in the environmental market

We assume that a Cournot-Nash strategic game takes place in the environmental sector between two asymmetric firms. Each firm has two decision centers, one in each country. Downstream, the last stage of the game is not modified. Polluting firms maximize their profits, which yields the overall inverse downstream demand in environmental goods in each country.

In the environmental market, each firm's decision center, in each country, maximizes its profit function, taking as given the production of the other decision center based in the country. So, $\forall\, j = s, n$

$$\Pi_{hj}^{up}(a_{hj}, a_{lj}) = p_j(a_j)a_{hj} - c_h(a_{hj}) \tag{22}$$

$$\Pi_{lj}^{up}(a_l, a_h) = p_j(a_j)a_{lj} - c_l(a_{lj}) \tag{23}$$

where for each country j, $p_j(a_j)$ is the overall inverse demand in environmental goods, a_{hj} the production of the Southern eco-industry, a_{lj} the production of the Northern eco-industry and $c_l(a_{lj})$ and $c_h(a_{hj})$ their respective cost functions. They are assumed linear and we suppose $c_l < c_h$ whatever the country. The difference in marginal production costs reflects the advantage of early movers that Norther firms hold. As environmental policies appeared sooner in developed countries, these eco-industry firms have been able to commit themselves to strategic capacities in a first stage of a strategic game. Consequently, we are facing the second stage of this game, when firms compete in quantities. According to Tirole (1995), this argument is of the same line that the one presented in Dixit (1980). Another explanation could be found in the fact that knowledge-based assets, as defined by Markusen (1995), remain in possession of the Northern multinational firm even when the plant is based in South, giving a competitive advantage to the Northern firm in both countries.

First order conditions for both firms are[8]: $\forall\, j = s, n$

$$\frac{\partial \Pi_{hj}^{up}}{\partial a_{hj}}(a_{lj}, a_{hj}) = p_j(a_j) + p_j'(a_j)a_{hj} - c_h = 0 \tag{24}$$

$$\frac{\partial \Pi_{lj}^{up}}{\partial a_{lj}}(a_{lj}, a_{hj}) = p_j(a_j) + p_j'(a_j)a_{lj} - c_l = 0 \tag{25}$$

The market share of the low-cost firm is always higher than the high-cost firm's one. However,

[8] We make the following assumptions in order to ensure the existence and uniqueness of a Nash-equilibrium:

Assumption 1 $\frac{\partial^2 \Pi_{hj}^{up}}{\partial a_{hj} a_{lj}} < 0$, $\frac{\partial^2 \Pi_{lj}^{up}}{\partial a_{lj} a_{hj}} < 0$

Assumption 2 $\frac{\partial^2 \Pi_{hj}^{up}}{\partial a_{hj}^2}\frac{\partial^2 \Pi_{lj}^{up}}{\partial a_{lj}^2} - \frac{\partial^2 \Pi_{hj}^{up}}{\partial a_{hj} a_{lj}}\frac{\partial^2 \Pi_{lj}^{up}}{\partial a_{lj} a_{hj}} > 0$

Assumption 1 means that reaction functions are downward sloping and Assumption 2 ensures the stability condition is satisfied. We are sure that there exists a unique Cournot-Nash equilibrium (a_{hj}^*, a_{lj}^*).

when tax rates vary, the sense of direction of market shares, given by comparative statics, is ambiguous. First, we can sum FOCs across the two firms: $\forall\, j = s, n$,

$$2p_j(a_j) + p'_j(a_j)a_j = c_h + c_l \tag{26}$$

As the market price of environmental goods is equal to $t_j w'(a_j)$, this equation can be rewritten by dividing both sides by t_j:

$$2w'(a_j) + a_j w''(a_j) = \frac{c_h + c_l}{t_j} \tag{27}$$

Totally differentiating this equation, we get:

$$\left(3w''(a_j) + a_j w'''(a_j)\right) da_j = \frac{-1}{t_j^2}(c_h + c_l)dt_j \tag{28}$$

which yields:

$$\frac{da_j}{dt_j} = \frac{-(c_h + c_l)}{t_j^2\left(3w''(a_j) + a_j w'''(a_j)\right)} \tag{29}$$

Given the assumptions made in order to ensure the existence and uniqueness of a solution, the denominator is always negative.

Lemma 1 *Whatever the country, pollution tax rates and overall environmental production vary in the same direction.*

As recalled by Long & Soubeyran (2001a), the equilibrium industry output is uniquely determined by the sum of marginal production costs. Furthermore, it is negatively correlated to this sum. Increasing a tax is equivalent to reducing the overall marginal production costs of the environmental industry. It gives an intuition to the positive correlation between tax and environmental production.

Within this framework, we specify the production patterns for both firms. Dividing both first order conditions by the tax rate and totally differentiating the equations yields, $\forall\, i = h, l$, $\forall\, j = s, n$:

$$w''(a_j)da_{ij} + (w''(a_j) + w'''(a_j)a_{ij})da_j = \frac{c_j}{t_j^2}dt_j \tag{30}$$

Using equation 29, and rearranging the expression, we present the comparative statics for the most efficient firm:

$$\frac{da_{lj}}{dt_j} = \frac{-1}{t_j^2 w''(a_j)}\left(\frac{c_l\left(2w''(a_j) + w'''(a_j)(a_j - a_{lj})\right) - c_h\left(w''(a_j) + w'''(a_j)a_{lj}\right)}{3w''(a_j) + a_j w'''(a_j)}\right) \tag{31}$$

This expression can either be positive or negative. For instance, when the marginal efficiency of marginal depollution is constant ($w''(a_j) = cst$, i.e. $p''_j(a_j) = 0$), $sign(\frac{da_{lj}}{dt_j}) = sign(2c_l - c_h)$.

