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## Environmental Taxation and International Eco-Industries

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## **Environmental Taxation and International Eco-Industries**

Joan Canton

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ETA – Economic Theory and Applications
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# Environmental Taxation and International Eco-Industries

## 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.

**Keywords:** Eco-Industry, Strategic Environmental Policy, Asymmetric Oligopolies

**JEL Classification:** D62, H23, F12

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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.

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.<sup>1</sup> 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. It is shown that it is indeed 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 all eco-industry firms have Northern assets, the Southern tax rate will fall short of marginal damage, even though restrictions in production in the environment market usually tend to push the regulator to choose a tax above the marginal

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<sup>1</sup>"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)

damage.<sup>2</sup> When a local eco-industry is introduced, rent-shifting effects tend to push up the tax in the South and our results become more ambiguous. The difference in optimal tax rates between both countries is then based on current eco-industry's market shares and the way they are influenced by a change in the tax.

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, Grecker (2006) adds the possibility of

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

foreign competition (both on local and international markets) and endogenizes the price of environmental 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 across countries.<sup>3</sup>

Second, average production costs are assumed constant, so there are no economies of scale. As the monopoly returns profits to its Northern shareholders, which makes welfare lower in South, it is shown that the optimal environmental tax rate is lower in South than it is in North. This difference is increased in the presence of a single world market because the Southern regulator underestimates the overall mark-up that a Northern eco-industry firm makes. The consequence is an even lower tax rate in South than in North. Afterward, an eco-industry with Southern shareholders enters the market. First, environmental markets are supposed segmented. Thus, 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 rent-shifting effects that lead to lower tax rates in the North than before competition takes place. The difference between both countries' environmental taxation depends on environment firms' market shares. 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. This situation, that can be seen as

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<sup>3</sup>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).

a consequence of trade liberalization in the environmental goods and services market, has ambiguous effects on environmental taxation in both countries. Introducing cooperative behaviors (as in Greiner (2003)) does not necessarily allow to increase the environmental performance.

The rest of the document proceeds as follows. Section 2 considers the monopoly case. 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:

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

where in each country,  $P_j$  is the final good market price,<sup>4</sup>  $c(x_j)$  is an increasing and convex cost function,  $p_j$  the price of environmental goods,  $a_j$  the quantities purchased of environmental

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<sup>4</sup> $P(x_j)$  is the inverse demand function and determines the market price equilibrium.

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 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,  $\forall j = s, n$ .

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

Second order conditions are:

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

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 inputs. Thus, first and second order conditions are,  $\forall j = s, n$ :

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

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

Assuming an interior solution will be chosen, i.e.  $\frac{p_j}{t_j} \in ]0; \lim_{a_j \rightarrow 0} w'(a_j)[$ , 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

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<sup>5</sup>As opposed to  $h$  for the Southern firm in the next section



equilibrium in environmental goods. Therefore,  $\forall j = s, n$ , its profit function  $\Pi_{lj}^{up}$  is such that:

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

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:

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

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

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<sup>6</sup> whereas in South, buying environmental goods and services only appears as costs for polluting firms.

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

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

where  $\nu$  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.<sup>7</sup>

#### 2.3.1 The regulator's decision in North

The welfare maximization condition in North is:

<sup>6</sup>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.

<sup>7</sup>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.

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

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

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

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

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

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:  $\forall j = s, n$

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

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

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:

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

where  $\frac{\partial p_s}{\partial t_s} = w'(a_s)$  is the direct impact of a change in the tax on the demand in environmental goods and services. Rewriting this condition using Equation 2, 4 and 7 yields:

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

In addition to the marginal environmental damage, the Southern regulator considers two other terms in order to set up its optimal environmental taxation. First, we find again the distortion presented in the Northern case. There is an incentive to increase the tax above the marginal damage so as to push polluting firms to increase their abatement activities. This impact is identical in both countries because 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 South, it is the marginal benefit. Second, a specific element appears in the case of a country purchasing abatement activities from a foreign firm. When the tax increases, demand is switched upward, and it increases the rents given to the foreign monopoly. This effect gives incentives to the regulator to lower the environmental tax. Because the equilibrium price of environmental goods and services always increases following an increase in the tax, we are sure that the second effect dominates the first one. The following proposition summarizes this position:

