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Green lobbies and transboundary pollution in large open economies

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Abstract

We employ a common agency model of policy making to examine how green lobbies affect the determination of trade and environmental policies in two large countries that are linked by trade flows and transboundary pollution. We show that the impact of green lobbying on environmental policy outcomes depends crucially on the prevailing trade regime—cooperative or non-cooperative—on whether environmental agencies act in a unilateral or coordinated manner, and on the size of the emission leakages and transboundary spillovers. Under free trade, a unilateral increase in pollution taxes reduces domestic emissions at the cost of increased foreign emissions; in this case, if the emission leakages and the associated transboundary spillovers are large enough, green lobbying can create a bias towards lower pollution taxes.

Keywords: Transboundary pollution; International trade; Political contributions

JEL classification: D72; F13; Q20; Q28

1. Introduction

This paper examines how the presence of green lobbies may affect the determination of trade and environmental policies in large countries linked by trade flows and transboundary pollution.

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It is widely recognized that, in the presence of transboundary pollution, uncoordinated environmental regulation at the national level is associated with market failures and that economic efficiency requires international policy cooperation. In the absence of cooperation, there is a presumption that, by exerting political pressure in favor of higher domestic pollution taxes, green lobbies might act as a partial remedy.[1]

In this paper, we argue that, when countries are large and environmental emissions spill over to trading partners, the presumption that green lobbying must lead to the adoption of stricter environmental policy is potentially misleading. This is because an increase in pollution taxes by a large country shifts the terms of trade in favor of trading partners, leading to an increase in their emissions. If the effect of domestic policies on foreign emissions (''emission leakages''), and the associated transboundary spillovers are large enough, unilateral efforts to reduce pollution by taxing domestic producers might actually increase environmental degradation and thus be opposed by green lobbies. Since the environmental policy leakage can be eliminated either through the use of import tariffs or through environmental policy coordination, the impact of green lobbying on the environmental policy outcome will also depend crucially on whether or not governments are bound by a free trade agreement and on whether they act in a unilateral or cooperative manner.

The possibility of emission leakages has received attention in various empirical studies on transboundary pollution, which have come to conflicting conclusions about the magnitude of such trade-related environmental effects. Some simulation-based studies find that unilateral actions to curb CO_2 emissions would have relatively small adverse effects on other countries' emissions.[2] Other studies find that the emission leakages could be significant.[3] The reasons behind these

[1]In recent years, green lobbies have significantly grown in size. For example, in 1998 in the United States the Environmental Defense Fund had 151 permanent staff and an annual budget of $23 m, Greenpeace (US) had 250 and $12 m, and the Natural Resource Defense Counsel 165 and $18 m. Green lobbies have also become increasingly important political actors: as well as exercising pressure on national governments and supra-national institutions such as the World Bank, the World Trade Organization and the EU (Charter and Deléage, 1998), they are active participants in all major international trade and environmental negotiations. For example, at the Kyoto Conference on greenhouse emissions in December 1997, several green NGOs were represented (Greenpeace alone sent an 18-strong delegation). They ''had considerable influence on the negotiations (and) served as sounding-board to assess how proposals would be received at home'' (*Financial Times*, December 11, 1997). More recently, influential environmental groups such as Friends of the Earth launched a fierce campaign against the new round of GATT/WTO negotiations in Seattle (*The Economist*, December 11, 1999).

[2]This is the conclusion reached, for example, by Olivera-Martins et al. (1992) and by a study of the Clinton Administration (1998) on the effects of the Kyoto Protocol. For a discussion, see Barret (1998).

[3]For example, Bernstein et al. (1999) find that, for every 100 tons of carbon abated by the Annex I countries of the Kyoto Protocol, emissions in the other countries could rise by 5–10 tons. Significant leakage effects are also predicted by Nordhaus and Boyer (1998) and Manne and Richels (1998). An earlier study by IPCC (1996) finds that pollution leakages could be more substantial.

contradictory results lie partly in the different assumptions about supply and demand elasticities, and partly in the general difficulties encountered in estimating actual emission spillovers.[4] Concerns about the emission leakages generated by unilateral efforts to reduce pollution have also been raised in the policy debates in Europe and the United States.[5]

In spite of this debate, surprisingly, the theoretical literature on transboundary pollution[6] has largely ignored the problem of emission leakages.[7] In early work in this area, Markusen (1975a,b) considers a model of two trading countries linked by a bilateral production externality. He characterizes optimal unilateral and co-operative trade and environmental policies, but does not consider the fact that, by unilaterally taxing its domestic firms, a country can encourage foreign production and emissions. Copeland and Taylor (1995) examine the interactions between pollution, income levels, and the patterns of trade in a general equilibrium setting. The bulk of their analysis focuses on small countries, thus leaving aside the problem of emission leakages.[8]

In this paper, we describe a common agency model of lobby influence of the kind introduced by Grossman and Helpman (1994). Green and producer lobbies confront incumbent politicians with contributions schedules, namely functions relating their binding promise of political support to the selected policies. Governments are semibenevolent, in the sense that they care both about social welfare and campaign contributions.

We use this model to examine the impact of green lobbying on environmental policy outcomes, under alternative assumptions about the trade regime—whether or not governments are bound by a free trade agreement—and the decision-making process—whether governments act in a unilateral or cooperative manner. We first focus on the policies adopted by two symmetric countries under the influence of national green lobbies. We show that, when international rules restrain trade policy intervention at the national level and governments act unilaterally, it is possible for green lobbying to create a bias towards lower pollution taxes. We then extend the analysis to the case in which governments are influenced by an international green lobby and the case in which both green and pro-industry lobbies are organized. We also explore the implications of country asymmetries.

Finally, focusing on the case of symmetric countries, we examine the impact of

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[4]See Missfeldt (1999) on this point.

[5]For example, the attempt to mitigate the adverse effects of unilateral emission abatement has been the main reason for the proposal of tax exemptions on energy intensive industries by the European Commission (CEC, 1992). In the United States, it has been stressed that a carbon tax adopted unilaterally would generate emission leakages and thus be more costly to the economy and less effective in reducing global emissions than one adopted multilaterally (see WRI, 1997).

[6]See Missfeldt (1999) for an extensive review of the game-theoretical literature on transboundary pollution.

[7]Exceptions are Merrifield (1988), Anderson (1992), and Copeland and Taylor (2000).

[8]However, the existence of emission leakages is implicit in Copeland and Taylor's (1995) discussion of the terms-of-trade effects associated with regional emission cutbacks.

green lobbying on the comparative efficiency of unilateral and cooperative environmental policy outcomes. Our results suggest that environmental policy coordination might be comparatively more beneficial under a free trade regime.

The importance of the interaction between trade regimes and the stringency of environmental regulation has been recognized in a number of studies.[9] However, since these studies focus on small economies and local environmental problems, they leave aside the issues of environmental policy leakages, emission spillovers, and international cooperation, which are central to our analysis. Our paper also contributes to a growing literature which examines the influence of interest groups on policy-making. Most existing studies, however, focus on a single policy instrument.[10] To the best of our knowledge, ours is the only study looking at the role of green lobbies on the *joint determination* of trade and environmental policies in large open economies.

The remainder of the paper is organized as follows. Section 2 describes the model. Section 3 examines the impact of green lobbying on unilateral and cooperative environmental policy outcomes. Section 4 concludes.