In other words, in this context, if the low-cost firm is much more efficient than the high-cost one ($2c_l - c_h < 0$),[9] an increase in the tax leads to a decrease in the low-cost firm's production.[10] In a more general context, it all depends on the sign of the term $\alpha = w''(a_j)(2c_l - c_h) + w'''(a_j)(c_l a_{hj} - c_h a_{lj})$.

Lemma 2 *If α is negative (resp. positive), the production of the low-cost firm increases (resp. decreases) in the tax rate. When the marginal depollution is constant, a high difference in marginal production costs yields $\alpha < 0$.*

The condition for the high-cost firm is the following one:

$$\frac{da_{hj}}{dt_j} = \frac{-1}{t_j^2 w''(a_j)} \left(\frac{c_h \left(2w''(a_j) + w'''(a_j)(a_j - a_{hj})\right) - c_l \left(w''(a_j) + w'''(a_j)a_{hj}\right)}{3w''(a_j) + a_j w'''(a_j)} \right) \tag{32}$$

If $\beta = c_h \left(w''(a_j)(2 - \frac{c_l}{c_h}) + w'''(a_j)(a_{lj} - a_{hj}\frac{c_l}{c_h}) \right)$ is negative (resp. positive), the production of the less efficient firm decreases (resp. increases) in t_j. When Assumption 1 holds, this term is always negative.[11]

Lemma 3 *Whatever the country, an increase in the tax rate always increases the production of the high-cost firm.*

Lemma 4 *As β is always higher than α, an increase (resp. a decrease) in the environmental tax rate leads to an increase (resp. a decrease) in the market share of the high-cost firm and a decrease (resp. an increase) in the market share of the low-cost firm.*

Appendix 6.1 presents what would be the price and consumption of environmental goods and services according to the tax rates when using specific functions.

3.2 Regulators' decisions

Regulators are concerned by the variations in firms' market shares. It appears in the first order condition of welfare maximization.

[9]The low-cost firm enters the market as soon as $t_j > 2c_l - c_h$ and the high cost firm when $t_j > 2c_h - c_l$. Therefore, the case discussed can be encountered when both firms have a strictly positive level of production.

[10]This condition is similar to the one presented in Carraro & Soubeyran (1996), where a polluting firm would benefit from an environmental policy if another firm pollutes twice as much per unit of output.

[11]In Simpson (1995), a pollution tax induced transfers from the low-efficient polluting firm to the high-efficient polluting firm. As in our case, the tax induces transfers in the opposite directions, further work in this direction should precise what are the true welfare consequences of an increase in the pollution tax.

3.2.1 Domestic competition in South

Compared to the previous section, the welfare function must take account of the profit of the domestic eco-industry, recalling that it has the highest production costs.

$$W_s(t_s) = \int_0^{x_s} P(u)du - c(x_s) - p_s(a_s)a_s + p_s(a_s)a_{hs} - c_h(a_{hs}) - \nu\left(\epsilon(x_s) - w(a_s)\right) \qquad (33)$$

where a_s is the overall demand in environmental goods in South, a_{hs} the demand satisfied by the domestic firm and $c_h(a_{hs})$ its cost function. Totally differentiating the program yields:

$$\begin{aligned}
\frac{dW_s(t_s)}{dt_s} &= P(x_s)\frac{dx_s}{dt_s} - c'(x_s)\frac{dx_s}{dt_s} - p_s(a_s)\frac{da_s}{dt_s} - p_s'(a_s)a_s\frac{da_s}{dt_s} \\
&+ (p_s(a_s) + p_s'(a_s)a_{hs} - c_h'(a_{hs}))\frac{da_{hs}}{dt_s} + (p_s'(a_s)a_{hs})\frac{da_{ls}}{dt_s} \\
&- \nu\left(\epsilon'(x_s)\frac{dx_s}{dt_s} - w'(a_s)\frac{da_s}{dt_s}\right) = 0 \qquad (34)
\end{aligned}$$

Using the conditions on the firms' profit maximization leads to:

$$t_s = \nu + \frac{p_s'(a_s)\left(a_s\frac{da_s}{dt_s} - a_{hs}\frac{da_{ls}}{dt_s}\right)}{\epsilon'(x_s)\frac{dx_s}{dt_s} - w'(a_s)\frac{da_s}{dt_s}} \qquad (35)$$

Compared to the monopoly's analysis, not only do variations in total production matter but also variations in the production of one specific firm, the foreign one.[12] In other words, the tax is positively distorted so as to increase incentives in abatement activities, but the distortion could be strengthened or lowered according to variations in the foreign firm's production. In general, it is not in the interest of the regulator to increase the tax, as it leads to more production for the foreign firm. However, recalling Lemma 2, in some cases, low-cost firms' outputs decrease. In addition to regulating the environmental damage, it is possible to reduce the influence of foreign firms in the country. A kind of double dividend argument appears in favor of more stringent environmental policies.

