The Political Economy of Environmental Policy Formation in an International Setting

by

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This version: 17. January 2009

Abstract

We analyze the formation of environmental policy to regulate transboundary pollution if governments are self-interested. In a common agency framework we portray the environmental policy calculus of two political support-maximizing governments that are in a situation of strategic interaction with each other. We show how governments will systematically deviate from socially optimal policies and how their policies will differ from political-economic calculus adopted by small open economies that are unaffected by their neighbor's environmental policy. Instead of internalizing the externalities it is possible that governments will actually subsidize pollution. Politically motivated environmental policy may be more or less harmful to the environment compared to the benevolent dictators' solution.

JEL classification: Q 58, F 5

Key words: Political economy, environmental policy, transboundary pollution, common agency

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1. Introduction

It is widely recognized that environmental policy formation is influenced by powerful interest groups – trade associations and environmentalists – and that governments respond to their lobbying as their first goal is to stay in power.[1] Yet many environmental problems are transboundary and therefore domestic environmental quality depends not only on domestic environmental policy, but also on foreign policy. Thus governments interact strategically with domestic lobbying groups and voters at home seeking to maximize political support; at the same time they are in a situation of strategic interaction with neighboring governments that are likewise seeking to maximize their political support. How will governments set their policies in this situation of double strategic interaction? This is the concern of this paper.

We analyze two open economies that are small on the international goods markets and thus their policies are not influenced by terms of trade considerations . At the same time their emissions will spill over to their neighboring country and vice versa and thus they have a large environmental impact regionally. For a lot of environmental problems this seems a realistic setting.[2] To portray the domestic political arena we employ a common agency model developed by Bernheim and Whinston (1986) and introduced in the literature on endogenous policy formation by Grossman and Helpman (1994). We assume functionally specified interest groups that pursue only one goal with respect to environmental policy. The strategic interaction between the countries results from transborder pollution – foreign environmental regulation is a substitute to domestic policy for environmental quality, but places the burden on foreign rather than domestic producers.

In this framework, we show that the optimal policy systematically deviates from the social welfare maximizing policy; it also deviates systematically from the policy that the government would pursue in the absence of the strategic interaction between the two governments. In equilibrium the politically optimal tax rate could be either higher or lower than the social welfare-maximizing tax rate, depending on the relative strength of the lobby groups and the intensity of damage that is caused by production, and thus environmental damage could be above or below the optimal level. We demonstrate that – contrary to the benevolent dictators' equilibrium – tax rate can be

[1] Cf. Binder and Neumayer (2005) and Fredriksson et al. (2005) for empirical evidence on the political influence of environmental lobby groups.

[2] We exclude thus environmental regulation of *global* pollutants which can be analyzed only in a multi-country setting (cf. Barrett 2003). Regional pollution includes emissions of NO_x and SO_x, acid rain, but also pollution of waters that shared by nations such as the Black Sea or the Baltic Sea.

negative in equilibrium, either for one country or for both. Tax rates on transboundary pollution will be lower than tax rates on pollution that does not transgress national boundaries.

Our paper adds to the literature on endogenous environmental policy. Fredriksson (1997) analyzes the effects of world price changes and lobbying on the politically optimal pollution tax rate. He shows that pollution may be increasing in the abatement subsidy because the pollution tax is reduced due to a change in lobbying influence. Schleich (1997) introduces a second policy instrument and analyzes the choice between domestic taxes (on consumption or production) and tariffs when the externality is in production or consumption.[3] Aidt (1998) assumes that pollution stems from the use of an input rather than production as such and demonstrates that a politically optimizing government will choose the efficient (input) tax instrument if it has the choice. He thus establishes a political economy version of Bhagwati's principle of targeting. [4] Fredriksson and Svensson (2003) analyze the interaction of corruption – seen as the weight that they attach to contributions-bribes by lobbies as opposed to social welfare – and political instability in a three stage game. In the first stage the lobby groups offer bribes contingent on the policy, in the second stage the government decides on the environmental policy and collects the bribe and in the third stage the government implements the policy but is subject to removal with a certain probability indicating the degree of instability. The authors show that political instability has a negative effect on the stringency of environmental policy if corruption is low and a positive effect when corruption is high.

These papers all use a common agency model to portray the political game that determines environmental policy. Yet, they do not take into account the strategic interaction that governments are exposed to in the international arena when deciding on their environmental policies; thus environmental policy is determined by domestic considerations alone.[5] The paper that comes closest to our approach is Conconi (2003). She models two large open economies that jointly determine trade and environmental policies. In her model emission leakages occur when a large country taxes the production of a polluting good which raises the world market price for it and thus foreign production. She shows that under free trade and strong emission leakages

[3] Schleich and Orden (1999) generalize the small economy case to the large economy setting.

[4] Hillman and Ursprung (1994) analyze the influence of environmental concerns on endogenous trade policy, but they do not study environmental policy formation. Bommer and Schulze (1997) consider the effect of trade liberalization on endogenous trade policy.

[5] Strategic interaction in the determination of environmental policy is analyzed in the literature on transboundary pollution (e.g. Markusen 1975) and the literature on strategic environmental policy (e.g. Barrett 1994). Both strands of literature, however, do not take into account the political-economic rationale in environmental policy formation.

environmental lobbying can actually lower emission taxes as unilaterally set taxes would increase degradation.

In our model these emission leakages do not occur because countries are small and thus environmental policies do not give rise to price changes in international markets. We show that small countries may adopt more or less stringent policies than social welfare maximization would imply. This depends on the relative strength of the environmental lobby group and the size of the industry-specific interest group. It also depends on the weight that governments place on social welfare, id est the degree to which voters determine the policy outcome. We show that – unlike in the case of social welfare maximizing governments – one or both countries may actually subsidize the polluting good rather than taxing it and thus exacerbate environmental degradation. To our knowledge, apart from Conconi (2003) our study is the only one to address international strategic interaction in a model of endogenous environmental policy. The nature of strategic interaction, however differs substantially as we disregard repercussions from international commodity markets that are unlikely for many small countries.

The remainder of this paper is organized as follows. Section 2 introduces the two country model with transboundary pollution. Section 3 derives the social welfare maximum for non-cooperative governments and the joint welfare maximum; which serve as reference points. Section 4 introduces the common agency approach, derives the politically optimal tax rate and simulates it for various parameter constellations and derives comparative-static results. Section 5 concludes.

2. Transborder Pollution in a Two Country Model

The model consists of two countries, which are small open economies on the product markets and which experience cross-border pollution from production.

Pollution, Sector Specific Income, Production, and Tax Income

Each economy has two sectors, denominated Z and X. Sector Z produces the non-polluting numeràire good z, which is produced by labor alone. Units are chosen so that the world and domestic price for the numeràire good equal one. Free trade prevails in both markets; goods prices are determined on the world markets. By choice of units, wage rate is normalized to unity. The second sector, X, produces the polluting good x with labor and a sector-specific factor, which is non-tradeable and inelastically supplied. Let S denote environmental pollution, which is perfectly transnational and assumed to affect both countries equally:

$$S = \beta\left(X + X^*\right)^2 \quad \textbf{(1)}$$

The variable β is an exogenously given damage coefficient and X (X^*) is the home (foreign) production of x. Foreign country variables are denominated with a "*". The government levies a tax on the environmental damage created by the production of *x* on the producer of *x* (if home production of x is positive). Sector-specific income from the production of *x* is defined as:

$$\begin{aligned}\Pi\left(X\right) &= \overline{p}X - X^2 - tS \\ &= \overline{p}X - X^2 - t\beta\left(X + X^*\right)^2,\end{aligned} \quad \textbf{(2)}$$

where $\overline{p}$ is the (exogenously given world market) price of *x*. Technology exhibits diminishing returns to scale. We assume that in both countries *x* is produced by only one firm, which chooses *X* in order to maximize (2) to:

$$X = \frac{1}{2}\frac{\left(\overline{p} - 2t\beta X^*\right)}{\left(1+\mathrm{t}\beta\right)} \quad \textbf{(3)}$$

By substituting foreign production into Eq. (3), we obtain the home production of *x*, which is contingent on domestic and foreign tax rates:

$$\hat{X} = \frac{1}{2}\frac{\overline{p}\left(1+\beta\left(t^* - t\right)\right)}{\left(1+\beta\left(\mathrm{t}^* + \mathrm{t}\right)\right)} \quad \textbf{(4)}$$

Foreign production is obtained symmetrically. Obviously tax policy of both countries affect the production levels in home and in foreign. We are interested in constellations in which both countries produce positive amounts of the polluting good x. From eq. (4) and the corresponding equation for $\hat{X}^*$ we can derive the following conditions for positive production in both countries.[6]

$t, t^* > 0$	$\hat{X} > 0 \quad if \quad t^* - t > -\frac{1}{\beta}$ $\hat{X}^* > 0 \quad if \quad t - t^* > -\frac{1}{\beta}$ only one restriction will be binding as β > 0.	**(5)**
$t, t^* < 0$	$\hat{X}, \hat{X}^* > 0 \quad if \quad t^* + t > -\frac{1}{\beta}$	**(5b)**

[6] Numerator and denominator of eq. (4) need to be both either positive or negative. The same must hold for the corresponding equation for the foreign production of x. This results in set of restriction of which only the binding are reported.

t>0, t*<0	$\hat{X}, \hat{X}^* > 0 \quad if \quad t^* - t > -1/\beta$	**(5c)**

If these conditions are not met one country will stop producing the polluting good.[7]

If $\hat{X}$ is positive, it decreases in the home tax rate and in the damage coefficient β, as producers' marginal tax payment from production increases with the home tax rate and with β.[8] $\hat{X}$ increases with the foreign tax rate, since such an increase leads to a decrease in foreign production X^*, and consequentially to a decrease in producer's marginal tax payment from production. As the world market price increases, marginal income from production increases and thereby $\hat{X}$.