2. The model

2.1. International trade with transboundary pollution

We begin by describing a simple model of international trade and transboundary pollution in which two countries, denominated foreign (*) and home (no *),

[9] For example, Rauscher (1994) shows that, if traditional trade policy instruments are not available, ''ecological dumping'' may arise: a country may have incentives to use too-lax environmental legislation as an instrument to shift the terms of trade in its favor. Fredriksson (1999) studies how environmental and industry lobbies can influence the determination of pollution taxes in sectors protected by tariffs. Taking the level of protectionism as given. He compares an initial scenario with exogenously given tariffs with a free trade scenario and finds that the level of political conflict on environmental policy falls with trade liberalization. Schleich (1999) examines the joint determination of trade and environmental policies, assuming that the government has a single or a variety of domestic and trade policy instruments to address production or consumption externalities and to obtain political contributions from producer lobby groups. He shows that, in the presence of both trade and environmental distortions, inefficient trade policies can lead to higher environmental quality than more efficient domestic policies.

[10] Hillman and Ursprung (1992, 1994) investigate how environmental concerns might affect international trade policy. Fredriksson (1997) and Aidt (1998) examine the effect of lobbying by green and producer groups on the determination of environmental policy. Fredriksson (1997) incorporates into his model a pollution abatement subsidy, showing that pollution may be increasing in the pollution abatement subsidy rate. Aidt (1998) assumes that a production externality arises from the use of a factor input. His analysis generalizes Bhagwati's principle of targeting to distorted political markets: the most efficient instrument to internalize the externality is a tax on the polluting input factor, which aims directly at the source. Similarly to our analysis, Fredriksson (1997) and Aidt (1998) use a common agency model of lobbying. However, since they focus on local environmental problems in a small open economy, they do not consider emission leakages.

produce and trade multiple goods. We focus on the political and economic structure of the home country; definitions for the foreign country can be obtained symmetrically.

There are $N+1$ sectors, $i=0,1,\ldots,N$, where 0 denotes a numeraire good. All goods are produced under constant returns to scale technology and sold under conditions of perfect competition. The numeraire good is traded freely across countries and is produced using labor alone. We choose units so that the international and domestic price of the numeraire good are both equal to one. We assume that aggregate labor supply, L, is large enough to sustain production of a positive amount of good 0. This implies that, in a competitive equilibrium, the wage rate equals unity. The domestic consumer and producer prices of a non-numeraire good i are denoted by q_i and p_i, respectively. International prices are given by π_i.

Each of the other goods is manufactured using labor and a sector-specific input, which is available in fixed supply. With a wage rate equal to unity, the total rent R_i accruing to the specific factor in sector i depends only on the producer price of the good, and thus can be expressed as $R_i(p_i)$. Industry supply is then given by $Y_i(p_i)=\partial R_i/\partial p_i$.

We assume that the production of the numeraire good is ''clean'', while the production of each non-numeraire good i generates pollution emissions $E_i=\alpha_i Y_i$, where α_i is an exogenously given emission coefficient.

The economy is populated by H individuals, $h=0,1,\ldots,H$, who have identical quasilinear and additively separable preferences. Individual h's utility can be written as

$$u_h(c_0,\ldots,c_N,Z)\equiv c_0+\sum_{i=1}^{N}u_i(c_i)-Z, \tag{1}$$

where c_0 and c_i represent the consumption of the numeraire and non-numeraire goods, and $u(c_i)$ is assumed to be twice differentiable, increasing, and strictly concave. The term Z denotes total environmental damage, which is a function of both domestic and foreign emissions:[11]

$$Z(\boldsymbol{p},\boldsymbol{p^*})\equiv\sum_{i=1}^{N}[(1-\theta_i)E_i(p_i)+\theta_i E_i^*(p_i^*)], \tag{2}$$

where $\boldsymbol{p}$ and $\boldsymbol{p^*}$ are vectors of producer prices, and $(1-\theta_i)$ and θ_i are the relative weights associated with domestic and foreign emissions in sector i, respectively. This specification captures different types of externalities: global environmental problems, whereby all countries are equally exposed to a given unit of pollution

[11]The concern about foreign pollution can derive from physical spillovers or from psychological spillovers motivated by aesthetic, altruistic or paternalistic reasons.

($\theta_i = \theta_i^* = 1/2$); regional environmental problems ($0 < \theta_i < 1/2$; $0 < \theta_i^* < 1/2$);[12] local environmental problems that generate no transboundary pollution ($\theta_i = \theta_i^* = 0$).

Trade and environmental policies in the model consist of vectors of specific import tariffs τ and pollution taxes $\boldsymbol{t}$.[13] Trade and environmental policies drive a wedge between consumer and producer prices and between domestic and international prices, respectively. Consumer prices are thus equal to $q_i = \pi_i + \tau_i$, while producer prices are given by $p_i = \pi_i + \tau_i - t_i$.

Provided that income always exceeds the expenditure on the nonnumeraire good, the domestic demand for good i can be expressed as a function of price alone, i.e. $D_i(q_i)$. Net import demand is then $M_i(q_i, p_i) = D_i(q_i) - Y_i(p_i)$. World product markets clear when

$$M_i(\tau_i, t_i, \pi_i) + M_i^*(\tau_i^*, t_i^*, \pi_i) = 0. \tag{3}$$

From (3) we can derive an expression for world equilibrium prices as a function of the policies in the two countries, i.e. $\pi_i(t_i, \tau, t_i^*, \tau_i^*)$.

2.2. The problem of emission leakages

In the setup described above, both countries are ''large'' in that they are able to affect world prices. In such a scenario, unilateral efforts to reduce pollution by taxing domestic producers, if unaccompanied by an increase in its import tariffs, raise world prices and hence lead to an increase in foreign emissions. This phenomenon is referred to in the literature as *emission leakage*.[14]

Formally, an increase in the domestic pollution tax on good i generates the following effect on its international price:

$$\frac{\partial \pi_i}{\partial t_i} \equiv \delta_i = \frac{\varepsilon_i^Y}{m_i[\varepsilon_i^M - \varepsilon_i^{M*}(p_i/p_i^*)]}, \tag{4}$$

where $m_i \equiv M_i/Y_i$ is the import-to-GDP share, $\varepsilon_i^M \equiv (\partial M_i/\partial p_i)(p_i/M_i)$ (with $p_i = q_i$) and $\varepsilon_i^{M*} \equiv (\partial M_i^*/\partial p_i^*)(p_i^*/M_i^*)$ (with $p_i^* = q_i^*$) are the domestic and foreign price elasticities of import demand or export supply (depending on whether M_i is positive or negative), and $\varepsilon_i^Y \equiv -(\partial Y_i/\partial p_i)(p_i/Y_i)$ is the domestic price elasticity of supply. Notice that δ_i always lies between 0 and 1, implying an increase in the

[12] Some regional environmental problems, such as pollution of river systems, are unidirectional, i.e. emissions produced by ''upstream'' countries negatively affect ''downstream'' countries, without any significant reverse emission flows (see Silva, 1997).

[13] Notice that, since in our model emissions and output are directly proportional, pollution taxes are equivalent to output taxes.