Proposition 2 *(i) When both firms increase their production pattern in the tax rate, the Southern regulator chooses a tax lower than what would have been necessary if both firms had been from the same country. (ii) When the production of the foreign firm decreases in the tax, there is an incentive for the regulator to over-tax, in order to shift more rents toward national firms.*

[12] In South, the foreign firm is the low-cost one.

Proof: Comparing Equations 17 and 35, the only difference comes from the term $-p_s'(a_s)a_{hs}\frac{da_{ls}}{dt_s}$. If this term is positive (resp. negative), it tends to lower (resp. intensify) the impact of imperfect competition among polluting firms on the second-best tax rate. □

In a sense, this model is similar to the one of Simpson (1995). The author studies the possibility for some asymmetric polluting firms competing à la Cournot to increase their production when they are subject to more stringent environmental taxation. We use the same argument, but about competition at an upstream level, when environmental taxation increases demand and can benefit the less efficient firms.

3.2.2 Foreign competition in North

We now introduce competition in North, where a less efficient firm than the domestic one enters the market. It changes the welfare function and modifies the optimal environmental policy.

$$W_n(t_n) = \int_0^{x_n} P(u)du - c(x_n) - p_n(a_n)a_n + p_n(a_n)a_{ln} - c_l(a_{ln}) - \nu\left(\epsilon(x_n) - w(a_n)\right) \tag{36}$$

The first order condition of welfare maximization yields:

$$t_n = \nu + \frac{p_n'(a_n)\left(a_n\frac{da_n}{dt_n} - a_{ln}\frac{da_{hn}}{dt_n}\right)}{\epsilon'(x_n)\frac{dx_n}{dt_n} - w'(a_n)\frac{da_n}{dt_n}} \tag{37}$$

As the production of the less efficient firm is positively correlated with the tax rate, the last term of the numerator is positive, which tends to lower the tax compared to the situation where both firms were domestic. In other words, when the market size is large enough for two firms to enter, the regulator lowers its environmental standards to reduce the rent-shifting toward foreign firms.

By comparing the distortions induced by foreign competition in both countries, we find that the tax in North is always lower than the tax in South. In fact, $a_{ln}\frac{da_{hn}}{dt_n} > a_{hn}\frac{da_{ln}}{dt_s}$, which means that market shares are shifted toward the high-cost firm in both countries when the tax rate is increased.

Proposition 3 *In the presence of an asymmetric Cournot oligopoly in a local environmental market, it is in the country where domestic firms are the most efficient that the tax rate should be the lowest.*

The choice of an optimal tax is the result of a trade-off between the fact that polluting firms do not abate enough and the fact that part of the environmental market is supplied by a foreign firm, sending profits abroad. When the latter effect dominates the former, the optimal Northern tax rate can even fall short of marginal damage, even though polluting firms are perfectly competitive. The following section is devoted to check the robustness of these results when the environmental market is open to international trade.

4 Tax competition

In this section, we consider eco-industry firms when they cannot discriminate between countries. There exists a unique world price of environmental goods and services. Two eco-industry firms, one based in each country, compete so as to supply the overall demand from polluting firms. There is no transport costs or tariffs so that polluting firms buy indifferently to foreign or domestic firms. Countries are symmetric apart from the production costs of eco-industries. Countries' decisions are now interrelated. Both non-cooperative and cooperative decisions are considered in this context.

4.1 Comparative statics

The analysis has been simplified by specifying the depollution function. The results would be of the same vein with more general depollution functions. We assume that $w(a_j) = a_j - \frac{1}{2}a_j^2$. This function respects the assumptions needed in order to ensure that a Cournot-Nash equilibrium exists in the environmental market. Using this function, Appendix 6.2 gives the details leading to the following comparative statics, deduced from the last two stages of the game (competition in final good and environmental goods and services markets).

$$\frac{da_l}{dt_j} = \frac{2c_l - c_h}{3t_j^2}, \quad \frac{da_h}{dt_j} = \frac{2c_h - c_l}{3t_j^2}, \quad \frac{dA}{dt_j} = \frac{c_l + c_h}{3t_j^2}, \quad \forall\, j = s, n \tag{38}$$

No matter which country modifies its tax rate, the production of the high cost firm varies in the same direction whereas the variation in the production of the low cost firm depends on the difference in production costs. The overall production of environmental goods is always positively correlated with tax rates.

On the demand side, the impact of a change in one of the tax in both countries is:

$$\frac{da_j}{dt_j} = \frac{1}{3}\left(\frac{c_l + c_h}{t_j^2} + \frac{2t_{-j}}{(t_j + t_{-j})^2}\right) \tag{39}$$

$$\frac{da_j}{dt_{-j}} = -\frac{2t_j}{3(t_j + t_{-j})^2} \tag{40}$$

An increase in the domestic tax reduces the consumption of foreign environmental goods, because the price of environmental goods is increased, without changing foreign incentives. It plays an important role in the choice of the optimal tax rate which did not appear when markets were segmented.