As we substitute $\hat{X}$ from Eq. (4), and symmetrically $\hat{X}^*$, into Eq. (1), we obtain pollution contingent on the tax rates:

$$\hat{S}(t,t^*) = \frac{\beta \overline{p}^2}{\left(1+\beta(t^*+t)\right)^2} \tag{6}$$

Pollution increases with $\hat{X}$, and thus with the world market price, and decreases with the tax rates. We may now obtain sector specific income contingent on the tax rates by substituting Eqs. (4) and (5) in Eq. (2). Rearrangements yield:

$$\hat{\Pi}(t,t^*) = \frac{\overline{p}^2}{4} \frac{\left[\left(1+\beta(t^*-t)\right)^2 + 4t\beta^2(t^*-t)\right]}{\left(1+\beta(t^*+t)\right)^2} \tag{7}$$

Sector specific income decreases in t and β while it increases with the foreign tax rate and the world market price. Total domestic revenue from pollution taxes, $\hat{\tau}(t,t^*) = t\hat{S}$, is:

$$\hat{\tau}(t,t^*) = \frac{t\beta \overline{p}^2}{\left(1+\beta(t^*+t)\right)^2} \tag{8}$$

$\hat{\tau}$ is redistributed uniformly to all citizens of the respective country.[9] If domestic production is positive, $\hat{\tau}$ increases (decreases) with the domestic (foreign) tax rate and the world market price. It also increases (decreases) with β, if total pollution S increases (decreases) with β.

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[7] These conditions state that various combinations of tax rates allow positive production of both countries; they do not indicate that these tax rates will indeed be set by the countries.

[8] All partial derivations from this section, which are not explicitly given in the text, can be found in Appendix A.

[9] If taxes are negative all individuals are taxed uniformly.

Population and Utility Functions

The home country is populated by N heterogeneous citizens of three different types: environmentalists, industrialists, and workers. N is normalized to one. All citizens have labor income. The total amount of labor in each country equals l. Each individual has the same share of l. Let α^E be the exogenously given share environmentalists in the population, α^I (α^W) the share of industrialists (workers). Environmentalists are concerned with pollution. Industrialists obtain factor income from production of good *x*, while workers do not derive disutility from pollution; they derive income from labor only (as do environmentalists).

Individual maximization problems are defined as follows:

Each Environmentalist solves:

$$\begin{aligned} &\max_{c^z,\, c^x}\ U^E = c^z + u\left(c^x\right) - S \\ &s.t. \quad l + \tau = c^z + \overline{p}c^x, \end{aligned} \tag{9}$$

while each industrialist solves

$$\begin{aligned} &\max_{c^z,\, c^x}\ U^I = c^z + u\left(c^x\right) \\ &s.t. \quad l + \tau + \frac{\Pi}{\alpha^I} = c^z + \overline{p}c^x. \end{aligned} \tag{10}$$

Lastly, workers solve

$$\begin{aligned} &\max_{c^z,\, c^x}\ U^W = c^z + u\left(c^x\right) \\ &s.t. \quad l + \tau = c^z + \overline{p}c^x. \end{aligned} \tag{11}$$

c^z is consumption of the numeraire good *z* and c^x is consumption of good *x*. $u\left(c^x\right)$ is the concave, differentiable utility function from consumption of *x*. All Environmentalists are equally affected in their utility by total pollution. The term Π/α^I in Eq. (10) expresses that sector-specific income is being equally proportioned to all industrialists.

Since prices are given by the world markets, we obtain the following aggregate utility functions of environmentalists, industrialists, and workers:

$$\Omega^E\left(t,t^*\right) \equiv \alpha^E\left[-S + \tau + l\right] \tag{12}$$

$$\Omega^I\left(t,t^*\right) \equiv \Pi + \alpha^I\left[\tau + l\right] \tag{13}$$

$$\Omega^W\left(t,t^*\right) \equiv \alpha^W\left[\tau + l\right] \tag{14}$$

The sum of the aggregate utility functions of each country is defined as gross aggregate welfare:

$$\Omega^A \equiv \Omega^E + \Omega^I + \Omega^W = \tau + l + \Pi - \alpha^E S \tag{15}$$

The term $\alpha^E S$ represents aggregate disutility from pollution of the environmentalists and thus to the society as a whole. It is contingent on the product of total pollution and the share of the environmentalists. Sector specific income, by contrast, is independent of the relative size of industrialists, since α^I merely defines the number of industrialist, among whom the sector-specific income is divided. To obtain gross aggregate welfare – being contingent on the tax rates – we substitute eqs. (5), (7), and (8) in eq. (15). Rearrangements yield:

$$\hat{\Omega}^A(t,t^*) \equiv \hat{\tau} + l + \hat{\Pi} - \alpha^E \hat{S}$$
$$= \frac{\overline{p}^2}{4} \frac{\left[\left(1+\beta\left(t^*-t\right)\right)^2 + 4t\beta\left(1+\beta\left(t^*-t\right)\right) - 4\alpha^E\beta\right]}{\left(1+\beta\left(t^*+t\right)\right)^2} + l. \tag{16}$$

3. Social Welfare Maximization

As a reference point for our further analysis we derive the benevolent dictators' solution if tax rates are set non-cooperatively and if both countries maximize joint welfare. We start with the non-cooperative solution.

Non-cooperative solution

Each government seeks to maximize its country's aggregate welfare. The domestic government chooses t in order to maximize eq. (16), taking the foreign tax rate as given:

$$\hat{\Omega}_t^A = \frac{2\beta^2\overline{p}^2\left(\alpha^E - t\left(1+t^*\beta\right)\right)}{\left(1+\beta\left(t^*+t\right)\right)^3} \overset{!}{=} 0 \tag{17}$$

Solving eq. (17) for t gives the domestic government's reaction function:

$$\hat{t}^{NC} = \frac{\alpha^E}{1+t^*\beta} \tag{18}$$

$\hat{t}^{NC}$ increases with the number of environmentalists and decreases with the foreign tax rate. The foreign country's reaction function is isomorphous. The Nash equilibrium tax rate is calculated as:

$$t^{NC} = \frac{\sqrt{\left(1+\beta\left(\alpha^{E*}-\alpha^E\right)\right)^2 + 4\alpha^E\beta} - \left(1+\beta\left(\alpha^{E*}-\alpha^E\right)\right)}{2\beta} \tag{19}$$

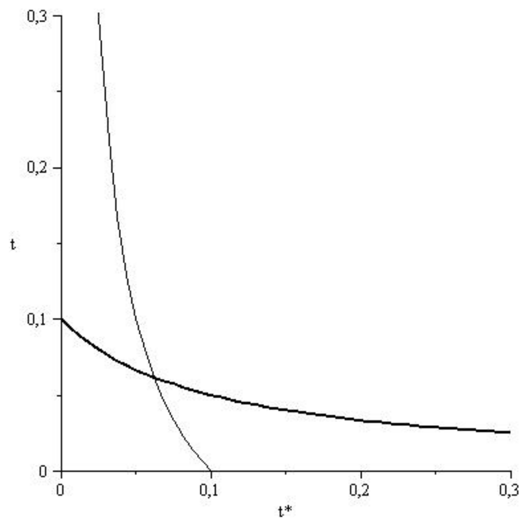
It is straightforward to show that the difference in equilibrium tax rates satisfies:

$$t^{NC} - t^{NC}* = \alpha^E - \alpha^E * \quad \textbf{(20)}$$

We can also establish that the equilibrium tax rates must be positive in the benevolent dictators' case. From eqs. (18) and (18*)[10] it follows that both countries' tax rates must be either both positive or both negative. If they were negative both denominators in (18) and (18*) would have to be negative which implied $1 + t\beta + t*\beta < 0$. This is equivalent to $t + t* < -1/\beta$. This condition however is inconsistent with the condition that both countries produce good *x*, cf. eq. (5c).

Figure 1 pictures the non-cooperative tax rates. The bold line is the home country's reaction function $\hat{t}^{NC}(t^{NC}*)$, while the thin line illustrates $\left(\hat{t}^{NC}*(t^{NC})\right)^{-1}$, the inverse of $\hat{t}^{NC}*$. The intersection depicts the Nash equilibrium. (The reaction functions are drawn for $\beta = 10$ and $\alpha_{\mathrm{E}} = \alpha*_{\mathrm{E}} = 0.1$).

Figure 1: Non-cooperative equilibrium



The non-cooperative tax rate $\hat{t}^{NC}$ is smaller than society's marginal damage from pollution α^E, if $\hat{t}^{NC}*$ is larger than zero. Figure 1 shows that the tax rate equals society's marginal damage only if $\hat{t}^{NC}* = 0$. This well-known effect is due to the strategic interaction of the two governments effect in this model.[11] The home government has an incentive to choose a tax rate lower than α^E in order to provoke an increase in the foreign tax rate, so that domestic producers are less

[10] Equation numbers with "*" indicate the foreign country's corresponding equation.

[11] As the home government lowers the tax rate, home production and thus pollution increase, and the foreign government reacts with an increase in its tax rate. The higher (smaller) the foreign tax rate, the smaller (higher) is the decrease in home production for a given home tax rate. See (A.1) in Appendix 1.

harmed by the domestic tax rate. This effect is characterized by $1+t^*\beta$ in the denominator and occurs unless $\hat{t}^{NC*}=0$.