[14] Some of the earlier studies to stress the problem of emission leakages are Merrifield (1988), Anderson (1992) and Gaskins and Weyant (1993).

international price. Hence, a unilateral increase in domestic pollution taxes shifts the comparative advantage of producing ‘‘dirty’’ goods in favor of the foreign country. This shift of the terms of trade results in an increase in foreign emissions equal to

$$\frac{\partial E_i^*}{\partial t_i} = \delta_i \alpha_i^* \frac{\partial Y_i^*}{\partial p_i^*}. \tag{5}$$

Hence, if emission taxes are raised unilaterally and unaccompanied by the use of import tariffs, they reduce domestic pollution at the cost of increased foreign pollution.

It is important to stress that what is leaking through trade is not domestic emissions but domestic environmental policy. Thus, a leakage could also arise if environmental problems are strictly local. However, it is only in the case of transboundary environmental problems ($\theta_i > 0$, $\theta_i^* > 0$) that the leakage negatively affects domestic residents. In this case, the environmental impact of an increase in the domestic pollution tax from the point of view of domestic residents is

$$\frac{\partial Z}{\partial t_i} = (1 - \theta_i)(\delta_i - 1)\alpha_i \frac{\partial Y_i}{\partial p_i} + \theta_i \delta_i \alpha_i^* \frac{\partial Y_i^*}{\partial p_i^*}; \tag{6}$$

hence in the presence of trade flows higher domestic pollution taxes have two opposite environmental effects: a *direct positive effect*, due to a reduction in domestic emissions by $(1 - \theta_i)(\delta_i - 1)\alpha_i(\partial Y_i)/(\partial p_i)$, and an *indirect negative effect*, due to an increase in foreign transboundary emissions by $\theta_i \delta_i \alpha_i^*(\partial Y_i^*)/(\partial p_i^*)$. The relative importance of the negative environmental effect increases with the size of the emission leakages and the degree to which foreign emissions spill over to the home country.

It follows that a *unilateral increase in pollution taxes, if unaccompanied by an increase in import tariffs, can lead to environmental degradation* A sufficient condition for this to occur is that the indirect environmental costs associated with the increase in transboundary foreign emissions outweigh the direct environmental benefits due to the reduction in domestic emissions.

It is well know that, when emissions are transboundary, welfare-maximizing governments will unilaterally adopt lower than optimal environmental policies. In the presence of emission leakages, equilibrium unilateral emission taxes will be even lower (see, for example, Barret, 1998). There is a presumption that green lobbies could counteract this downward bias by exerting political pressure in favor of higher environmental taxes. However, in Section 3 we will show that the existence of emission leakages and transboundary spillovers reduces (and might even reverse) the environmental groups’ lobbying incentives. We will also show that the impact of green lobbying on environmental policy crucially depends on whether governments can eliminate emission leakages through the use of import tariffs and/or environmental policy coordination.

2.3. The political arena

We assume that only two groups of citizens overcome the free-riding problem described by Olson (1965) and get politically organized: a proportion s^{E} of the population, the ''environmentalists'', who form a green lobby; and the owners of a subset S of all specific factors, who form producer lobbies in their respective sectors. In each sector $i \in S$, capital owners represent a proportion s_i^{P} of the population.[15]

Political competition can be modeled as a two-stage game. In the first stage, green and producer lobbies simultaneously present incumbent policy makers with contribution schedules, namely functions mapping every combination or trade and environmental policy into a level of political contribution.[16] The contribution schedules will not be formal contracts, nor will they be explicitly announced. However, the government knows that an implicit link exists between the way it treats the environmentalists and the contributions it can expect to receive from that group.[17]

In the second stage, incumbent politicians select trade and environmental policies, given the equilibrium contribution schedules, and collect the corresponding contributions from every lobby. They are concerned with aggregate well-being, but also with the support they get from interest groups. In equilibrium, the decision-makers balance optimally the marginal benefit of net aggregate contributions against the marginal welfare cost of distortionary trade and environmental policies.

In contrast to Grossman and Helpman (1994), we assume that interest groups are ''functionally specialized'' (Aidt, 1998), in the sense that the green lobby is only concerned about environmental damage and producer lobbies are only concerned about industry profits.[18] The gross (of contributions) welfare of the national environmental lobby is thus given by

$$W^{\mathrm{NE}}(\boldsymbol{t},\tau,\boldsymbol{t}^*,\boldsymbol{\tau}^*) \equiv B - s^{\mathrm{E}} HZ(\boldsymbol{t},\tau,\boldsymbol{t}^*,\boldsymbol{\tau}^*), \tag{7}$$

where B is a constant, while the utility a producer lobby $i \in S$ is

$$W_i^{\mathrm{P}}(\boldsymbol{t},\tau,\boldsymbol{t}^*,\tau^*) \equiv s_i^{\mathrm{P}} HR_i(t_i,\tau_i,t_i^*,\tau_i^*), \ \forall i \in S. \tag{8}$$

[15] For simplicity, we assume that citizens own a share of the specific capital in at most one sector and are members of at most one interest group.

[16] Contributions should be interpreted broadly as bribes, campaign funds, or support demonstrations, to reflect different strategies used by lobby groups.

[17] The implicit assumption is that lobby groups keep their promises. It is hard to achieve this commitment in a one-shot game, but in a dynamic context reputation considerations could enforce it.

[18] The motivation for focusing on functionally specialized lobby groups is empirical: while it is possible to find examples of lobby groups with multiple goals, most interest groups are highly specialized (see Marshall, 1998).

We exclude the possibility of coordination between green and producer lobbies. However, we allow environmentalists in different countries to act cooperatively, forming an international green lobby,[19] whose welfare is simply the sum of the utilities of the national green lobbies:

$$W^{\mathrm{IE}}(\boldsymbol{t},\tau,\boldsymbol{t}^*,\tau^*) \equiv B + B^* - \sum_{i=1}^{N}[s^{\mathrm{E}}H(1+\theta_i) + s^{\mathrm{E}*}H^*\theta_i^*]E_i(t_i,\tau_i,t_i^*,\tau_i^*) - \sum_{i=1}^{N}[s^{\mathrm{E}*}H^*(1+\theta_i) + s^{\mathrm{E}}H\theta_i]E_i^*(t_i^*,\tau_i^*,t_i,\tau_i). \quad (9)$$

National green and producer lobbies present their government with contribution schedules $C_i(\boldsymbol{t},\tau;\boldsymbol{t}^*,\tau^*)$. Their objective functions are, respectively,

$$\tilde{W}^{\mathrm{NE}}(t,\tau,t^*,\tau^*) \equiv W^{\mathrm{NE}}(t,\tau,t^*,\tau^*) - \sum_i C_i(t_i,\tau_i;t_i^*,\tau_i^*), \quad (10)$$

$$\tilde{W}_i^{\mathrm{P}}(\boldsymbol{t},\tau,\boldsymbol{t}^*,\tau^*) \equiv W_i^{\mathrm{P}}(t_i,\tau_i,t_i^*,\tau_i^*) - C_i(t_i,\tau_i;t_i^*,\tau_i^*), \ \forall i \in S. \quad (11)$$

When environmentalists in the two countries act as an international green lobby, they offer political contributions to both governments[20] so as to maximize

$$\tilde{W}^{\mathrm{IE}} \equiv W^{\mathrm{IE}}(\boldsymbol{t},\tau,\boldsymbol{t}^*,\tau^*) - \sum_i C_i(t_i,\tau_i;t_i^*,\tau_i^*) - \sum_i C_i^*(t_i^*,\tau_i^*;t_i,\tau_i). \quad (12)$$

The implicit objective of incumbent politicians is to be reelected.[21] This implies that they care about the utility level achieved by the representative voter, particularly if voters are well informed about the effects of government policy and base their vote partly on their standard of living. Incumbent politicians also value political contributions for financing future campaigns and deterring competitors. The government's objective is thus given by

$$G(\boldsymbol{t},\tau,\boldsymbol{t}^*,\tau^*) \equiv \omega W(\boldsymbol{t},\tau,\boldsymbol{t}^*,\tau^*) + \sum_i C_i(t_i,\tau_i;t_i^*,\tau_i^*), \ \ \omega \geq 0, \quad (13)$$

where W is the welfare of citizens (or ''social welfare'') and ω represents the weight that the government attaches to social welfare relative to lobbies' contributions.