4.2 Non-cooperative strategies

Both countries choose simultaneously their environmental policy. When the polluting sector is imperfectly competitive, the common fear is that it would lead to a race-to-the-bottom so as to protect domestic competitiveness. In this model, polluting firms are perfectly competitive but the environmental policy determines the demand for the imperfectly competitive eco-industry. Tax competition can change the incentives previously described. National welfare depends on local and foreign tax rates as both taxes influence the market price of environmental goods.

$$\begin{aligned} W_s(t_s,t_n) &= \int_0^{x_s} P(u)du - c(x_s) - p(A)a_s \\ &+ p(A)a_h - c_h(a_h) - \nu\left(\epsilon(x_s) - w(a_s)\right) \end{aligned} \tag{41}$$

$$\begin{aligned} W_n(t_s,t_n) &= \int_0^{x_n} P(u)du - c(x_n) - p(A)a_n \\ &+ p(A)a_l - c_l(a_l) - \nu\left(\epsilon(x_n) - w(a_n)\right) \end{aligned} \tag{42}$$

Each country considers in its welfare function the demand of its polluting firms and the profit of its eco-industry firm. Each regulator is going to choose its tax taking the emission tax of the other country as given. However, it takes into account the impact of a change in the tax on the world price of environmental goods. First order conditions of welfare maximization are, for both countries.

$$\begin{aligned} \frac{dW_s(t_s,t_n)}{dt_s} &= P(x_s)\frac{dx_s}{dt_s} - c'(x_s)\frac{dx_s}{dt_s} - p(A)\frac{da_s}{dt_s} - p'(A)a_s\frac{da_s}{dt_s} - p'(A)a_s\frac{da_n}{dt_s} \\ &+ \left(p(A) + p'(A)a_h - c_h'(a_h)\right)\frac{da_h}{dt_s} + p'(A)a_h\frac{da_l}{dt_s} \\ &- \nu\left(\epsilon'(x_s)\frac{dx_s}{dt_s} - w'(a_s)\frac{da_s}{dt_s}\right) = 0 \end{aligned} \tag{43}$$

$$\begin{aligned} \frac{dW_n(t_n,t_s)}{dt_n} &= P(x_n)\frac{dx_n}{dt_n} - c'(x_n)\frac{dx_n}{dt_n} - p(A)\frac{da_n}{dt_n} - p'(A)a_n\frac{da_n}{dt_n} - p'(A)a_n\frac{da_s}{dt_n} \\ &+ \left(p(A) + p'(A)a_l - c_l'(a_l)\right)\frac{da_l}{dt_n} + p'(A)a_l\frac{da_h}{dt_n} \\ &- \nu\left(\epsilon'(x_n)\frac{dx_n}{dt_n} - w'(a_n)\frac{da_n}{dt_n}\right) = 0 \end{aligned} \tag{44}$$

Using the firms' profit maximization conditions and rearranging the expressions gives:

$$t_s = \nu + \frac{p'(A)\left(a_s \frac{da_s}{dt_s} + a_s \frac{da_n}{dt_s} - a_h \frac{da_l}{dt_s}\right)}{\epsilon'(x_s)\frac{dx_s}{dt_s} - w'(a_s)\frac{da_s}{dt_s}} \tag{45}$$

$$t_n = \nu + \frac{p'(A)\left(a_n \frac{da_n}{dt_n} + a_n \frac{da_s}{dt_n} - a_l \frac{da_h}{dt_n}\right)}{\epsilon'(x_n)\frac{dx_n}{dt_n} - w'(a_n)\frac{da_n}{dt_n}} \tag{46}$$

Proposition 4 *(i) A single world market and non-cooperative behaviors induce a new negative incentive to the choice of the environmental taxation. (ii) The tax rate chosen remains lower in the country having the most efficient firms.*

Proof: (i) The terms into brackets of the numerators of Equations 45 and 46 summarize the strategic incentives. In addition to the impact on the supply side of the environmental sector, regulators consider the impact of a change of their own tax on the overall demand. As the price of environmental inputs is increased by the tax, the foreign demand is always decreased, which lowers the optimal second-best tax rate in the domestic country. The denominator refers to the same terms than in Equations 35 and 37. (ii) The line of argument is similar to the one presented in Proposition 3. Whatever the tax rates, $a_l \frac{da_h}{dt_n} > a_h \frac{da_l}{dt_s}$. Therefore, if both tax rates were identical, the RHS of Equations 45 and 46 would be different, which is in contradiction with the assumption of similar tax rates. Indeed, it would not be possible to find an optimal Northern tax rate higher than in South. □

A decomposition of the optimal tax rate. Rewriting the previous conditions as in Duval & Hamilton (2002), it becomes possible to present the three kind of incentives playing a role in the choice of the environmental taxation.

$$t_s = \nu + \frac{p'(A)}{\epsilon'(x_s)\frac{dx_s}{dt_s} - w'(a_s)\frac{da_s}{dt_s}}\left((a_s - a_h)\frac{da_l}{dt_s} + a_s\frac{da_h}{dt_s}\right) \tag{47}$$

$$t_n = \nu + \frac{p'(A)}{\epsilon'(x_n)\frac{dx_n}{dt_n} - w'(a_n)\frac{da_n}{dt_n}}\left((a_n - a_l)\frac{da_h}{dt_n} + a_n\frac{da_l}{dt_n}\right) \tag{48}$$