**Proposition 1** *(i) The presence of a foreign monopoly selling environmental goods and services adds a negative incentive in the choice of the optimal tax for the Southern regulator. (ii) The optimal pollution tax then falls short of marginal damage.*

*Proof:*  $t_s < \nu \Leftrightarrow p'_s(a_s) \frac{da_s}{dt_s} + \frac{\partial p_s}{\partial t_s} > 0$ . By definition,  $p'_s(a_s) \frac{da_s}{dt_s} + \frac{\partial p_s}{\partial t_s} = \frac{dp_s}{dt_s}$  is the overall price variation following an increase in the tax. We have already mentioned that an increase in the tax switched upward the demand and always increases the quantity of environmental goods consumed. By considering the profit maximization condition of the monopoly, it has a non-ambiguous positive impact on the price of abatement goods.  $\square$

It is almost immediate to see that previous results hold 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. Let us now focus on international environmental markets.

## 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:

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

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

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:

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

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

where  $A = a_s + a_n$ . Compared to the segmented markets case, the Southern regulator has another incentive to lower its tax. In fact, 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 for two different reasons. In that country, the regulator considers the profit function of the eco-industry, and therefore its overall production. Rents are also positive for this country, so the tax can be chosen above the marginal cost of pollution.

In terms of policy recommendations, when abatement activities are supplied by a monopoly, 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, environmental taxation is less stringent in the country that does not hold the eco-industry firm. 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 taxes.

#### 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,  $\forall j = s, n$

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

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

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 Northern 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:  $\forall j = s, n$

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

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

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

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

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

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  $(a_{hj}^*, a_{lj}^*)$ . The market share of the low-cost firm is always higher than the high-cost firm's one. However, 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:  $\forall j = s, n$ ,

$$2p_j(a_j) + p'_j(a_j)a_j = c_h + c_l \quad (26)$$

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  $t_j$ :

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

Totally differentiating this equation, we get:

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

which yields:

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

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 (2001), 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,  $\forall i = h, l$ ,  $\forall j = s, n$ :

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

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

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

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 ( $2c_l - c_h < 0$ ),<sup>8</sup> an increase in the tax leads to a decrease in the low-cost firm's production.<sup>9</sup> 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  $\alpha$  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:

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

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.<sup>10</sup>

<sup>8</sup>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.

<sup>9</sup>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.

<sup>10</sup>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 should precise what are the true welfare consequences of an increase in the pollution tax.

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

**Lemma 4** *As  $\beta$  is always higher than  $\alpha$ , 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.

### 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.

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

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:

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

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

$$t_s = \nu + \frac{p'_s(a_s)a_s\frac{da_s}{dt_s} - p'_s(a_s)a_{hs}\frac{da_{ls}}{dt_s} + \frac{\partial p_s}{\partial t_s}a_{ls}}{\epsilon'(x_s)\frac{dx_s}{dt_s} - w'(a_s)\frac{da_s}{dt_s}} \quad (35)$$

Compared to the monopoly's analysis, not only do variations in overall demand matter but also variations in the production of one specific firm, the foreign one.<sup>11</sup> In other words, the tax remains positively distorted so as to increase incentives in abatement activities, but this distortion

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<sup>11</sup>In South, the foreign firm is the low-cost one.



could be strengthened or lowered according to variations in the foreign firm's production. In general, this effect will push toward a lower tax rate, as an increase in the tax 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. Finally, the rent effect is now only based on the initial production pattern of the foreign firm. Rents are only negative for the regulator if they are given to the foreign firm, which reduces the incentives toward a lower environmental tax, compared to the monopoly case.

**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.*

*Proof:* (i) If both firms came from the same country, only the first distortion would remain. When  $\frac{da_{ls}}{dt_s} > 0$ , the two other terms in Equation 35 are positive, leading to a lower tax than in the case of local competition only. (ii) Comparing Equations 17 and 35, two differences appear. First, the rent effect term is lower, as the Southern regulator now only considers the foreign firm's market share, which pushes up the optimal pollution tax. Second, there is a new term:  $-p'_s(a_s)a_{hs}\frac{da_{ls}}{dt_s}$ . When this term is negative, i.e. when  $\frac{da_l}{dt_s} < 0$ , it tends to give more incentives to increase the tax.  $\square$

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.