Comparative static effects of variations in α^E and β are depicted in Figure 2 and Figure 3. An increase in α^E shifts the reaction function outwards with the Nash being characterized by a higher domestic and a lower foreign tax rate (the dashed line in Figure 2 represents $\hat{t}^{NC}$ for $\alpha^E=0.2$, the dotted line for $\alpha^E=0.05$; the solid line for $\alpha^E=0.1$ as before.). This follows straightforwardly from differentiating eq. (19) w.r.t. α^E and the corresponding eq. (19*) w.r.t. t. A higher valuation of the environment increases the tax rate at home; the foreign country as a reaction reduces the own tax rate as it can benefit from lower cross-border pollution and reduce the tax burden for its own firm.

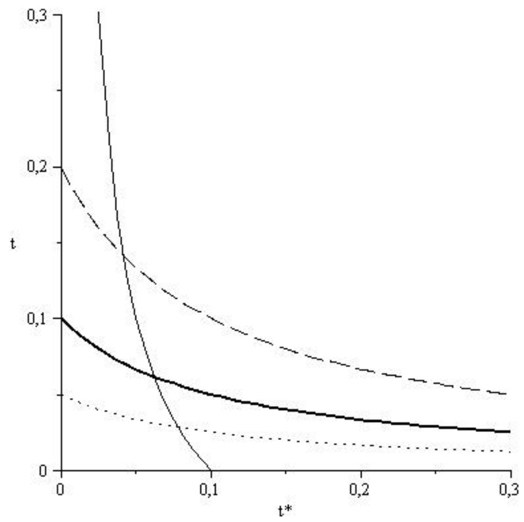


Figure 2: The effect of a change in α^E

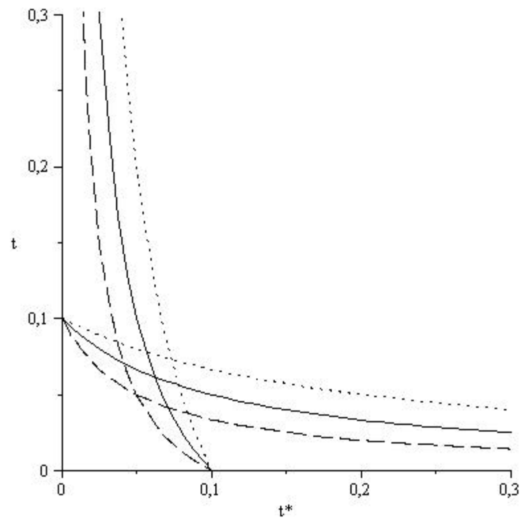


Figure 3: The effect of a change in β

An increase in β rotates both reaction curves inwards with the resulting Nash equilibrium at lower tax rates (The dashed line in Figure 3 represents $\beta=20$, the dotted line $\beta=5$ and the solid line, as before, $\beta=10$.). Algebraically this result is derived by differentiating eq. (19) and (19*) w.r.t. β and signing it as $\frac{\partial t^{NC}}{\partial \beta}<0$.[12] Other things being equal, an increase in the damage coefficient β increases the environmental damage proportionally (as society's marginal disutility

[12] $\frac{\partial t^{NC}}{\partial \beta}=\frac{\sqrt{\left(1+\beta\left(\alpha^{E*}-\alpha^E\right)\right)^2+4\alpha^E\beta}-\left(1+\beta\left(\alpha^{E*}+\alpha^E\right)\right)}{2\beta^2\sqrt{\left(1+\beta\left(\alpha^{E*}-\alpha^E\right)\right)^2+4\alpha^E\beta}}$, which is clearly negative.

from pollution is constant $\left(=\alpha^{E}\right)$ but increases the tax burden on the firm more than proportionally $(T = t\beta(X + X^{*})^{2}$. Re-equating marginal benefits and costs of taxation thus requires a reduction in the tax rate.[13]

Joint Welfare Maximum

The previous subsection reproduced the inefficiency of non-cooperative environmental policy in the presence of transboundary pollution (Markussen 1975). We now establish the joint welfare maximizing solution. Joint welfare maximization requires:

$$\left(\hat{\Omega}^{A}\right)_{t} + \left(\hat{\Omega}^{A}*\right)_{t} \overset{!}{=} 0 \tag{21}$$

Solving Eq. (20) for t we obtain, with rearrangements:

$$\hat{t}^{C} = \frac{\alpha^{E} + \alpha^{E}* + \mathrm{t}*^{2}\beta}{\mathrm{t}*\beta + 1} \tag{22}$$

The foreign cooperative tax rate can be found symmetrically. By substituting $\hat{t}^{C}*$ into eq. (22), we obtain the equilibrium cooperative tax rate:

$$\hat{t}^{C} = \alpha^{E} + \alpha^{E}* \tag{23}$$

The cooperative tax $\hat{t}^{C}$ equals aggregate marginal damage from pollution to both societies and is thus not contingent on β.[14] Total pollution is lower in the cooperative case than in the non-cooperative case, since $\hat{t}^{C}$ is larger than $\hat{t}^{NC}$

4. Interest Based Approach

We now employ a more realistic setting and assume that governments are self-interested. More specifically, we assume a common agency framework (Bernheim and Whinston 1986, Grossman and Helpman 1994), in which governments maximize a political support function (rather than purely social welfare) which is a weighted sum of social welfare and contributions offered by political interest groups.

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[13] The intersections with the vertical and horizontal axes in Figure 3 remain unchanged as β is modified, since home and foreign society's marginal damage from pollution does not change with β.

[14] If the two countries have different populations, N=1 and N*, eq. (23) would change into $\hat{t}^{C} = \left(\alpha^{E} + N*\alpha^{E}*\right)/\left(N + N*\right)$

4.1. The Political Setting

We assume that individuals with similar interests in environmental policy form lobby groups, which offer campaign contributions to the government. Environmentalists form an environmental lobby group and industrialists form an industry lobby group. Workers do not form a lobby group, although they have an interest in lobbying for higher pollution tax revenue.[15] The underlying assumption is that workers are large in number and cannot overcome the free-riding problem described by Olson (1965). Let i denote the type of lobby group, E for environmental and I for industry. α^i defines the fraction of the population that are members of lobby group i.

Each lobby group offers campaign contribution schedules to their country's government denoted by $\Lambda^i(t)$.[16] Their intention is to influence the incumbent government's choice of environmental policy. These contribution schedules are made dependent on the pollution tax rate selected by the home government and work as a reward to the government for its policy choice. They are neither formal contracts nor do they have to be explicitly announced. We only assume that governments know that there is an implicit relationship between their chosen tax rates and the contributions from lobby groups which they expect to receive. Each lobby group's strategy consists of a continuous function $\Lambda^i : T \rightarrow \Re_+$. Lobby groups offer a monetary payment Λ^i to the government for choosing tax rate $t \in T,\ T \in \mathbb{R}$. All contribution schedules are assumed to be non-negative and differentiable around the equilibrium point.[17] The foreign pollution tax rate will be taken as given when lobby groups decide on their lobby schedules.[18]

Faced with the lobby contribution offers, the incumbent government selects a pollution tax rate, with the objective to maximize its own political welfare, i.e. the probability of re-election. The government's objective function is a weighted sum of average welfare and lobby contributions. Average welfare is important to the government because chances for re-election depend on the well-being of the general voter or citizen. Contributions matter as they can be

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[15] Note that if workers also formed a lobby group, and hence all individuals were organized in lobby groups, the tax rates of the political game would equal the benevolent dictator tax rates.

[16] Campaign contributions should be interpreted broadly as campaign funds, support demonstrations, or bribes, since lobby groups employ different strategies to influence governments. See Conconi (2003).

[17] Contribution schedules are not differentiable if the assumption of non-negativity becomes binding, that is, when the government chooses a tax rate from which follows that $\Lambda^i = 0$.

[18] We follow Grossman and Helpman (1995) who argue that contribution schedules cannot be observed from abroad and thus have no influence on the decisions made abroad. We may then assume that lobby groups take foreign policies as given, and decide upon their contribution schedules before the actual foreign tax rate is set.

used to influence imperfectly informed voters, e.g. through political advertising (Grossman and Helpman, 1995). Hence, the home government's objective function is defined as:

$$v = \sum_{i \in L} \Lambda^i + a\Omega^A \tag{24}$$

where L is the set of lobby groups, and $a \geq 0$ is the exogenously given weight that the government places on aggregate social welfare relative to campaign contributions. The government weighs the political value of lobbying funds (in terms of votes gained) against their political cost associated with the loss of welfare in the determination of the weighting parameter a (Fredriksson, 1997).

4.2. The Formation of Environmental Policy

The game between the incumbent government and the lobby groups has two stages. In the first stage, the lobby groups simultaneously offer their campaign contribution schedules, taking the other lobby group's strategy as given. Lobby groups at home and abroad act independently from each other, cf. fn. 18. In the second stage, the two governments select their tax rates, which maximize their objective functions v and $v*$ given the strategic interaction with the other government, and collect from the lobby groups in their country the corresponding contribution.[19] The lobby groups offer contribution schedules anticipating the optimization calculus of their governments in the second stage.