First, there is the marginal environmental damage caused by domestic polluting firms.[13] Then, the terms into brackets on the RHS of Equations 47 and 48 sum up a terms-of-trade effect and an imperfect competition effect. The sign of the terms-of-trade effect is determined by the trade balance of each country and the comparative statics of eco-industry firms. Assume

[13] Note that we have always assumed that the marginal environmental damage of pollution was identical between countries. If it was lower in South, which in a sense seems more plausible, then the optimal tax rate would be negatively distorted.

that the difference in production costs is not too important (i.e. the level of production of both firms increases in the tax rate), then there is a positive (resp. negative) incentive on the level of taxation for the net importer (resp. net exporter). The imperfect competition effect, taking into account the sub-optimal level of abatement supplied by local eco-industry firms, will be positive as long as a more stringent environmental policy increases both eco- industry firms' production patterns. As, so far, the tax rate should be lower in North and that Northern firms, because they are the most efficient, hold more than one half of the market shares, North is net exporter in this world. So, there is a trade-off in the choice of the environmental policy. If the terms-of-trade effect is more important than the imperfect competition one, the environmental tax could even fall short of marginal damage. Note that this trade-off is different from the one presented in Section 3 as there was no trade effects when markets were segmented.

A remark about the impact of tax rates on net pollution Studying equilibrium tax rates is only a first step in the analysis of the impact of eco-industry firms on local pollution. Introducing international environmental markets adds an incentive to lower tax rates in both countries, compared to segmented markets. If optimal tax rates decrease, the production from polluting firms is higher in each country and thus gross emissions are necessarily more important. In terms of abatement activities, two effects need to be considered. First, the impact via the change in the tax rate but also the impact via the change in the market price. If we use the specific functions already presented, it results (cf Appendix 6.3) in a lower level of abatement in North but the impact is ambiguous in South. It simply means that the negative impact of a decrease in the tax rate on abatement demand can be more than compensated by a positive impact due to a decrease in the market price. Therefore, an international market for abatement goods and services tends to worsen the environmental condition in Northern countries and has an ambiguous impact in Southern ones.

4.3 A cooperative strategy

Assume now that regulators join their decisions and consider the overall welfare.[14] It is generally assumed that it would hamper the decision to lower the tax rate and therefore would prevent too much pollution. In our context, maximizing the overall welfare would mean to consider the following equation:

$$\begin{aligned} W^C(t_s, t_n) &= \int_0^{x_s} P(u)du + \int_0^{x_n} P(u)du - c(x_s) - c(x_n) \\ &- c_l(a_l) - c_h(a_h) - \nu\big(\epsilon(x_s) + \epsilon(x_n) - w(a_s) - w(a_n)\big) \end{aligned} \tag{49}$$

[14]It also means that side payments are possible among countries

Maximizing this function with regard to t_n and t_s yields:

$$t_s = \nu + \frac{p'(A)\left(a_l \frac{da_l}{dt_s} + a_h \frac{da_h}{dt_s}\right)}{\epsilon'(x_s)\frac{dx_s}{dt_s} - w'(a_n)\frac{da_n}{dt_s} - w'(a_s)\frac{da_s}{dt_s}} \tag{50}$$

$$t_n = \nu + \frac{p'(A)\left(a_l \frac{da_l}{dt_n} + a_h \frac{da_h}{dt_n}\right)}{\epsilon'(x_n)\frac{dx_n}{dt_n} - w'(a_n)\frac{da_n}{dt_n} - w'(a_s)\frac{da_s}{dt_n}} \tag{51}$$

Given the comparative statics presented above,[15] even though eco-industry firms are asymmetric, a cooperative decision leads to an identical cooperative tax in both countries. As is the case where eco-industries came from the same country, it is the overall production that matters and not market shares.

Proposition 5 *(i) Cooperative taxation leads to similar taxes in both countries. (ii) the tax is increased in North compared to the non-cooperative decision whereas the impact in South remains ambiguous.*

Proof: See Appendix 6.4.

It is generally assumed that non-cooperative taxation leads to lower levels of taxation than the optimal cooperative decision. Tax competition is considered as sub-optimal in the sense that it does not protect enough the environment. In our approach, this line of argument can be used when one talks about the Northern case. However, as far as South is concerned, the rent-shifting effect emphasized in the previous section can lead to too much protection of the environment. It is the way to increase market shares of high-cost firms. In this case, it would be in the interest of a global regulator to reduce the stringency of the environmental policy. It would help maintaining a correct level of consumers' surplus. So, one can see that sub-optimal levels of environmental taxation do not always lead to a reduction in the environmental performance. The environment can also be over-protected.

5 Conclusion

This work considers environmental taxation when cleaning up activities are supplied by international eco-industries. The first concern was whether foreign-owned eco-industries could act as a brake on the stringency of environmental policies in less developed countries. From that point of view, the answer would rather be no. The only case where a Southern regulator would choose a lower level of environmental taxation than what would have been needed is when eco-industries are all foreign-owned and the market for environmental goods is global. If it is true that 90%

[15] Tax variations give similar impacts on supply and demand, whatever the country considered

of eco-industries come from OECD countries, it is also true that environmental markets are relatively segmented, often due to technical or geographical considerations. However, the WTO objective of a trade liberalization in environmental goods and services, directed to a better consideration of environmental issues in deve- loping countries, should be carefully considered as it could lead to lower environmental taxation in the poorest countries.