Domestic welfare is defined as aggregate domestic income, including tax and tariff revenues, plus total consumer surplus minus environmental damage:

[19] For example, this could be the case of a green lobby like Greenpeace, which is formed by 41 coordinated national lobbies (see www.greenpeace.org).

[20] We rule out corner solutions, in which the international lobby offers contributions to one government only.

[21] See Grossman and Helpman (1996) for an explicit treatment of the electoral stage.

$$W(\boldsymbol{t},\tau,\boldsymbol{t}^*,\tau^*) \equiv L + \sum_{i=1}^{N} R_i(t_i,\tau_i,t_i^*,\tau_i^*) + \sum_{i=1}^{N} t_i Y_i(t_i,\tau_i,t_i^*,\tau_i^*) + \sum_{i=1}^{N} \tau_i M_i(t_i,\tau_i,t_i^*,\tau_i^*) + H\left[\sum_{i=1}^{N} u(D_i(t_i,\tau_i,t_i^*,\tau_i^*)) - \sum_{i=1}^{N} q_i D_i(t_i,\tau_i,t_i^*,\tau_i^*)\right] - HZ(\boldsymbol{t},\tau,\boldsymbol{t}^*,\tau^*). \qquad (14)$$

In order to derive the equilibrium cooperative policies, we can rely on the notion that the outcomes of international negotiations must satisfy Pareto efficiency for the two policy makers involved (see Grossman and Helpman, 1995). This implies that cooperative policies must maximize the weighted sum

$$G^{\mathrm{W}} \equiv \omega^* G + \omega G^* = \omega^*\omega[W(\boldsymbol{t},\tau,\boldsymbol{t}^*,\tau^*) + W^*(\boldsymbol{t}^*,\tau^*,\boldsymbol{t},\tau)] + \omega^* \sum_i C_i(t_i,\tau_i,t_i^*,\tau_i^*) + \omega \sum_i C_i^*(t_i^*,\tau_i^*,t_i,\tau_i). \qquad (15)$$

Thus the cooperative equilibrium policies are the same that would be selected by a single decision (a ‘‘supra-national mediator’’) with preferences as given on the right-hand side of (15).[22]

We model policy making under lobby influence as a two-stage common agency game. In the first stage, lobbies confront politicians with their contribution schedules, which are assumed to be continuous and differentiable, at least in the neighbourhood of an equilibrium. In the second stage, policy makers unilaterally or cooperatively set trade and environmental policies and receive the corresponding political contributions. A subgame perfect equilibrium for this game is found by working backwards, from the last stage to the first.

An equilibrium for a common agency game must be efficient for both the principals (lobbies) and the agent (the incumbent national or supra-national government). The existence of such an equilibrium has been demonstrated by Bernheim and Whinston (1986). We leave out its derivation, which can be found in Grossman and Helpman (1994, 1995), Dixit (1996) and Fredriksson (1997). Following Bernheim and Whinston (1986), we focus on ‘‘truthful’’ equilibria, where lobbies make contributions up to the point where the resulting change in

[22] Notice that (15) stipulates that cooperative policies must be efficient for the two governments without specifying how the surplus will be divided between them. To determine which utility pair (G,G^*) will be selected, a bargaining procedure should be introduced. One could adopt the Nash bargaining solution or, as in Grossman and Helpman (1995), the Rubinstein's bargaining solution.

economic policies is exactly offset by the marginal cost of the contributions.[23] Equilibrium conditions for both the unilateral and the cooperative policy scenarios are given in Appendix A.

3. Green lobbying and environmental policy equilibria

We now want to turn to the question of how green lobbying affects the determination of environmental policy. In Section 2.2, we showed that a unilateral increase in domestic emission taxes generates emission leakages and can cause environmental deterioration. Combining these results with (7) and (9), it is straightforward to verify that a unilateral increase in emission taxes can have an ambiguous impact on the welfare of green lobbies, implying that the direction of the pressure exerted by green lobbies will also be ambiguous.

Furthermore, since environmental policy leakages can be eliminated either through the use of import tariffs[24] or through environmental policy coordination, the impact of green lobbying on the environmental policy outcome will depend crucially on whether or not governments are bound by a free trade agreement and on whether they act in a unilateral or cooperative manner.

Formally, to evaluate the impact of green lobbies on the environmental policy outcomes we examine the effect of an increase in their influence, as measured by s^E, on the equilibrium emission taxes. From the analysis of the equilibrium conditions presented in Appendix A, it is straightforward to verify that, if environmental policies are selected cooperatively and/or combined with the use of trade policies, an increase in the influence of green lobbies will unambiguously lead to an increase in pollution taxes ($\partial t/\partial s^E > 0$). If instead environmental policies are selected unilaterally under a free trade regime, an increase in the influence of green lobbies has an ambiguous effect on the environmental policy outcome ($\partial t/\partial s^E \gtreqless 0$).

In what follows, we shall first look at the case of two symmetric countries and then explore the implications of country asymmetries. Finally, we will examine the comparative efficiency of unilateral and cooperative environmental taxes in the case of symmetric countries.

3.1. The symmetric case

Consider first a sector $i \not\in S$ of the economy in which only national green

[23] Bernheim and Whinston (1986) show that only truthful contributions yield coalition proof Nash equilibria.

[24] Notice that in our setup trade and the environment are fully linked: trade can generate adverse environmental effects, but at the same time provides a mechanism to avoid them, since import tariffs can be used to counteract the terms-of-trade effects of domestic pollution taxes.

Table 1
Policy outcomes (national green lobbies)

Trade policy regime	Policy-making process	
	Decentralized	Centralized
Free trade	$t=\dfrac{\alpha H(\omega+s)(\delta+\theta-1)}{\omega(\delta-1)}$	$t=\dfrac{\alpha H(\omega+s^{\mathrm{E}})}{\omega}$
No trade agreement	$t=\dfrac{\alpha H(\omega+s^{\mathrm{E}})(1-\theta)}{\omega}$	$t=\dfrac{\alpha H(\omega+s^{\mathrm{E}})}{\omega}$
	$\tau=\dfrac{\alpha H(\omega+s^{\mathrm{E}})\theta\ \partial Y/\partial p}{\omega(\partial Y/\partial p-\partial D/\partial q)}$	$\tau=0$

lobbies are organized.[25] The corresponding equilibrium policies are reported in Table 1. Notice that, if governments are constrained by free trade rules and select environmental policies unilaterally, an increase in the size of the green lobby[26] has an ambiguous effect on the policy outcomes:

$$\frac{\partial t}{\partial s^{\mathrm{E}}}=\frac{\alpha H(\delta+\theta-1)}{\omega(\delta-1)}; \tag{16}$$

this is positive if and only if $\delta+\theta<1$. This implies that, if the terms-of-trade and spillover effects are large enough ($\delta+\theta>1$), green lobbying could actually create a bias towards lower environmental taxes.