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

The first order condition of welfare maximization yields:

$$t_n = \nu + \frac{p'_n(a_n)a_n\frac{da_n}{dt_n} - p'_n(a_n)a_{ln}\frac{da_{ln}}{dt_n} + \frac{\partial p_n}{\partial t_n}a_{hn}}{\epsilon'(x_n)\frac{dx_n}{dt_n} - w'(a_n)\frac{da_n}{dt_n}} \quad (37)$$

As the production of the less efficient firm is positively correlated with the tax rate, the last two terms of the numerator are 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 can be lower or higher than the tax in South, depending on the relative importance of a “stock” effect and a “flow” one. 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. However, we also know that  $\frac{\partial p_n}{\partial t_n} a_{hn} < \frac{\partial p_s}{\partial t_s} a_{ls}$ , which means that market shares remain higher than one half for the most efficient firm.

**Proposition 3** *(i) In the presence of a foreign eco-industry firm, the Northern optimal tax is lower than in the case of local competition only (ii) The difference between the Northern tax and the Southern one is ambiguous, and depends on the relative influence of the initial market shares and their variations following an increase in the tax*

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, which for instance happens when the production of the low-cost firm decreases following an increase in the tax, 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).

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

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:

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

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

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.

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

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

Each regulator 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.

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

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

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

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

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

**Proposition 4** (i) A single world market and non-cooperative behaviors induce a new negative incentive to the choice of the environmental taxation. In the same time, it has an ambiguous impact on the rent effect, leading to an uncertain overall impact of trade liberalization (ii) In this world, North becomes net exporter and South net importer (iii) The difference in tax rates between countries remains ambiguous

*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 has a negative incentive on the optimal second-best tax rate in the domestic country. On the other hand, the rent effect is now based on the trade balance of the country, which can

push toward a higher, or a lower pollution tax. The denominator refers to the same terms than in Equations 35 and 37. (ii)  $\forall t_s, t_n, a_l \frac{da_h}{dt_n} > a_h \frac{da_l}{dt_s}$ , which gives the Northern regulator a more important strategic incentive to reduce its tax. If North is net importer, by definition  $a_n - a_l > 0$  and  $a_s - a_h < 0$ , which implies  $t_n^* > t_s^*$  as  $a_l > a_h$ . However,  $a_n - a_l > 0$  would mean another negative incentive in the choice of the Northern tax and a positive one in the Southern case. It would imply  $t_n^* < t_s^*$ , which is a contradiction. (iii) This directly comes from the fact that North is net exporter and South net importer.  $\square$

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

$$t_s = \nu + \frac{1}{\epsilon'(x_s) \frac{dx_s}{dt_s} - w'(a_s) \frac{da_s}{dt_s}} \left( (a_s - a_h) \frac{dp}{dt_s} + a_h p'(A) \frac{da_h}{dt_s} \right) \quad (47)$$

$$t_n = \nu + \frac{1}{\epsilon'(x_n) \frac{dx_n}{dt_n} - w'(a_n) \frac{da_n}{dt_n}} \left( (a_n - a_l) \frac{dp}{dt_n} + a_l p'(A) \frac{da_l}{dt_n} \right) \quad (48)$$

where  $\frac{dp}{dt_i} = \frac{\partial p}{\partial t_i} + p'(A) \frac{dA}{dt_i}$ .

First, there is the marginal environmental damage caused by domestic polluting firms.<sup>12</sup> 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. There is a positive (resp. negative) incentive on the level of taxation for the net exporter (resp. net importer), as it means more (resp. less) rents due to the increase in demand for abatement activities. 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. For the net importer country (South), 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 direct trade effects when markets were segmented.

### 4.3 A cooperative strategy

Assume now that regulators join their decisions and consider the overall welfare.<sup>13</sup> It is generally assumed that it would hamper the decision to lower the tax rate and therefore would prevent

<sup>12</sup>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.