General Characterization of the Political Equilibrium

A policy $\tilde{t}^{NC}$ and a set of contribution schedules $\left\{\tilde{\Lambda}^i\right\}_{i \in L}$ are a Subgame Perfect Nash Equilibrium if: firstly, the tax rate $\tilde{t}^{NC}$ maximizes the government's utility function v, taking contribution schedules and foreign policies as given; secondly, each contribution schedule is feasible; and, thirdly, given the schedule of lobby group j, $\left\{\tilde{\Lambda}^j\right\}_{j \neq i}$, and the anticipated government's decision, no lobby group i has a feasible strategy that yields a greater net payoff than the equilibrium net payoff (Fredriksson, 1997).

From Lemma 2 of Bernheim and Whinston (1986), or Proposition 1 in Grossman and Helpman (1994), the equilibrium can be characterized as follows.

[19] It is assumed that lobby groups keep their promises and thus make the announced payments. We also disregard the possibility that interest groups lobby across the border. For such an analysis cf. Hillman and Ursprung (1988).

Proposition 1: $\left(\left\{\tilde{\Lambda}^i\right\}_{i\in L},\tilde{t}^{NC}\right)$ *is a Subgame Perfect Nash Equilibrium of the pollution tax game, if and only if:*

(a) $\tilde{\Lambda}^i$ *is feasible for all* $i \in L$ *;*

(b) $\tilde{t}^{NC}$ *maximizes* $\sum_{i\in L}\tilde{\Lambda}^i(t)+a\Omega^A(t)$ *on* T *;*

(c) $\tilde{t}^{NC}$ *maximizes* $\Omega^j(t)-\tilde{\Lambda}^j(t)+\sum_{i\in L}\tilde{\Lambda}^i(t)+a\Omega^A(t)$ *on* T $\forall$ $j\in L$ *;*

(d) $\forall$ $j \in L$ *there exists a* $t^{-j}\in T$ *that maximizes* $\sum_{i\in L}\tilde{\Lambda}^i(t)+a\Omega^A(t)$ *on* T *such that* $\tilde{\Lambda}^j\left(t^{-j}\right)=0$.

Condition (a) stipulates that contribution schedules must be feasible, that is, they must be non-negative and no greater than the aggregate income available to the lobby group's members. Condition (b) ascertains that the government sets the pollution tax to maximize its objective function given the contribution schedules offered by the lobby groups. Condition (c) stipulates that the equilibrium tax rate must maximize the joint welfare of the government and each lobby group j, given the contribution schedule offered by the other lobby group. This condition must hold, since otherwise lobby j could modify its contribution bid to induce the government to choose the jointly optimal pollution tax and gain most of the generated surplus from the policy change. No such unexploited chance for profits can exist for any lobby in equilibrium.[20] Condition (4) requires that for every lobby j, a tax policy t^{-j} provides the government with just the same utility as the equilibrium tax rate $\tilde{t}^{NC}$, and yields a contribution of zero from lobby group j. If no such t^{-j} existed, lobby group j could increase its welfare by lowering its campaign bid without changing the government's choice of tax policy. This would leave lobby group j better off and can thus not be possible in equilibrium (Bernheim and Whinston 1986).

From conditions (b) and (c) in Proposition 1, we obtain the first order conditions for the government's maximization of its objective function v, and for each lobby group j at $\tilde{t}^{NC}$. Subscripts denote partial derivatives:

$$\sum_{i\in L}\tilde{\Lambda}_t^i\left(\tilde{t}^{NC}\right)+a\Omega^A{}_t\left(\tilde{t}^{NC}\right)\overset{!}{=}0 \quad (25)$$

and

$$\Omega^j{}_t\left(\tilde{t}^{NC}\right)-\tilde{\Lambda}_t^j\left(\tilde{t}^{NC}\right)+\sum_{i\in L}\tilde{\Lambda}_t^i\left(\tilde{t}^{NC}\right)+a\Omega^A{}_t\left(\tilde{t}^{NC}\right),\ \forall\, j\in L. \quad (26)$$

[20] For a formal derivation of condition (3), see Grossman and Helpman (1994).

Eqs. (25) and (26) imply that, in equilibrium, each lobby group defines its contribution schedule such that, at the margin, a change of the tax rate equally affects the lobby group's aggregate utility and the contribution offer:

$$\Omega^i{}_t\left(\tilde{t}^{NC}\right)=\tilde{\Lambda}^i_t\left(\tilde{t}^{NC}\right),\ \forall\ i\in L\,. \tag{27}$$

As we substitute eq. (27) into eq. (25), we obtain the equilibrium characterization:

$$\sum_{i\in L}\Omega^i{}_t\left(\tilde{t}^{NC}\right)+a\Omega^A{}_t\left(\tilde{t}^{NC}\right)=0 \tag{28}$$

To find the equilibrium non-cooperative tax rate, we need to calculate the derivations of the lobby group's utility functions with respect to the tax rate. Therefore, we substitute Eqs. (6), (7), and (8) in Eqs. (12) and (13), and differentiate with respect to t. We obtain:

$$\hat{\Omega}^E_t=\frac{\alpha^E\beta\overline{p}^2\left(1+t*\beta+\beta\left(2-t\right)\right)}{\left(1+\beta\left(\mathrm{t}*+\mathrm{t}\right)\right)^3} \tag{29}$$

and

$$\hat{\Omega}^I_t=-\frac{\beta\overline{p}^2\left[\left(1-\alpha^I\right)\left(1+\beta\left(t*+t\right)\right)+2\mathrm{t}\beta\left(\alpha^I+\mathrm{t}*\beta\right)\right]}{\left(1+\beta\left(\mathrm{t}*+\mathrm{t}\right)\right)^3} \tag{30}$$

Environmentalists' Marginal Utility with respect to the home tax rate is strictly positive, as in Eq. (29). If the domestic tax rate increases, home production of x decreases, and hence Pollution. Furthermore, Environmentalists' share of Total Tax Revenue increases with t. Eq. (30) states that industrialists' marginal utility from a change in t is strictly negative. As the domestic tax rate increases, sector specific income $\hat{\Pi}$ decreases. This effect is weakened by the extent to which the changes in tax revenues are passed back to industrialists.

The change in marginal aggregate social welfare due to a change in the home tax rate in eq. (28) has already been calculated in eq. (17). It is positive, if t is smaller than $\hat{t}^{NC}$, the non-cooperative tax rate from the benevolent dictator case, and negative otherwise, since $\hat{t}^{NC}$ maximizes aggregate social welfare.

Calculation of the Political-Economic Equilibrium

We calculate the reaction functions by substituting eqs. (17), (29), and (30) in Eq. (28).

$$\tilde{t}^{NC}=\frac{2\alpha^E\beta\left(a+1\right)-\left(1+\mathrm{t}*\beta\right)\left(1-\alpha^E-\alpha^I\right)}{\beta\left(2\left(a+1\right)\left(\mathrm{t}*\beta+1\right)-\left(1-\alpha^E-\alpha^I\right)\right)} \tag{31}$$

Like in the benevolent dictator case, the reaction function depends on the relative size of the environmental lobby group, the damage coefficient, and the foreign tax rate. Additionally, it is contingent on the relative size of the industry lobby group, and on the government's weight on social welfare relative to lobby contributions.

The political non-cooperative tax rate is lower (higher) than the welfare maximizing non-cooperative tax rate chosen by a benevolent dictator, if $(t^*\beta+1)^2 > (<)\alpha^E\beta$.[21] Eq. (31) shows that if all individuals were organized in a lobby group, i.e. $\alpha^E+\alpha^I=1$, the tax rate would equal the non-cooperative tax rate in the Benevolent Dictator Case (cf. eq. 18). The government would maximize the aggregate welfare of all lobby group members, and thus of the society as a whole.

The sign of the tax rate is not unambiguously positive, as the numerator can be positive or negative. Hence, the tax is only positive if:

$$2\alpha^E\beta(a+1) > (1+t^*\beta)(1-\alpha^E-\alpha^I) \tag{32}$$

The right hand side of the Eq. (31) expresses the influence of the industry lobby group, while the left hand side states the interest of the environmental lobby group. The influence of the industry lobby group increases with the political distortion, i.e. the share of unorganized voters. On the LHS of eq. (32) the term $\alpha^E\beta$ is multiplied by $(a+1)$, which represents the influence of Environmentalists' lobbying and the disutility to the society from pollution. The larger the whole product, the more likely is a positive tax rate. In Summary, we may say that the tax turns into a subsidy, if most citizens are not members of a lobby group, the foreign tax rate is very high, few citizens are affected by pollution, and the government is highly susceptible through lobbying.

We can calculate a close form solution for the equilibrium, which however is very cumbersome. It is given in Appendix 8. Parallel to eq. (20), however, we can calculate the difference between the two countries' equilibrium tax rates which is much easier to read:

$$t_{PG}-t_{PG}^* = \frac{2\beta(1+a)(1+a^*)(\alpha_E-\alpha_E^*)+(1+a)(1-\alpha_E^*-\alpha_I^*)-(1+a^*)(1-\alpha_E-\alpha_I)}{\beta\left((1+a)(\alpha_E^*+\alpha_I^*+a^*)+(1+a^*)(\alpha_E+\alpha_I+a)\right)} \tag{33}$$

[21] See Appendix 2 for a proof.