Moreover, compared to the traditional strategic environmental trade analysis, regulators behave strategically so as to shift rents not in the final good market but at an upstream level. It leads to rather surprising results. When countries differ according to the efficiency of their environmental industry, the environmental taxation should be higher for the least efficient countries. It allows those countries, in addition to the environmental benefit, to increase their market shares in the eco-industry sector. However, it does not mean that the overall welfare will be increased, notably because it leads to less efficiency among eco-industry firms. The argument that tax competition damages the environment remains partly relevant. It is true in the country with the most efficient firms but not necessarily in the other one. Therefore, the cooperative strategy does not necessarily have to improve the overall environmental performance.

This work presents important caveats. We do not endogenize the market structure in the environmental market. A free entry assumption would lead to more firms and maybe less profits. In the long run, the less efficient firms will also disappear or will have to become more effective. Furthermore, there are other raising issues when dealing with eco-industries. As eco-industries can also be seen as a source of employment, an important extension seems to reconsider the traditional trade-off between unemployment and environmental performance. Finally, if the regulator can manipulate the tax to shift rents, the opposite argument should also be relevant: there is no reason not to assume that the eco-industry will not try to influence the environmental policy.

6 Appendix

6.1 Price and consumption of environmental goods and services

Let us consider country s (South) and present the second stage of the game (the environmental market equilibrium). We take the tax rate as given (first stage), so the analysis is symmetric for country n. We specify the depollution function : $w(a_s) = a_s - \frac{1}{2}a_s^2$. The overall inverse demand is then: $p_s(a_s) = t_s(1 - a_s)$. Environmental firms anticipate the demand in order to maximize their profits, competing in a Cournot-Nash strategic game.

$$\Pi^{up}_{a_{hs}} = t_s(1 - (a_{hs} + a_{ls}))a_{hs} - c_h a_{hs} \tag{52}$$

$$\Pi^{up}_{a_{ls}} = t_s(1 - (a_{hs} + a_{ls}))a_{ls} - c_l a_{ls} \tag{53}$$

First order conditions of profit maximization give the reaction functions of both firms. From the reaction functions, an optimal level of production for each firm is determined. Basic algebra yields:

$$a_{ls} = \frac{t_s - 2c_l + c_h}{3t_s}; \; a_{hs} = \frac{t_s - 2c_h + c_l}{3t_s}; \; a_s = a_{hs} + a_{ls} = \frac{2t_s - c_l - c_h}{3t_s} \tag{54}$$

Comparative statics from this optimal levels of production give:

$$\frac{da_{ls}}{dt_s} = \frac{2c_l - c_h}{3t_s^2}; \; \frac{da_{hs}}{dt_s} = \frac{2c_h - c_l}{3t_s^2}; \; \frac{da_s}{dt_s} = \frac{c_l + c_h}{3t_s^2} \tag{55}$$

The equilibrium price of environmental inputs can now be deduced from the optimal level of production: $p_s = \frac{c_l+c_h+t_s}{3}$. Profits are then, for both firms: $\Pi^{up}_{a_{hs}} = \frac{(t_s+c_l-2c_h)^2}{9t_s}$ and $\Pi^{up}_{a_{ls}} = \frac{(t_s+c_h-2c_l)^2}{9t_s}$.

6.2 Comparative statics

We describe the last two stages of the game. It allows us to consider comparative statics. In each country, it is assumed that polluting firms are similar, choosing their environmental demand as follows:

$$p = t_j(1 - a_j), \; \forall \; j = s, n \tag{56}$$

where p is the world price of environmental goods. The overall demand is the sum of national demands. The functions are invertible:

$$a_n + a_s = A = 2 - \frac{p}{t_n} - \frac{p}{t_s} \tag{57}$$

From this equation, we find the overall inverse demand:

$$p(A) = \frac{t_n t_s}{t_n + t_s}(2 - A) \tag{58}$$

Everything else being identical, the price of environmental goods and services increases when the tax rate is increased in one of the countries ($p'_{t_j} > 0$). Eco-industry firms, based in each country, compete in a Cournot-Nash strategic game.

$$\Pi^{up}_{a_h} = \frac{t_n t_s}{t_n + t_s}(2 - (a_h + a_l))a_h - c_h a_h \tag{59}$$

$$\Pi^{up}_{a_l} = \frac{t_n t_s}{t_n + t_s}(2 - (a_h + a_l))a_l - c_l a_l \tag{60}$$

First order conditions of profit maximization give the reaction functions of both firms. From the reaction functions, an optimal level of production for each firm is determined. Basic algebra yields:

$$a_l = \frac{2t_nt_s - 2c_l(t_n+t_s) + c_h(t_n+t_s)}{3t_nt_s} \tag{61}$$

$$a_h = \frac{2t_nt_s - 2c_h(t_n+t_s) + c_l(t_n+t_s)}{3t_nt_s} \tag{62}$$

$$A = a_h + a_l = \frac{(4t_n - c_l - c_h)t_s - (c_l+c_h)t_n}{3t_nt_s} \tag{63}$$