Notice that, in the other three policy scenarios, an increase in the size of the green lobby will unambiguously result in the adoption of higher pollution taxes. This is due to the fact that, when environmental policies are chosen cooperatively and/or combined with the use of import tariffs, they do not give rise to emission leakages.

It is important to stress that the problem of emission leakages and the consequent ambiguity of the role of green lobbying will persist even if national green lobbies coordinate their activities.[27] To verify this, we can examine the policies emerging when the two governments act under the influence of an international green lobby. These are reported in Table 2. Notice that, in the

[25] Given the quasilinearity of the utility function, there is no substitution among goods such that the amount of pollution resulting from a given level of production can be varied. This allows us to examine the equilibrium trade and environmental policies in a representative sector i of the economy. For ease of the exposition, in what follows we drop the sectoral subscript.

[26] Eq. (16) captures the symmetric change in domestic and foreign unilateral pollution taxes given symmetric changes in the strength of the green lobbies organized in the two countries.

[27] Notice, however, that the terms-of-trade effects, the emission leakages, and the ambiguity of the role of green lobbying could be eliminated if the sequencing of the game was reversed, i.e. if the international green lobby could offer its political contributions after the selection of environmental policies.

Table 2
Policy outcomes (international green lobby)

Trade policy regime	Policy-making process	
	Decentralized	Centralized
Free trade	$t = \frac{\alpha H[\omega(\delta + \theta - 1) + s^E(1+2\theta)(2\delta - 1)]}{\omega(\delta - 1)}$	$t = \frac{\alpha H[\omega + s^E(1+2\theta)]}{\omega}$
No trade agreement	$t = \frac{\alpha H[\omega(1-\theta) + s^E(1+2\theta)]}{\omega}$	$t = \frac{\alpha H[\omega + s^E(1+2\theta)]}{\omega}$
	$\tau = \frac{\alpha H[s^E(1+2\theta) + \omega\theta]}{\omega(\partial Y/\partial p - \partial D/\partial q)}$	$\tau = 0$

scenario where governments are bound by free trade rules and select environmental policies unilaterally, an increase in the size of the international green lobby has the following impact on the equilibrium pollution taxes:[28]

$$\frac{\partial t}{\partial s^E} = \frac{\alpha H(2\delta - 1)(1+2\theta)}{\omega(\delta - 1)}. \tag{17}$$

It is straightforward to verify that expression (17) is negative if $\theta > 1/2$. Hence, an increase in the influence of environmental groups—even when they act as an international green lobby—does not guarantee that environmental policy will be stricter.

The existence of emission leakages has also important implications for the nature of the relationship between green and producer interests.[29] In Table 3, we report equilibrium policies for a sector $i \in S$ of the economy in which both green and producer interests are politically organized. While producer lobbying always

Table 3
Policy outcomes (national green and producer lobbies)

Trade policy regime	Policy-making process	
	Decentralized	Centralized
Free trade	$t = \frac{H[\alpha\, \partial Y/\partial p(\omega + s^E)(\delta + \theta - 1) - s^P Y(\delta - 1)]}{\omega\, \partial Y/\partial p(\delta - 1)}$	$t = \frac{H[\theta\, \partial Y/\partial p(\omega + s^E) - s^P Y]}{\omega\, \partial Y/\partial p}$
No trade agreement	$t = \frac{H[\alpha(\omega + s^E)(1-\theta) - s^P Y]}{\omega\, \partial Y/\partial p}$	$t = \frac{H[\alpha\, \partial Y/\partial p(\omega + s^E) - s^P Y]}{\omega\, \partial Y/\partial p}$
	$\tau = \frac{\alpha H\theta\, \partial Y/\partial p(\omega + s^E)}{\omega(\partial Y/\partial p - \partial D/\partial q)}$	$\tau = 0$

[28]Eq. (17) captures the change in cooperative pollution taxes in response to a symmetric increase in the size of the green lobbies.

[29]For a discussion on this point, see Conconi (2001).

creates a bias towards the adoption of lower pollution taxes ($\partial t/\partial s^{P} < 0$), the role of green lobbying depends on the type of policy-making process and on the prevailing trade regime: if environmental policies are selected cooperatively or are combined with the use of import tariffs, green lobbies will unambiguously exert political pressure in favor of higher pollution taxes ($\partial t/\partial s^{E} > 0$); however, in the case of free trade and decentralized decision making, they might support lower pollution taxes ($\partial t/\partial s^{E} < 0$). It follows that the interests of green and producer lobbies over environmental policy can only coincide in the presence of emission leakages.

The analysis of Table 3 also reveals that, when both policy instruments are available, only pollution taxes are dependent on the strength of the producer lobbies.[30] However, it should be stressed that, if trade policy were the only available policy instrument, import tariffs would also depend on the strength of producer lobbies.[31]

The results of our analysis can be summarized as follows:

Proposition 1.

(*i*) *When policy makers select pollution taxes unilaterally and are bound by free trade rules, green lobbying has an ambiguous impact of the environmental policy outcome.*
(*ii*) *When policy makers select pollution taxes cooperatively and/or combine them with the use of import tariffs, green lobbying unambiguously creates a bias towards higher pollution taxes.*

The first part of this result follows directly from the fact that, in the presence of emission leakages, the environmental impact of a unilateral increase in pollution taxes—and hence the corresponding green lobbies' policy stance—is ambiguous. In particular, the support of green lobbies for higher domestic pollution taxes decreases with the size of the emission leakages and the degree to which pollution is transboundary. If the emission leakages and the associated transboundary spillovers are large enough, green lobbies could even favour a reduction in domestic taxes. This result is in contrast with the conclusion of Fredriksson (1997) and Aidt (1998) who, focusing on a small open economy and local pollution problems, argue that green lobbying will unambiguously lead governments to adopt higher pollution taxes.

The reason behind the second part of Proposition 1 is that, if the terms-of-trade

[30] This result is obtained using the equilibrium conditions given in Appendix A. For example, using (A.6) and (A.7) it is straightforward to verify that all the terms containing s^{P} cancel out in the derivation of the equilibrium unilateral import tariffs.

[31] This can be shown by setting $t = t^{*} = 0$ and using equilibrium conditions (A.7) and (A.12) to solve for the equilibrium unilateral and cooperative import tariffs.

effects generated by a unilateral increase in pollution taxes are offset by a simultaneous increase in emission taxes in the foreign country, supported by international policy coordination, and/or are counteracted by an increase in import tariffs, the environmental policy leakage, which is the reason for the ambiguity of the green lobbies' policy stances, is eliminated.