The denominator is strictly positive, while the numerator can be positive or negative. It follows that

$$t_{PG} - t_{PG}* > 0, \text{ iff } \alpha_E - \frac{\alpha_W}{2\beta(1+a)} > \alpha_E * - \frac{\alpha_W *}{2\beta(1+a*)} \quad \textbf{(34)}$$

where $a_W = 1 - a_I - a_E$ denotes the share of unorganized citizens (workers). In the benevolent dictators' case the country with the higher preference for environment (i.e. the higher α_E) chooses the higher tax rate. In the political game this holds only if the difference in distortion from the political sector denoted by the "correction terms" $-\frac{\alpha_W}{2\beta(1+a)}$ and $-\frac{\alpha_W *}{2\beta(1+a*)}$ does not outweigh the differences in the populations' preferences, i.e. iff $\alpha_E - \alpha_E * > \frac{\alpha_W}{2\beta(1+a)} - \frac{\alpha_W *}{2\beta(1+a*)}$.

We can now state our main result.

Proposition 2: *(i) In equilibrium, the governments select lower (higher) tax rates than the benevolent dictators, if, firstly, each contribution schedule is differentiable around the equilibrium point, and, secondly,* $(\text{t*}\beta + 1)^2 > (<) \alpha^E \beta$.

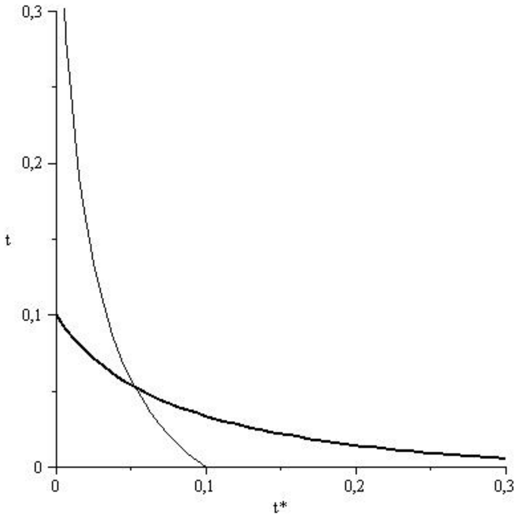
(ii) A country's tax rate will be the larger, the higher α_E*, and the lower the distortion through the political system is, i.e. the higher* a *and the lower* α_W.

(iii) The tax rates can have either sign for each country.

Unlike in the benevolent dictators' Nash equilibrium, in which governments set only positive tax rates, the political economic equilibrium can also have negative tax rates for both countries or only for one country with both countries still producing the polluting good *x*. Of course, both countries can still have positive tax rates. Obviously, negative tax rates create a welfare loss for the country that exceeds the welfare loss of non-cooperatively set taxes of benevolent dictators (cf. Sect 3).

Figure 4 illustrates a possible equilibrium with positive tax rates equilibrium. On the vertical axis we measure $\tilde{t}^{NC}$, on the horizontal axis $\tilde{t}^{NC}*$. The bold line depicts $\tilde{t}^{NC}(\tilde{t}^{NC}*)$, while the thin line illustrates $\left(\tilde{t}^{NC}*(\tilde{t}^{NC})\right)^{-1}$, the inverse function of $\tilde{t}^{NC}*$. The following values are assumed analogous to section 2: $\beta = 10$, $\alpha_{\mathrm{E}} = \alpha*_{\mathrm{E}} = 0.1$, $\alpha_{\mathrm{I}} = \alpha*_{\mathrm{I}} = 0.1$, and $a = a* = 1$.

Figure 4: The political equilibrium



Yet other equilibria are possible as well. Because the closed form solution is so unwieldy, we simulate three different cases: (1) both countries have positive tax rates, (2) both countries have negative tax rates and (3) the home country has a negative tax rate and the foreign country a positive tax rate. The equilibrium values for the tax rates, production levels, and sector-specific incomes are given in Appendix 7.

4.3 Comparative Statics

We proceed with comparative statics, analyzing how the political non-cooperative equilibrium reacts with regard to changes of the foreign tax rate, of lobby group membership, of a change in government's weight on social welfare relative to campaign contributions, and of the damage coefficient.

Proposition 3: *In equilibrium, (i) a positive non-cooperative tax rate decreases with the foreign tax rate, and (ii) a negative non-cooperative tax rate decreases (increases) with the foreign tax rate if* $\left(1-\alpha^E-\alpha^I\right)^2 < (>) 4\alpha^E\beta\left(a+1\right)^2$*:*

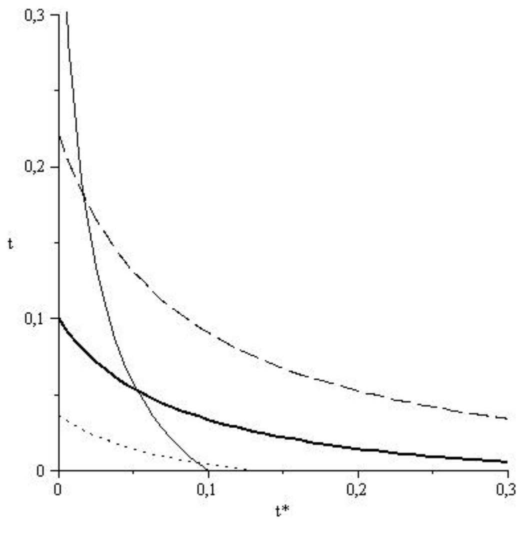
$$\frac{\partial \tilde{t}^{NC}}{\partial t^*} = \frac{\left(1-\alpha^E-\alpha^I\right)^2 - 4\alpha^E\beta\left(a+1\right)^2}{\left(2\left(a+1\right)\left(t^*\beta+1\right)-\left(1-\alpha^E-\alpha^I\right)\right)^2} \qquad \textbf{(35)}$$

The numerator of Eq. (35) can be positive or negative, while the denominator is clearly positive. However, for a positive equilibrium home tax rate, i.e. inequality (32) holds, the numerator is strictly negative. [22] Hence, a positive home tax rate decreases with the foreign tax rate. As the foreign tax rate increases it becomes less important for the domestic environmental lobby group to lobby for higher taxes, since the decrease in pollution from a change in the home tax rate becomes smaller

Proposition 4: *The non-cooperative tax rate increases with the relative size of the environmental lobby group:*

$$\frac{\partial \tilde{t}^{NC}}{\partial \alpha^E} = \frac{\left(a+1\right)\left[\left(t^*\beta+1\right)^2 + 2t^*\beta^2\left(a+1\right)+\beta\left(2a+\alpha^I+1\right)\right]}{\beta\left[2\left(a+1\right)\left(t^*\beta+1\right)-\left(1-\alpha^E-\alpha^I\right)\right]^2} \qquad \textbf{(36)}$$

The denominator and the numerator of Eq. (33) are both positive. There are three effects as α_E increases: firstly, aggregate social welfare is more intensely affected by pollution. Secondly, total disutility from pollution to the environmental lobby group increases. And thirdly, tax revenue of the environmental lobby group increases. Each effect increases the incentive to choose a higher tax rate. Figure 5 illustrates the effects of changes in α_E on the equilibrium. The dashed line indicates $\tilde{t}_{NC}(t^*)$ with $\alpha_E = 0.2$ and the dotted line indicates $\tilde{t}_{NC}(t^*)$ with $\alpha_E = 0.05$, while all other values remain unchanged.



[22] See Appendix 3 for a proof.

[23] See (A.2) in Appendix 1 for a proof.

Figure 5: The effects of a change in α_E on the political equilibrium.

The home government's reaction function is shifted upward (downward) as α_E increases (decreases). Furthermore, the strategic effect of an increase in the foreign tax rate on $\hat{t}^{NC}$ increases with α^E. Figure 5 has thus the same properties as Figure 2 from section 2.

Proposition 5: *The non-cooperative tax rate increases (decreases) with the relative size of the industrialist lobby group α^I, if it is lower (higher) than the tax rate chosen by a benevolent dictator:*

$$\frac{\partial \tilde{t}^{NC}}{\partial \alpha^I} = \frac{2(a+1)\left[(t^*\beta+1)^2 - \alpha_E\beta\right]}{\beta\left[2(a+1)(t^*\beta+1) - (1-\alpha^E-\alpha^I)\right]^2} \qquad \textbf{(37)}$$

The numerator of Eq. (37) can be positive or negative, while the denominator is clearly positive. There are two effects, as α^I increases: firstly, the distortion from the political game decreases, since less citizens are unorganized, assuming that the relative size of the Environmentalists remains constant. Hence, the influence of each lobby group decreases, which creates an incentive for the government to increase (decrease) the tax rate, if it is lower (higher) than in the benevolent dictator case. The reason is that the decrease in influence is relatively stronger for the lobby group which has more influence on the government. The deviation from the tax rate chosen by a benevolent dictator thus decreases.

Secondly, the incentive for the industry lobby group to lobby for lower taxes decreases, since a higher fraction of their tax payment is redirected to its members. If, in equilibrium, the tax rate is smaller than in the benevolent dictator case, both effects lead to an increase of the tax rate as α^I increases. If, in equilibrium, the tax rate is higher, the first effect creates an incentive to lower the tax rate, while the second effect creates an incentive to raise the tax rate. Eq. (34) shows that the incentive to lower the tax rate dominates the incentive to raise it, if the tax rate is higher than in the benevolent dictator case. Hence, the tax rate decreases. Figure 6 illustrates the effect of changes in the size of the industrialist lobby group, with $\beta = 1$; $\alpha^E = \alpha^{E*} = 0{,}1$; $\bar{p} = 1$, and $a^* = a = 1$.