The equilibrium price of environmental inputs can now be deduced from the optimal level of production:

$$p = \frac{(c_l+c_h)t_n + (c_l+c_h+2t_n)t_s}{3(t_n+t_s)} \tag{64}$$

From this price, we deduce the optimal demand in environmental goods and services of polluting firms in both countries.

$$a_j = \frac{3t_j + t_{-j}}{3(t_j+t_{-j})} - \frac{c_l+c_h}{3t_j}, \forall\, j, -j \in [s,n] \tag{65}$$

6.3 Comparison of abatement decisions

First, one can compare the optimal abatement decisions in North when markets are partitioned (t_n^p) with abatement decisions when markets are worldwide (t_n^w).

$$\begin{aligned} a_n^w < a_n^p \quad &\Leftrightarrow \quad \frac{3t_n^w + t_s^w}{3(t_n^w+t_s^w)} - \frac{c_l+c_h}{3t_n^w} < \frac{2}{3} - \frac{c_l+c_h}{3t_n^p} \\ &\Leftrightarrow \quad \frac{t_n^w - t_s^w}{3(t_s^w+t_n^w)} < \frac{(c_l+c_h)(t_n^p - t_n^w)}{3t_n^w t_n^p} \end{aligned} \tag{66}$$

As the tax rate is always lower in North than in South and that it is lower when the market is international rather than segmented, the previous condition is always satisfied (the LHS will always be negative and the RHS always positive). Therefore, at least with specific functions, net emissions are more important in North when there is international competition.

The condition in South is:

$$\begin{aligned} a_s^w < a_s^p \quad &\Leftrightarrow \quad \frac{3t_s^w + t_n^w}{3(t_s^w+t_n^w)} - \frac{c_l+c_h}{3t_s^w} < \frac{2}{3} - \frac{c_l+c_h}{3t_s^p} \\ &\Leftrightarrow \quad \frac{t_s^w - t_n^w}{3(t_s^w+t_n^w)} < \frac{(c_l+c_h)(t_s^p - t_s^w)}{3t_s^w t_s^p} \end{aligned} \tag{67}$$

Both sides of this inequation are positive. Therefore, it is not possible to conclude in a general context whether abatement activities will be decreased or increased.

6.4 Proof of Proposition 3.5

First, let us notice that the denominator of Equation 51 is necessarily higher than the denominator of Equation 46, but still negative. Therefore, if $a_l \frac{da_l}{dt_n} + a_h \frac{da_h}{dt_n}$ is higher than $a_n \frac{dA}{dt_n} - a_l \frac{da_h}{dt_n}$, the cooperative tax is higher than the non-cooperative tax. Considering that the market share of the low-cost firm is always higher than one half and that the demand in environmental goods will be identical in both countries when cooperative decisions are chosen, this condition is necessarily satisfied.

In South, both cases can appear, namely either a higher or a lower cooperative tax compared to the non cooperative one. It can be shown by comparing first-order conditions of welfare maximization in both cases:

$$t_s^C - \nu = \frac{p'(A)\left(a_l \frac{da_l}{dt_s} + a_h \frac{da_h}{dt_s}\right)}{\epsilon'(x_s)\frac{dx_s}{dt_s} - w'(a_n)\frac{da_n}{dt_s} - w'(a_s)\frac{da_s}{dt_s}} \tag{68}$$

$$t_s^{NC} - \nu = \frac{p'(A)\left((a_s - a_h)\frac{da_l}{dt_s} + a_s \frac{da_h}{dt_s}\right)}{\epsilon'(x_s)\frac{dx_s}{dt_s} - w'(a_s)\frac{da_s}{dt_s}} \tag{69}$$

First, let us present the most intuitive case where the cooperative tax is higher than the non-cooperative one. Let us assume that eco-industry firms are similar, i.e. marginal costs are equal. Thus:

$$\begin{aligned} t_s^C > t_s^{NC} \quad &\Leftrightarrow \quad \frac{p'(A)\left(a_l \frac{da_l}{dt_s} + a_h \frac{da_h}{dt_s}\right)}{\epsilon'(x_s)\frac{dx_s}{dt_s} - w'(a_n)\frac{da_n}{dt_s} - w'(a_s)\frac{da_s}{dt_s}} > \frac{p'(A)\left((a_s - a_h)\frac{da_l}{dt_s} + a_s \frac{da_h}{dt_s}\right)}{\epsilon'(x_s)\frac{dx_s}{dt_s} - w'(a_s)\frac{da_s}{dt_s}} \\ &\Leftrightarrow \quad \frac{a_l \frac{da_l}{dt_s} + a_h \frac{da_h}{dt_s}}{\epsilon'(x_s)\frac{dx_s}{dt_s} - w'(a_n)\frac{da_n}{dt_s} - w'(a_s)\frac{da_s}{dt_s}} < \frac{a_s \frac{da_h}{dt_s}}{\epsilon'(x_s)\frac{dx_s}{dt_s} - w'(a_s)\frac{da_s}{dt_s}} \end{aligned} \tag{70}$$

When everything is the same in both countries, non-cooperative taxes and market shares of eco-industry firms are necessarily identical. Thus, the numerator on the LHS of this condition is more important than the second one. As denominators are both negative, the first one being less negative than the second one, we have: $t_s^C > t_s^{NC}$.