3.2. The role of asymmetries

Tables 1–3 were obtained by assuming that the two countries were characterized by identical economical and political structures. However, the ambiguity of the role of green lobbying does not rely on this symmetry assumption. For example, Proposition 1 would still hold if the two countries were different in terms of their exposure to transboundary pollution. Suppose that the home country is less exposed to emission spillovers than the foreign country, i.e. $\theta < \theta^*$. It is easy to verify that, everything else being equal, the green lobby in the home country will support stricter environmental policies than the foreign green lobby and the equilibrium unilateral and cooperative pollution taxes will be higher at home than abroad.[32]

The ambiguity of the role of green lobbying would also persist if the two countries were different in size. However, country size could exacerbate or mitigate the problem of emission leakages. For example, if the home country is larger than the foreign country (i.e. its import demand elasticity is larger in absolute value), a unilateral increase in its pollution taxes will generate larger terms-of-trade effects ($\partial\pi/\partial t > \partial\pi/\partial t^*$), and will thus have a larger impact on foreign productive activities and emissions; on the other hand, the problem of emission leakages might be less important, due to the other country's smaller size ($\alpha^* Y^*(t_i^*, \tau_i^*, t_i, \tau_i) < \alpha Y(t_i, \tau_i, t_i^*, \tau_i^*)$).[33]

3.3. Green lobbying and economic efficiency

The model described in Section 2 is characterized by the existence of three types of distortions: a trade distortion, due to the fact that countries can affect the

[32]For example, in a free trade regime the equilibrium unilateral pollution taxes will be

$$t = \frac{\alpha H(\omega + s^{E})(\delta + \theta - 1)}{\omega(\delta - 1)} > t^* = \frac{\alpha^* H^*(\omega + s^{E*})(\delta^* + \theta^* - 1)}{\omega^*(\delta^* - 1)},$$

while cooperative taxes will be given by

$$t = \frac{\alpha H(\omega + s^{E})(1 - \theta - \delta)}{\omega} > t^* = \frac{\alpha^* H^*(\omega^* + s^{E*})(1 - \theta^* - \delta^*)}{\omega^*}.$$

[33]Notice that in a model with income effects, unlike in the quasilinear specification used here, larger import demand elasticities are associated with larger factor endowments. With quasilinear preferences, elasticity differentials between countries are captured by differences in the demand parameters.

terms of trade; an environmental distortion, due to the existence of transboundary emission spillovers; and a political distortion, due to green and producer lobbying.

In Section 3.1 we have shown that the impact of green lobbying on environmental policy outcomes depends crucially on whether or not governments are bound by free trade rules. Hence the prevailing trade regime will also affect the comparative efficiency of unilateral and cooperative environmental policies. This can be easily shown in the case of two symmetric countries—in which the trade distortion is eliminated[34]—when governments are influenced by national green lobbies (the scenario of Table 1). In this case, the relative efficiency of unilateral and cooperative environmental policies can be measured in terms of their distance from the optimal Pigouvian tax $t_{\mathrm{P}} = \alpha H$.[35] We obtain the following result:

Proposition 2. *In the case of two symmetric countries, efficient Pigouvian taxes can only be achieved in an uncoordinated framework, and only if green lobbies are of a certain size* $\hat{s}^{E}$.

Proof. See Appendix B.

The intuition behind this result is the following: at the decentralized level, the bias towards higher pollution taxes caused by the political distortion (green lobbying) counteracts the bias towards lower pollution taxes caused by the environmental distortion (environmental spillovers); at the level of international negotiations, on the other hand, green lobbying distorts upwards policies that would otherwise be optimal.[36]

[34] In the case of symmetric countries, the first-best policies—achieved when governments are benevolent and act in a cooperative manner—are free trade and the adoption of Pigouvian taxes. In equilibrium, symmetric countries will always adopt identical tariffs and there will be no trade. Domestic prices, world prices and industry outputs will be the same as in free trade and there will be no allocative distortions other than those associated with uninternalized externalities.

[35] Notice that, if the policies lie on the same side of the optimum, the distance from the Pigouvian taxes can be unambiguously interpreted as a welfare measure. This is also the case for policies that lie on different sides of the optimum, if the welfare function is symmetric with respect to the environmental tax. In the general case of asymmetric countries, the existence of trade, environmental, and political distortions would make the comparison between the relative efficiency of unilateral and cooperative policy outcomes more ambiguous.

[36] It is important to stress that Proposition 2 applies only to the scenario in which green lobbying is the only political distortion. If both green and producer lobbies are present (the scenario of Table 3), first-best efficiency can be achieved in an uncoordinated or coordinated manner, depending on the relative size of the two lobby groups. For example, it can be shown that, when governments are not bound by a free trade agreement, Pigouvian taxes will be adopted unilaterally if

$$s^{\mathrm{E}} = \frac{s^{\mathrm{P}} Y + \alpha\omega\theta Y_{\mathrm{P}}}{\alpha Y_{\mathrm{P}}(1-\theta)}$$

and cooperatively if

$$s^{\mathrm{E}} = \frac{s^{\mathrm{P}} Y}{\alpha Y_{\mathrm{P}}}.$$

Clearly, the requirement for first-best efficiency is unlikely to be met. We can, however, ask a question of a second-best nature: would the environmental policies set by individual governments be more or less efficient than those set by a supra-national authority? The answer to this question is given in Proposition 3:

Proposition 3. *In the case of two symmetric countries*:

(*i*) *if governments are not bound by international trade rules, environmental policy coordination is efficiency enhancing if and only if* $s^E < \omega\theta/(2-\theta)$;
(*ii*) *under a free trade regime, environmental policy coordination is efficiency enhancing if and only if* $s^E < \omega\theta/(2-\theta-2\delta)$.

Proof. See Appendix C.

In the proof for the above result we show that a necessary condition for cooperative taxes (t_C) to be closer to the optimal Pigouvian taxes (t_P) than unilateral taxes (t_{NC}) is $t_C > t_P > t_{NC}$.[37] If this condition is satisfied, environmental policy cooperation is efficiency enhancing if and only if green lobbies are smaller than a certain critical size. From Proposition 3, notice that this critical size is smaller in the case of a free trade regime. The reason behind this is that, in a free trade regime, due to the existence of emission leakages, the green lobbies' support for higher domestic pollution taxes is weaker; therefore, free trade increases the comparative efficiency of cooperative environmental policies.

4. Concluding remarks

We have investigated how the presence of green lobbies can influence environmental policy determination in the presence of transboundary pollution in economies that are linked by trade flows and are large. The main results of our analysis can be summarized as follows:

(i) the impact of green lobbying on the environmental policy outcomes depends on the existing trade policy regime, the type of decision-making process, and the size of the emission leakages and the associated transboundary spillovers;
(ii) in the absence of pre-existing international trade rules, green lobbying unambiguously creates a bias towards the adoption of higher pollution taxes;
(iii) when governments are bound by free trade rules but select environmental policy unilaterally, the existence of emission leakages reduces (and might even reverse) green lobbies' support for higher pollution taxes.

[37] This condition is satisfied if $s^E < \omega\theta/(1-\theta)$, when import tariffs are available, and if $s^E < \omega\theta/(1-\theta-\delta)$, in the case of a free trade regime.

Does the presence of green lobbies weaken the need for environmental policy coordination? The analysis above suggests that the answer to this question depends crucially on the degree of trade policy cooperation. On the one hand, countries that have not committed to trade cooperation might find it more efficient to choose policies in a unilateral manner. On the other hand, countries that are already cooperating on trade policies are more likely to gain by coordinating their environmental policies too.