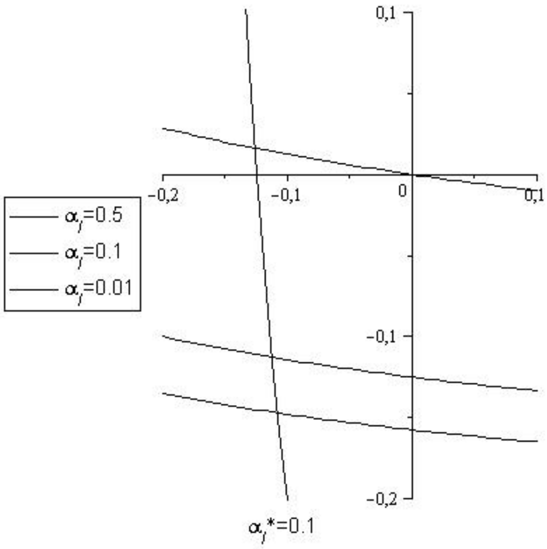


Figure 6: The effects of a change in α_I on the political equilibrium.

Proposition 6: *In equilibrium, the non-cooperative tax rate chosen by self-interested governments approaches the non-cooperative tax rate chosen by a benevolent dictator as* a *increases, and equals the latter for* $a=\infty$ *:*

$$\frac{\partial \tilde{t}^{NC}}{\partial a}=\frac{2\left(1-\alpha^{E}-\alpha^{I}\right)\left(\left(t^{*}\beta+1\right)^{2}-\alpha^{E}\beta\right)}{\beta\left[2\left(a+1\right)\left(t^{*}\beta+1\right)-\left(1-\alpha^{E}-\alpha^{I}\right)\right]^{2}} \tag{38}$$

The sign of Eq. (38) is positive (negative) for $\left(t^{*}\beta+1\right)^{2}>(<)\alpha^{E}\beta$. As a increases, the government places more value on the maximization of social welfare. The influence of the lobby groups thus decreases, and the equilibrium tax rate approaches the result from the benevolent dictator case. At the limit, when $a=\infty$, lobby groups have no influence at all, and the government selects the non-cooperative tax rate from section 2.[24] Figure 7 illustrates the effects of a change in the home government's valuation of social welfare relative to campaign contributions. With the assumed values, the domestic equilibrium tax rate increases with a, since the equilibrium tax rates are lower than in the benevolent dictator case. We depict the reaction functions for $\beta=1$; $\alpha^{E}=\alpha^{E}*=0{,}1$; $\bar{p}=1$, $\alpha^{I}=\alpha^{I}*=0.1$ and $a^{*}=1$ and different values for a.

[24] See Appendix 4 for a proof.

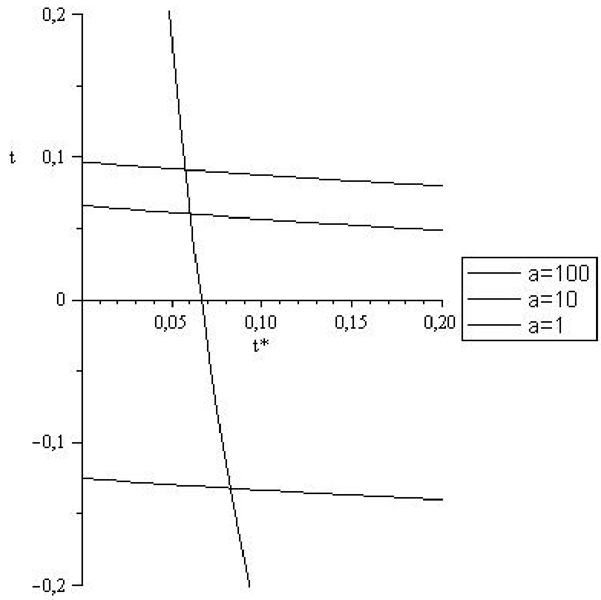


Figure 7: The effects of a change in a on the political equilibrium

5. Concluding Remarks

In this model, we developed a framework for a positive theory of pollution taxes in two strategically interacting, small open economies. First, we laid out the basis for the analysis by assuming benevolent governments. In this basic framework, the Pigouvian tax rate is only achieved by cooperation. In the non-cooperative solution, governments neglect damages imposed on foreigners caused by domestic production. In addition, there is a strategic effect due to the assumptions that marginal pollution from an increase in production is contingent on domestic and foreign production levels. This assumption is crucial, since we also assumed that governments tax total pollution. Due to both assumptions, the tax payment of the producers of one country increases with the production levels of the other country. The disutility of producers, created by the pollution tax, thus decreases as foreign production decreases. Hence, the governments have an incentive to provoke an increase in the foreign taxation by choosing a lower tax rate than their domestic marginal disutility from pollution. This international strategic effect increases with the value of the damage coefficient β.

The complexity of the taxation structure dramatically increases when we enter the political arena. We have shown that the tax rates chosen by politically self-interested governments may even be larger than in the benevolent dictator game. Whether a benevolent dictator or self-interested decision makers raise higher taxes crucially hinges on the relative strength of the lobby groups and the international strategic effect described above. In the case of politically self-interested governments, it is possible that one or both governments subsidize pollution.

The results of our model should be interpreted with caution, as our framework strongly simplifies political processes. More research is to be done on how the efficiency of environmental policy making influenced by political interests can be enhanced, especially when it comes to global externalities. It would be interesting to model incentives and structures of cooperation between a large number of countries with a large number of interest groups involved. The role of price effects in the determination of cooperative environmental policies may be analyzed in such frameworks. Additionally, more attention should be devoted to modeling the influence of self-interest on cooperation procedures and mechanisms in International Environmental Agreements.

Appendix

Appendix 1

Partial derivations for Section 2

Production

$$\hat{X}_{\mathrm{t}} = -\frac{\overline{p}\beta\left(1+t^*\beta\right)}{\left(1+\beta\left(\mathrm{t}^*+\mathrm{t}\right)\right)^2} < 0$$

$$\hat{X}_{\mathrm{t\,t^*}} = \frac{\overline{p}\beta^2\left[1+\beta\left(\mathrm{t}^*-\mathrm{t}\right)\right]}{\left(1+\beta\left(\mathrm{t}^*+\mathrm{t}\right)\right)^3} > 0$$

$$\hat{X}_{\mathrm{t^*}} = \frac{\overline{p}t\beta^2}{\left(1+\beta\left(\mathrm{t}^*+\mathrm{t}\right)\right)^2} > 0 \tag{A.1}$$

$$\hat{X}_{\overline{p}} = \frac{1+\beta\left(\mathrm{t}^*-\mathrm{t}\right)}{2\left(1+\beta\left(\mathrm{t}^*+\mathrm{t}\right)\right)} > 0$$

$$\hat{X}_{\beta} = -\frac{\overline{p}\beta}{\left(1+\beta\left(\mathrm{t}^*+\mathrm{t}\right)\right)^2} < 0$$

Pollution

$$\hat{S}_{\overline{p}} = \frac{2\beta\overline{p}}{\left(1+\beta\left(t^*+t\right)\right)^2} > 0$$

$$\hat{S}_{t} = \hat{S}_{t^*} = -\frac{2\beta^2\overline{p}^2}{\left(1+\beta\left(t^*+t\right)\right)^3} < 0 \tag{A.2}$$

$$\hat{S}_{t\,t^*} = \frac{6\beta^3\overline{p}^2}{\left(1+\beta\left(t^*+t\right)\right)^4} > 0$$

Sector Specific Income

$$\begin{aligned}
\hat{\Pi}_t &= -\frac{\beta \overline{p}^2 \left[1+\beta(t^*+t)+2tt^*\beta^2\right]}{\left(1+\beta(t^*+t)\right)^3} < 0 \\
\hat{\Pi}_\beta &= -\frac{\overline{p}^2 t\left(1+\beta(t-t^*)\right)}{\left(1+\beta(t^*+t)\right)^3} < 0 \\
\hat{\Pi}_{t^*} &= \frac{2\beta^2 \overline{p}^2 t(1+t\beta)}{\left(1+\beta(t^*+t)\right)^3} > 0 \\
\hat{\Pi}_{\overline{p}} &= \frac{\overline{p}}{2}\frac{\left[\left(1+\beta(t^*-t)\right)^2+4t\beta^2(t^*-t)\right]}{\left(1+\beta(t^*+t)\right)^2} > 0
\end{aligned} \qquad \text{(A.3)}$$

Tax income

$$\begin{aligned}
\hat{\tau}_t &= \frac{\beta \overline{p}^2\left(1+\beta(t^*-t)\right)}{\left(1+\beta(t^*+t)\right)^3} > 0 \\
\hat{\tau}_{\overline{p}} &= \frac{2\beta \overline{p} t}{\left(1+\beta(t^*+t)\right)^2} > 0 \\
\hat{\tau}_{t^*} &= -\frac{2t\beta^2 \overline{p}^2}{\left(1+\beta(t^*+t)\right)^3} < 0 \\
\hat{\tau}_\beta &= \frac{\overline{p}^2 t\left(1-\beta(t^*+t)\right)}{\left(1+\beta(t^*+t)\right)^3}
\end{aligned} \qquad \text{(A.4)}$$

Appendix 2

We will prove that the non-cooperative tax rate from the benevolent dictator case $\hat{t}^{NC}$ is larger (smaller) than the non-cooperative tax rate from the political game $\tilde{t}^{NC}$, if and only if $(t^*\beta+1)^2 > (<)\alpha^E\beta$. Let Δt^{NC} define the difference between $\hat{t}^{NC}$ and $\tilde{t}^{NC}$:

$$\begin{aligned}
\Delta t^{NC} &= \hat{t}^{NC} - \tilde{t}^{NC} \\
&= \frac{\alpha^E}{(t^*\beta+1)} - \frac{2\alpha^E\beta(a+1)-(1+t^*\beta)(1-\alpha^E-\alpha^I)}{\beta\left(\alpha^E+\alpha^I-1+2(t^*\beta+1)(a+1)\right)}.
\end{aligned} \qquad \text{(B.1)}$$