Second, the non-cooperative tax can be more important than the cooperative one. Let us consider the case where $\frac{da_l}{dt_s} = 0$. When depollution and cost functions are linear, it will happen iff $2c_l = c_h$. It simplifies the comparison of first order conditions.

$$\begin{aligned} t_s^C < t_s^{NC} \quad &\Leftrightarrow \quad \epsilon'(x_s)(a_s - a_h)\frac{dx_s}{dt_s} < w'(a_s)(a_s - a_h)\frac{da_s}{dt_s} + w'(a_n)a_s\frac{da_n}{dt_s} \\ t_s^C < t_s^{NC} \quad &\Leftrightarrow \quad \epsilon'(x_s)\frac{dx_s}{dt_s} < w'(a_s)\frac{da_s}{dt_s} + \frac{w'(a_n)a_s\frac{da_n}{dt_s}}{a_s - a_h} \end{aligned} \tag{71}$$

The LHS of this condition is necessarily negative. Furthermore, it decreases in $\epsilon'(x_s)$. As the depollution function is additively separable, a higher $\epsilon'(x_s)$ does not influence the RHS. Therefore, there exists a threshold $\bar{\epsilon'}$ from which this condition will be fulfilled. □

References

Barrett, S. (1994), 'Strategic environmental policy and international trade', *Journal of Public Economics* **54**, 325–358.

Barton, J. R. (1997), 'The north-south dimension of the environment and cleaner technology industries', *Discussion paper, Institute for New Technologies, United Nations University, Maastricht* .

Brander, J. and Spencer, B. J. (1985), 'Export subsidies and international market share rivalry', *Journal of International Economics* **18**, 83–100.

Canton, J., Soubeyran, A. and Stahn, H. (2005), 'Environmental taxation and vertical cournot oligopolies: How eco-industries matter', *In revision for Environmental and Resource Economics* .

Carraro, C. and Soubeyran, A. (1996), *Environmental Taxation, Market Share and Profits in Oligopoly*, Kluwer Academic Publishers Dordrecht.

Copeland, B. R. (2005), 'Pollution policy and the market for abatement services', *Work in Progress: presented during the EAERE conference in Bremen* .

David, M. and Sinclair-Desgagné, B. (2005), 'Environmental regulation and the eco-industry', *Journal of Regulatory Economics* **28**(2), 141–155.

Dixit, A. K. (1980), 'The role of investment in entry deterrence', *Economic Journal* **90**, 95–106.

Duval, Y. and Hamilton, S. F. (2002), 'Strategic environmental policy and international trade in asymmetric oligopoly markets', *International Tax and Public Finance* **9**, 259–271.

Fees, E. and Muehlheusser, G. (2002), 'Strategic environmental policy, clean technologies and the learning curve', *Environmental and Resource Economics* **23**, 149–166.

Greaker, M. (2003), 'Strategic environmental policy; eco-dumping or a green strategy ?', *Journal of Environmental Economics and Management* **45**, 692–707.

Greaker, M. (2006), 'Spillovers in the development of new pollution abatement technology: A new look at the porter-hypothesis', *Journal of Environmental Economics andManagement* **56**, 411–420.

Ishikawa, J. and Spencer, B. (1999), 'Rent-shifting export subsidies with an imported intermediate product', *Journal of International Economics* **48**, 199–232.

Kennett, M. and Steenblik, R. (2005), 'Environmental goods and services: A synthesis of country studies', *OECD Trade and Environment Working Papers 2005/3* .

Kirkspatrick, C., George, C. and Scrieciu, S. S. (2006), 'Trade liberalisation in environmental services: Why so little progress?', *Globla Economy Journal* **6**, 1–17.

Lee, S. (1990), 'International equity markets and trade policy', *Journal of International Economics* **29**, 173–181.

Long, N. V. and Soubeyran, A. (2001*a*), 'Cost manipulation games in oligopoly with costs of manipulating', *International Economic Review* **42**, 505–534.

Long, N. V. and Soubeyran, A. (2001*b*), 'International cross-ownership and strategic trade policies', *Review of International Economics* **9**, 1–15.

Markusen, J. R. (1995), 'The boundaries of multinational enterprises and the theory of international trade', *Journal of Economic Perspectives* **9**, 169–189.

Nimubona, A.-D. and Sinclair-Desgagné, B. (2005), 'The pigouvian tax rule in the presence of an eco-industry', *FEEM. Nota de lavoro* (57-2005).

Numeri, I. and R.D.I. (2004), Panorama des eco-entreprises, Technical report, Ministère de l'économie et des finances.

OECD (1996), The global environmental goods and services industry, Technical report.

OECD (1999), *The Environmental Goods and Services Industry: Manual for Data Collection and Analysis*, Paris: OCDE Editions.

Simpson, R. (1995), 'Optimal pollution tax in a cournot duopoly', *Environmental and Resource Economics* **6**, 359–369.

Tirole, J. (1995), *Théorie de l'organisation industrielle*, Vol. 1 et 2, Economica.

Ulph, A. (1996), 'Environmental policy and international trade when governments and producers act strategically', *Journal of Environmental Economics and Management* **30**, 265–281.

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