At the international level, our findings suggest that the existence of WTO rules restricting governments' ability to use trade barriers implies the need for the creation of a World Environmental Organization (WEO).[38] However, if WTO rules are not binding[39] unilateral policy-making could lead to more efficient policy outcomes. At the regional level, our results hint at the need for environmental cooperation among the members of preferential trade agreements such as the E.U., NAFTA, MERCOSUR and ASEAN.[40]

The analytical framework described in this paper is highly simplified and the results obtained must be interpreted with caution. More work is needed to examine how economic policies, including trade and environmental policies, are determined by political and economic interests. For example, it would be interesting to incorporate the analysis of the underlying electoral process into the common agency model adopted in this paper, to provide clearer microfoundation for the governments' objective functions. More attention should also be devoted to the analysis of the process of lobby formation, to explain how some groups of citizens overcome the free-rider problem of collective action and become politically organized.

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[38]For a discussion of the arguments in favor of the creation of a WEO, see Whalley and Zizzimos (2000).

[39]WTO obligations are eroded by the fact that countries are able to invoke many exceptions to them. Examples are exceptions for health, welfare, and national security reasons (Articles XX and XXI), the General Waivers (Article XXV), or antidumping and countervailing duties (Articles VI).

[40]To some extent, environmental policy cooperation already happens within the E.U. and NAFTA (see Carraro and Siniscalco, 1993; Bulmer-Thomas et al., 1994).

Appendix A. Policy equilibria

We define the following indicator variables:

- I^{NE} ($I^{\mathrm{NE}*}$): equal to one if the home (foreign) government is influenced by a national green lobby, and zero otherwise.
- I^{IE}: equal to one if the governments are influenced by an international green lobby, and zero otherwise.
- I^{P} ($I^{\mathrm{P}*}$): equal to one if the home (foreign) government is influenced by a producer lobby, and zero otherwise.

For notational simplification, we drop sectoral subscripts. We define $D_q = \partial D/\partial q$ and $Y_p = \partial Y/\partial p$, and indicate the effect of an increase in domestic tariffs on the international price with

$$\frac{\partial \pi}{\partial \tau} = -\frac{\varepsilon^M}{(p/p*)(\varepsilon^M - \varepsilon^{M}*)} \equiv -\phi. \tag{A.1}$$

Notice that δ_i always lies between 0 and 1, implying an increase in the international price.

Unilateral policies

Let us consider first the case of a unilateral decision-making process, in which policies are chosen so as to maximize (13). Under the assumption that lobbies offer truthful political contributions, the non-cooperative equilibrium policies must satisfy the following conditions:

$$\omega\frac{\partial W}{\partial t} + I^{\mathrm{NE}}\frac{\partial W^{\mathrm{NE}}}{\partial t} + I^{\mathrm{IE}}\frac{\partial W^{\mathrm{IE}}}{\partial t} + I^{\mathrm{P}}\frac{\partial W^{\mathrm{P}}}{\partial t} = 0, \tag{A.2}$$

$$\omega\frac{\partial W}{\partial \tau} + I^{\mathrm{NE}}\frac{\partial W^{\mathrm{NE}}}{\partial \tau} + I^{\mathrm{IE}}\frac{\partial W^{\mathrm{IE}}}{\partial \tau} + I^{\mathrm{P}}\frac{\partial W^{\mathrm{P}}}{\partial \tau} = 0, \tag{A.3}$$

while foreign unilateral policies must satisfy

$$\omega*\frac{\partial W*}{\partial t*} + I^{\mathrm{NE}}*\frac{\partial W^{\mathrm{NE}}*}{\partial t*} + I^{\mathrm{IE}}\frac{\partial W^{\mathrm{IE}}}{\partial t*} + I^{\mathrm{P}}*\frac{\partial W^{\mathrm{P}}*}{\partial t*} = 0, \tag{A.4}$$

$$\omega*\frac{\partial W}{\partial \tau*} + I^{\mathrm{NE}}*\frac{\partial W^{\mathrm{E}}*}{\partial G\tau*} + I^{\mathrm{IE}}\frac{\partial W^{\mathrm{IE}}}{\partial \tau*} + I^{\mathrm{P}}*\frac{\partial W^{\mathrm{P}}*}{\partial \tau*} = 0. \tag{A.5}$$

Substituting partial derivatives into (A.2) and (A.3), we obtain

$$\omega\{Y(\delta-1)+tY_p(\delta-1)+Y+\tau[D_q\delta-Y_p(\delta-1)]-D\delta$$
$$-H[(1-\theta)\alpha Y_p(\delta-1)+\theta\alpha^*Y_p^*\delta]\}$$
$$-I^{NE}s^EH[(1-\theta)\alpha Y_p(\delta-1)+\theta\alpha^*Y_p^*\delta]$$
$$-I^{IE}\{\alpha Y_p(\delta-1)[s^EH(1+\theta)+s^{E*}H^*\theta^*]$$
$$+\alpha^*Y_p^*\delta[s^{E*}H^*(1+\theta^*)+s^EH\theta]\}$$
$$+I^Ps^PHY(\delta-1)=0, \tag{A.6}$$

$$w\{Y(1-\phi)+\tau(1-\phi)(D_q-Y_p)+D-Y+tY_p(1-\phi)-D(1-\phi)$$
$$-H[(1-\theta)\alpha Y_p(1-\phi)-\phi\theta\alpha^*Y_p^*]\}$$
$$-I^{NE}s^EH[(1-\theta)\alpha Y_p(1-\phi)-\theta\alpha^*Y_p^*\phi]$$
$$-I^{IE}\{\alpha Y_p(1-\phi)[s^EH(1+\theta)+s^{E*}H^*\theta^*]$$
$$-\alpha^*Y_p^*\phi[s^{E*}H^*(1+\theta^*)+s^EH\theta]\}$$
$$+I^Ps^PHY(1-\phi)=0. \tag{A.7}$$

Foreign environmental and trade policies must satisfy conditions that are symmetric to the above.

The non-cooperative policy equilibria reported in Section 3 are obtained by combining (A.6) and (A.7) with the market clearing condition (3)[41] for the case of two symmetric countries.

Cooperative policies

Let us move to the case of a cooperative decision-making process, in which environmental and trade policies are chosen so as to maximize (15). Under the assumption that lobbies offer truthful political contributions, this implies the following first-order conditions:

[41]Market clearing implies the following equilibrium conditions:

$$\frac{\partial M}{\partial \tau}=-\frac{\partial M^*}{\partial \tau}\Rightarrow(Dq-Yp)(1-\phi)=-\phi(Yp^*-Dq^*),$$
$$\frac{\partial M}{\partial t}=-\frac{\partial M^*}{\partial t}\Rightarrow Dq\delta-Yp(\delta-1)=(Yp^*-Dq^*)\delta.$$

$$\omega^*\left[I^{NE}\frac{\partial W^{NE}}{\partial t}+I^{IE}\frac{\partial W^{IE}}{\partial t}+I^{P}\frac{\partial W^{P}}{\partial t}\right] + \omega\left[I^{NE*}\frac{\partial W^{NE*}}{\partial t}+I^{P*}\frac{\partial W^{P*}}{\partial t}\right]+\omega\omega^*\left[\frac{\partial W}{\partial t}+\frac{\partial W^*}{\partial t}\right]=0, \tag{A.8}$$

$$\omega^*\left[I^{NE}\frac{\partial W^{NE}}{\partial \tau}+I^{IE}\frac{\partial W^{IE}}{\partial \tau}+I^{P}\frac{\partial W^{P}}{\partial \tau}\right] + \omega\left[I^{NE*}\frac{\partial W^{NE*}}{\partial \tau}+I^{P*}\frac{\partial W^{P*}}{\partial \tau}\right]+\omega\omega^*\left[\frac{\partial W}{\partial \tau}+\frac{\partial W^*}{\partial \tau}\right]=0, \tag{A.9}$$