It follows:

$$\Delta t^{NC} = \frac{\alpha^E \beta\left(\alpha^E + \alpha^I - 1 + 2\left(t^*\beta + 1\right)\left(a+1\right)\right)}{\left(t^*\beta+1\right)\beta\left(\alpha^E + \alpha^I - 1 + 2\left(t^*\beta+1\right)\left(a+1\right)\right)} - \frac{\left[2\alpha^E\beta\left(a+1\right) - \left(1+t^*\beta\right)\left(1-\alpha^E-\alpha^I\right)\right]\left(t^*\beta+1\right)}{\left(t^*\beta+1\right)\beta\left(\alpha^E + \alpha^I - 1 + 2\left(t^*\beta+1\right)\left(a+1\right)\right)} = \frac{\left(1-\alpha^E-\alpha^I\right)\left[\left(1+t^*\beta\right)^2 - \alpha^E\beta\right]}{\left(t^*\beta+1\right)\beta\left(\alpha^E + \alpha^I - 1 + 2\left(t^*\beta+1\right)\left(a+1\right)\right)} \quad \text{(B.2)}$$

Δt^{NC} is thus larger (smaller) than zero, if:

$$\left(t^*\beta+1\right)^2 > (<) \alpha^E\beta \quad \text{(B.3)}$$

□

Appendix 3

We know from Eq. (31) that, in equilibrium, the home tax rate is positive, iff:

$$\left(1+t^*\beta\right)\left(1-\alpha^E-\alpha^I\right) < 2\alpha^E\beta\left(a+1\right). \quad \text{(C.1)}$$

Eq. (32) states that, in equilibrium, the home tax rate decreases with the foreign tax rate, iff

$$\left(1-\alpha^E-\alpha^I\right)^2 < 4\alpha^E\beta\left(a+1\right)^2. \quad \text{(C.2)}$$

Assuming a positive foreign tax rate, the left hand side of (C.1) is strictly larger than the left hand side of (C.2):

$$\left(1-\alpha^E-\alpha^I\right) < \left(1+t^*\beta\right)\left(1-\alpha^E-\alpha^I\right). \quad \text{(C.3)}$$

Since $a > 0$, the right hand side of (C.2) is strictly larger than the right hand side of (C.1):

$$2\alpha^E\beta\left(a+1\right) < 4\alpha^E\beta\left(a+1\right)^2. \quad \text{(C.4)}$$

If the home tax rate is positive, and (C.1) is thus true, we can combine (C.3) and (C.4) to:

$$\left(1-\alpha^E-\alpha^I\right) < \left(1+t^*\beta\right)\left(1-\alpha^E-\alpha^I\right) < 2\alpha^E\beta\left(a+1\right) < 4\alpha^E\beta\left(a+1\right)^2. \quad \text{(C.5)}$$

From transitivity follows:

$$\left(1-\alpha^E-\alpha^I\right) < 4\alpha^E\beta\left(a+1\right)^2. \quad \text{(C.6)}$$

□

Appendix 4

Starting from the non-cooperative reaction function

$$\tilde{t}^{NC} = \frac{2\alpha^E \beta (a+1) - (1+\text{t*}\beta)(1-\alpha^E - \alpha^I)}{\beta(\alpha^E + \alpha^I - 1 + 2(\text{t*}\beta + 1)(a+1))}, \tag{D.1}$$

we will prove that

$$\lim_{a\to\infty} \tilde{t}^{NC} = \frac{\alpha^E}{(\text{t*}\beta + 1)}. \tag{D.2}$$

We apply L'Hospital's Rule:

$$\lim_{a\to\infty} \frac{f(a)}{g(a)} = \lim_{a\to\infty} \frac{f'(a)}{g'(a)}. \tag{D.3}$$

$$\frac{f(a)}{g(a)} = \frac{2\alpha^E \beta (a+1) - (1+\text{t*}\beta)(1-\alpha^E - \alpha^I)}{\beta(\alpha^E + \alpha^I - 1 + 2(\text{t*}\beta + 1)(a+1))}. \tag{D.4}$$

$$\frac{f'(a)}{g'(a)} = \frac{2\alpha^E \beta}{2\beta(\text{t*}\beta + 1)} = \frac{\alpha^E}{(\text{t*}\beta + 1)}. \tag{D.5}$$

It follows immediately:

$$\lim_{a\to\infty} \tilde{t}^{NC} = \frac{\alpha^E}{(\text{t*}\beta + 1)}. \tag{D.6}$$

□

Appendix 5

$$\hat{\Omega}^E_{t*} = \frac{2\alpha^E \beta^2 \overline{p}^2 (1-t)}{(1+\beta(\text{t*}+\text{t}))^3} \tag{E.1}$$

$$\hat{\Omega}^I_{t*} = \frac{2t\beta^2 \overline{p}^2 (1+\text{t}\beta - \alpha^I)}{(1+\beta(\text{t*}+\text{t}))^3} \tag{E.2}$$

$$\hat{\Omega}^A_{t*} = \frac{2\beta^2 \overline{p}^2 (\alpha^E + t^2\beta)}{(1+\beta(t*+t))^3} \tag{E.3}$$

Appendix 6

Starting from the cooperative reaction function

$$\tilde{t}^C(t^*) = \frac{2\alpha^E\beta(a+1) - (1+t^*\beta)(1-\alpha^E-\alpha^I)}{\beta\left(2(a+1)(t^*\beta+1) - (1-\alpha^E-\alpha^I)\right)} + \frac{2a\left[\left(\alpha^E{}^*\beta + (t^*\beta)^2\right)(a^*+1) + t^*\beta\left(1-\alpha^E{}^*-\alpha^I{}^*\right)\right]}{a^*\beta\left(2(a+1)(t^*\beta+1) - (1-\alpha^E-\alpha^I)\right)}, \quad \text{(F.1)}$$

we will prove that

$$\lim_{a,a^*\to\infty} \tilde{t}^C(t^*) = \frac{\alpha^E + \alpha^E{}^* + (t^*)^2\beta}{t^*\beta+1}. \quad \text{(F.2)}$$

The first half of Eq. (F.1) equals the reaction function from the non-cooperative case. From Appendix D, we know that:

$$\lim_{a\to\infty} \frac{2\alpha^E\beta(a+1) - (1+t^*\beta)(1-\alpha^E-\alpha^I)}{\beta\left(\alpha^E+\alpha^I-1+2(t^*\beta+1)(a+1)\right)} = \frac{\alpha^E}{(t^*\beta+1)}. \quad \text{(F.3)}$$

For simplicity, we assume in the second half of Eq. (F.1) that $a = a^*$. Now, we apply L'Hospital's Rule:

$$\lim_{a\to\infty} \frac{f(a)}{g(a)} = \lim_{a\to\infty} \frac{f'(a)}{g'(a)}. \quad \text{(F.4)}$$

$$\frac{f(a)}{g(a)} = \frac{2\left[\left(\alpha^E{}^*\beta + (t^*\beta)^2\right)(a+1) + t^*\beta\left(1-\alpha^E{}^*-\alpha^I{}^*\right)\right]}{\beta\left(2(a+1)(t^*\beta+1) - (1-\alpha^E-\alpha^I)\right)}. \quad \text{(F.5)}$$

$$\frac{f'(a)}{g'(a)} = \frac{2\left(\alpha^E{}^*\beta + (t^*\beta)^2\right)}{2\beta(t^*\beta+1)} = \frac{\alpha^E{}^* + t^{*2}\beta}{(t^*\beta+1)}. \quad \text{(F.6)}$$

It follows immediately:

$$\lim_{a,a^*\to\infty} \tilde{t}^C = \frac{\alpha^E}{(t^*\beta+1)} + \frac{\alpha^E{}^* + t^{*2}\beta}{(t^*\beta+1)} = \frac{\alpha^E + \alpha^E{}^* + t^{*2}\beta}{(t^*\beta+1)}. \quad \text{(F.7)}$$

□

Appendix 7

The following table gives the values for the politically optimal tax rates in home and foreign and the resulting production quantities, sector specific incomes and the values of the governments' objective functions for both countries. For each case production quantities are positive. The share of environmentalists takes on the value $\alpha_E = \alpha_E* = 0.1$ and $\beta = 10$, p=1 (as before) in all cases.