<sup>13</sup>It also means that side payments are possible among countries

too much pollution. In our context, maximizing the overall welfare would mean to consider the following equation:

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

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,<sup>14</sup> even though eco-industry firms are asymmetric, a cooperative decision leads to an identical cooperative tax in both countries. As in the case where eco-industries come from the same country, it is the overall production that matters and not the firms' market shares.

**Proposition 5** (i) *Cooperative taxation leads to similar taxes in both countries.* (ii) *When production patterns increase in the tax, the cooperative environmental policy always leads to higher pollution tax rates in South compared to the non-cooperative decision. The impact in North is ambiguous.*

*Proof:* See Appendix 6.3.

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 argument can be used when one talks about the Southern case. However, as far as North is concerned, the rent-shifting effect emphasized in the previous section can lead to too much protection of the environment. 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.

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<sup>14</sup>Tax variations give similar impacts on supply and demand, whatever the country considered

## 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 the less developed countries. From that point of view, the answer would rather be yes. It is particularly relevant when a Northern eco-industry monopoly supplies Southern polluting firms in abatement goods and services. As 90% of eco-industries come from OECD countries, one should be concerned about the consequences of this asymmetry on environmental policies in developing countries. Moreover, the WTO objective of a trade liberalization in environmental goods and services, directed to a better consideration of environmental issues in developing countries, should be carefully considered as it could lead to even lower environmental taxation in the poorest countries.

According to this work, what seems more important is to introduce competition in the environmental industry. 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. Even though Southern firms are less efficient, as their market shares are increasing when pollution taxes are higher, it gives a strategic incentive to the Southern regulator to push up its tax. However, it does not necessarily mean that the overall welfare will be increased, notably because it leads to less efficiency among eco-industry firms. The argument that international cooperation could improve the environmental performance remains partly relevant. It is generally true in the Southern case, but not necessarily in North. Rents in the environmental sector can push Northern countries to over-tax polluting firms compared to what should be socially optimal.

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.

$$\Pi_{a_{hs}}^{up} = t_s(1 - (a_{hs} + a_{ls}))a_{hs} - c_h a_{hs} \quad (52)$$

$$\Pi_{a_{ls}}^{up} = t_s(1 - (a_{hs} + a_{ls}))a_{ls} - c_l a_{ls} \quad (53)$$

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:

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

Comparative statics from this optimal levels of production give:

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

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:  $\Pi_{a_{hs}}^{up} = \frac{(t_s + c_l - 2c_h)^2}{9t_s}$  and  $\Pi_{a_{ls}}^{up} = \frac{(t_s + c_h - 2c_l)^2}{9t_s}$ .

### 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:

$$p = t_j(1 - a_j), \quad \forall j = s, n \quad (56)$$

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

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



From this equation, we find the overall inverse demand:

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

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.

$$\Pi_{a_h}^{up} = \frac{t_n t_s}{t_n + t_s} (2 - (a_h + a_l)) a_h - c_h a_h \quad (59)$$

$$\Pi_{a_l}^{up} = \frac{t_n t_s}{t_n + t_s} (2 - (a_h + a_l)) a_l - c_l a_l \quad (60)$$

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:

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

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

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

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

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

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

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

### 6.3 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. When we look at the numerators of Equations 51 and 46, we only need to compare  $(a_s - a_h) \frac{dp}{dt_s}$  and  $a_l p'(A) \frac{da_l}{dt_s}$ . The first term is necessarily positive and the second one negative. Therefore, we are sure that the non-cooperative tax in South is lower than the cooperative one.

In the Norther case, the comparison of numerators means to compare the expressions  $(a_n -$

$a_l)\frac{dp}{dt_n}$  and  $a_h p'(A)\frac{da_h}{dt_n}$ , which are both negative. Therefore, it is not possible to conclude on whether the cooperative tax is necessarily higher than the non-cooperative one.

When both countries are similar, i.e. eco-industry firms are identical, no international trade arises and the cooperative tax is necessarily higher than the non-cooperative one.

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