$$\omega\left[I^{NE*}\frac{\partial W^{NE*}}{\partial t^*}+I^{IE}\frac{\partial W^{IE}}{\partial t^*}+I^{P*}\frac{\partial W^{P*}}{\partial t^*}\right] + \omega^*\left[I^{NE}\frac{\partial W^{NE}}{\partial t^*}+I^{P}\frac{\partial W^{P}}{\partial t^*}\right]+\omega\omega^*\left[\frac{\partial W}{\partial t^*}+\frac{\partial W^*}{\partial t^*}\right]=0, \tag{A.10}$$

$$\omega\left[I^{NE*}\frac{\partial W^{NE*}}{\partial \tau^*}+I^{IE}\frac{\partial W^{IE}}{\partial \tau^*}+I^{P*}\frac{\partial W^{P*}}{\partial \tau^*}\right] + \omega^*\left[I^{NE}\frac{\partial W^{NE}}{\partial \tau^*}+I^{P}\frac{\partial W^{P}}{\partial \tau^*}\right] + \omega\omega^*\left[\frac{\partial W}{\partial \tau^*}+\frac{\partial W^*}{\partial \tau^*}\right]=0. \tag{A.11}$$

Substituting partial derivatives into (A.8) and (A.9), we obtain

$$\begin{aligned}
&\omega^*\{-I^{NE}s^{E}H[(1-\theta)\alpha Y_p(\delta-1)+\theta\alpha^*Y_p^*\delta] \\
&-I^{IE}[\alpha Y_p(\delta-1)(s^{E}H(1+\theta)-s^{E*}H^*\theta^*)-\alpha^*Y_p^*\delta(s^{E*}H^*(1+\theta^*) \\
&+s^{E}H\theta)]+I^{P}s^{P}HY(\delta-1)\} \\
&+\omega\{-I^{NE*}s^{E*}H^*[(1-\theta^*)\alpha^*Y_p^*\delta+\theta^*\alpha Y_p(\delta-1)]+I^{P*}s^{P*}H^*Y^*\delta\} \\
&+\omega\omega^*\{Y(\delta-1)+tY_p(\delta-1)+Y+\tau[D_q\delta-Y_p(1-\delta)]-D\delta \\
&-H[(1-\theta)\alpha Y_p(\delta-1)+\theta\alpha^*Y_p^*\delta] \\
&+Y^*\delta+t^*Y_p^*\delta+\tau^*\delta(D_q^*-Y_p^*)-D^*\delta \\
&-H^*[(1-\theta^*)\alpha^*Y_p^*\delta+\theta^*\alpha Y_p(\delta-1)]\}=0,
\end{aligned} \tag{A.12}$$

$$\begin{aligned}
&\omega^*\{-I^{NE}s^{E}H[(1-\theta)\alpha Y_p(1-\phi)-\theta\alpha^*Y_p^*\phi] \\
&-I^{IE}[\alpha Y_p(1-\phi)(s^{E}H(1+\theta)+s^{E*}H^*\theta^*)-\alpha^*Y_p^*\phi(s^{E*}H^*(1+\theta^*) \\
&+s^{E}H\theta)]+I^{P}s^{P}HY(1-\phi)\} \\
&+\omega\{-I^{NE*}s^{E*}H^*[-(1-\theta^*)\alpha^*Y_p^*\phi+\theta^*\alpha Y_p(1-\phi)]-I^{P*}s^{P*}H^*Y^*\phi\} \\
&+\omega\omega^*\{Y(1-\phi)+\tau(1-\phi)(D_q-Y_p)+D-Y+tY_p(1-\phi)-D(1-\phi) \\
&-H[(1-\theta)\alpha Y_p(1-\phi)-\theta\alpha^*Y_p^*\phi]
\end{aligned}$$

$$- Y^*\phi - \tau^*\phi(D_q^* - Y_p^*) - t^*Y_p^*\phi + D^*\phi - H^*[-(1-\theta^*)\alpha^*Y_p^*\phi + \theta^*\alpha Y_p(1-\phi)]\} = 0. \quad \text{(A.13)}$$

Two symmetric conditions must hold for the foreign country.

The cooperative policy equilibria reported in Section 3 are obtained by combining (A.12) and (A.13) with the market clearing condition.

Free trade

In the case of a free trade regime, we set $\tau = \tau^* = 0$ and equilibrium conditions (A.6) and (A.12) and the market clearing condition to solve for the unilateral and cooperative environmental taxes adopted by two symmetric countries.

Appendix B. Proof of Proposition 2

In Section 4, we compare the relative efficiency of the unilateral and cooperative taxes (t_{NC} and t_C) adopted by two symmetric countries, defined in terms of their distance from the optimal Pigouvian solution t_P.

From the analysis of Table 1, it is straightforward to verify that while cooperative taxes are always higher than optimal ($t_C > t_P$), unilateral taxes can be optimal ($t_{NC} = t_P$) if an only if green lobbies have critical size $\hat{s}^E$. If both policies are available, $\hat{s}^E = \omega\theta/(1-\theta)$; in the case of a free trade regime, $\hat{s}^E = \omega\theta/(1-\delta-\theta)$. □

Appendix C. Proof of Proposition 3

Trade and environmental policies

When both trade and environmental policies are available, we can distinguish two cases:

(1) if $s^E > \omega\theta/(1-\theta) \Rightarrow t_C > t_{NC} > t_P$;
(2) if $s^E < \omega\theta/(1-\theta) \Rightarrow t_C > t_P > t_{NC} > 0$. There are two subcases:
   (a) $(t_P - t_{NC}) < (t_C - t_P) \Leftrightarrow s^E > \omega\theta/(2-\theta)$,
   (b) $(t_P - t_{NC}) > (t_C - t_P) \Leftrightarrow s^E < \omega\theta/(2-\theta)$.

Therefore, cooperative taxes are closer to the optimal Pigouvian solution than unilateral taxes if and only if $s^E < \omega\theta/(2-\theta) < \omega\theta/(1-\theta)$.

Free trade

When governments are bound by free trade rules, we can distinguish three cases:

(1) if $\delta + \theta < 1$ and $s^E > \omega\theta/(1 - \theta - \delta) \Rightarrow t_C > t_{NC} > t_P$;
(2) if $\delta + \theta < 1$ and $s^E < \omega\theta/(1 - \theta - \delta) \Rightarrow t_C > t_P > t_{NC} > 0$. There are two subcases:
   (a) $(t_P - t_{NC}) < (t_C - t_P) \Leftrightarrow s^E > \omega\theta/(2 - \theta - 2\delta)$,
   (b) $(t_P - t_{NC}) > (t_C - t_P) \Leftrightarrow s^E < \omega\theta/(2 - \theta - 2\delta)$;
(3) if $\delta + \theta > 1 \Rightarrow t_C > t_P > 0 > t_{NC}$ and $(t_P - t_{NC}) > (t_C - t_P)$.

Therefore, cooperative taxes are closer to the optimal Pigouvian solution than non-cooperative taxes if and only if $s^E < \omega\theta/(2 - \theta - 2\delta) < \omega\theta/(1 - \theta - \delta)$. □

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