Parameter values / Variables	$\alpha^I = \alpha^I* = 0.1$ $a = a* = 10$	$\alpha^I = \alpha^I* = 0.1$ $a = a* = 1$	$\alpha^I = \alpha^I* = 0.1$ $a = 1;\ a* = 100$	$\alpha^I = 0.1;\ \alpha^I* = 0.5$ $a = a* = 1$	For comparison: benevolent dictator equilibrium
$\hat{t}_{PG}$ (home tax rate in political equilibrium)	0.06	-0.113	-0.134	-0.127	0.092
$\hat{t}_{PG}*$ (foreign tax rate in political equilibrium)	0.06	-0.113	0.112	0.016	0.092
$\hat{X}$ (home equilibrium production level)	0.446	0.646	0.637	0.642	0.423
$\hat{X}*$ (foreign equilibrium production level)	0.446	0.646	0.385	0.482	0.423
$\hat{\Pi}$ (home equilibrium sector specific income)	0.199	0.416	0.372	0.39	0.179
$\hat{\Pi}*$ (foreign equilibrium sector specific income)	0.199	0.416	0.12	0.23	0.179
$\hat{v}$ (value of home government's objective fcn in PE)	12	1.475	1.565	1.53	–
$\hat{v}*$ (value of foreign government's objective fcn in PE)	12	1.475	113.5	1.84	–
$\frac{\partial^2 \hat{v}}{\partial t^2}$ (home SOC)	-16.03	-5.9	-3.9	-4.63	–
$\frac{\partial^2 \hat{v}*}{\partial t*^2}$ (foreign SOC)	-16.03	-5.9	-186.2	-4.4	–
Ω_A (home welfare)	1.161	1.062	1.127	1.103	1.173
Ω_A* (foreign welfare)	1.161	1.062	1.132	1.123	1.173
S (Total Pollution)	0.797	1.667	1.046	1.263	0.714

PE: political equilibrium, BD: benevolent dictator, PG: political game

Appendix 8

Here we present a closed form solution for the equilibrium. Here, capital letters denote foreign variables (not asterisks as in the main text).

$$
\begin{aligned}
\tau_{nc} := \Big(& a\,\beta\,\alpha_E - A\,\beta\,A_E + \alpha_E\,\beta\,A + a\,\beta\,\alpha_E\,A - A_E\,\beta - \beta\,a\,A\,A_E + \alpha_E\,\beta \\
& - a\,A_E\,\beta - A - a\,A_E - A_I - a\,A - A_E - a\,A_I \\
& + \Big(A\,\beta\,A_E + a\,\beta\,\alpha_E + A_E\,\beta\,A_I - \alpha_E\,\beta\,A_I - \alpha_I\,A_E\,\beta \\
& - 2\,\alpha_E\,A_E\,\beta - \alpha_E\,\beta\,A - a\,A_E\,\beta + 2\,\alpha_I\,A_E\,A_I - a\,A_E - a\,A_I + a\,\beta\,\alpha_E\,A \\
& - \alpha_I\,A\,\beta\,A_E + a\,\alpha_E\,A - a\,\beta\,\alpha_E\,A_I + a\,A\,A_E + a\,\beta\,\alpha_E^2\,A_I + 3\,a\,\beta\,\alpha_E^2\,A \\
& + 2\,a\,\beta\,\alpha_E\,A_I^2 + 3\,a\,\beta\,\alpha_E\,A_E^2 + \alpha_E\,A\,\beta\,A_E^2 + \alpha_I\,A\,\beta\,A_E^2 + 2\,\alpha_I^2\,A\,\beta\,A_E \\
& + \alpha_E^2\,A\,\beta\,A_I + \alpha_E^2\,A^2\,\beta\,A_E + 2\,\alpha_E^2\,A^2\,a\,\beta + 2\,\alpha_E\,A\,\alpha_I\,A_I \\
& + 2\,\alpha_E\,A\,\alpha_I\,A_E + 3\,\alpha_E^2\,A\,\beta\,A_E + \alpha_I\,A_E^2 + \alpha_E\,A_E^2 + 4\,a\,\beta^2\,\alpha_E^2\,A \\
& + 2\,a^2\,\beta^2\,\alpha_E^2\,A - 4\,a\,\beta^2\,\alpha_E\,A_E - 2\,a^2\,\beta^2\,\alpha_E\,A_E + 2\,a^2\,\beta\,\alpha_E\,A \\
& - 2\,A^2\,\beta^2\,A_E\,\alpha_E + 2\,A^2\,\beta^2\,A_E^2\,a - 4\,A\,\beta^2\,A_E\,\alpha_E + 4\,A\,\beta^2\,A_E^2\,a + 3\,A\,\beta \\
& A_E^2\,a + \beta\,a\,A\,A_E + a^2\,\beta^2\,\alpha_E^2 + 2\,a\,\beta^2\,\alpha_E^2 + \alpha_I\,A\,A_E - 4\,A^2\,\beta^2\,A_E\,a\,\alpha_E \\
& + A^2\,\beta\,A_E + A\,\beta\,A_E^2 + \alpha_E^2\,\beta^2\,A^2 + 2\,\alpha_E^2\,\beta^2\,A - 2\,A_E\,\beta^2\,\alpha_E + 2\,A_E^2\,\beta^2\,a \\
& + 3\,A_E^2\,\beta\,a + a^2\,A_E^2\,\beta^2 + 2\,a^2\,A_E^2\,\beta + 2\,a^2\,A_E\,A - 8\,a\,\beta^2\,\alpha_E\,A\,A_E \\
& - 4\,a^2\,\beta^2\,\alpha_E\,A\,A_E + A^2\,\beta^2\,A_E^2 + 2\,A\,\beta^2\,A_E^2 + A_E^2\,\beta^2 + A_E^2\,\beta + \alpha_E^2\,\beta^2 \\
& + a^2\,A_E^2 + a\,A_E^2 + a\,A_I^2 + a^2\,A^2 + 2\,\beta\,a^2\,A\,A_E\,A_I + 2\,a^2\,A_E\,\beta\,A \\
& + 2\,a^2\,A_E\,\beta\,A_I + 3\,A\,\beta\,A_E\,a\,A_I + 6\,\alpha_E\,\beta\,A\,a\,A_E + 3\,\alpha_E\,\beta\,A\,a\,A_I \\
& - 2\,a^2\,\beta^2\,\alpha_E\,A^2\,A_E + 2\,a^2\,\beta\,\alpha_E\,A\,A_E + 2\,a^2\,\beta\,\alpha_E\,A\,A_I + 2\,A^2\,\beta\,A_E\,a \\
& + 2\,\alpha_E^2\,\beta^2\,A^2\,a + 2\,\alpha_E\,\beta\,A^2\,a + a^2\,\beta^2\,\alpha_E^2\,A^2 + 2\,a^2\,\beta\,\alpha_E\,A^2 \\
& + 3\,A_E\,\beta\,a\,A_I + \beta^2\,a^2\,A^2\,A_E^2 + 2\,\beta^2\,a^2\,A\,A_E^2 + 2\,\beta\,a^2\,A\,A_E^2 \\
& + 2\,\beta\,a^2\,A^2\,A_E + 2\,a^2\,A_E\,A_I + 2\,a^2\,A\,A_I + A\,a\,A_I + 2\,a\,A_E\,A_I \\
& + 5\,\alpha_E\,\alpha_I\,A\,\beta\,A_E + a^2\,A_I^2 + \alpha_E^2\,A_I + \alpha_E^2\,A + \alpha_E^2\,\beta + \alpha_E^2\,A_E \\
& + A\,\beta\,A_E\,A_I + \alpha_E\,\beta\,A\,A_I + a\,\beta\,\alpha_E^2\,A_E + a\,\alpha_E\,A_E + \alpha_E\,A\,A_E + a\,\alpha_E\,A_I \\
& - \alpha_E\,A - \alpha_E\,A_E - \alpha_E\,A_I - \alpha_I\,A_E - \alpha_I\,A - \alpha_I\,A_I + 2\,\alpha_E\,A_E\,A_I \\
& + \alpha_E\,\beta\,A_I^2 + \alpha_I\,A_E^2\,\beta + 2\,\alpha_E\,A_E^2\,\beta + \alpha_I^2\,A_E\,\beta + a^2\,\beta\,\alpha_E + \alpha_E^2\,A\,A_I + 2 \\
& \alpha_E^2\,A^2\,\beta + 2\,\alpha_E\,A^2\,\alpha_I + \alpha_E^2\,A\,A_E + \alpha_I^2\,A\,A_I + \alpha_I^2\,A\,A_E + a\,A_E^2\,\alpha_I + a \\
& A_E^2\,\alpha_E + a\,A_I^2\,\alpha_E + a\,A_I^2\,\alpha_I + 2\,a\,A^2\,\alpha_E + 2\,a\,A^2\,\alpha_I + 2\,\alpha_E\,\alpha_I\,A_I \\
& + 2\,\alpha_E\,\alpha_I\,A + 2\,\alpha_E\,\alpha_I\,A_E + A\,\alpha_E\,A_I + A\,\alpha_I\,A_I + \alpha_E\,A_I^2 + \alpha_I\,A_I^2 + a\,\beta \\
& \alpha_E^2 + 3\,\alpha_E^2\,\beta\,A + 2\,\alpha_E^2\,A_E\,\beta + \alpha_E^2\,\beta\,A_I + \alpha_I^2\,A_I + \alpha_I^2\,A + \alpha_I^2\,A_E + \alpha_E^2\,A^2 \\
& + 2\,a^2\,A_E\,\beta\,\alpha_E\,A_I + a\,A_E^2\,\alpha_E\,A\,\beta + a\,A_E^2\,\alpha_I\,A\,\beta + a^2\,A_I^2\,\beta\,\alpha_E \\
& + 3\,a\,A_I\,\alpha_E\,A + 3\,a\,A_I\,\alpha_I\,A + \alpha_I\,A\,a\,\beta\,\alpha_E\,A_E + \alpha_I\,A\,a\,\beta\,\alpha_E\,A_I \\
& + \alpha_I\,A\,\alpha_E\,\beta\,A_I + 2\,\alpha_I\,A^2\,a\,\beta\,\alpha_E + \alpha_I^2\,A^2 + \alpha_E^2\,A\,a\,\beta\,A_E + \alpha_E^2\,A\,a\,\beta\,A_I \\
& + 2\,\alpha_E\,A^2\,\alpha_I\,\beta\,A_E + 2\,\alpha_I\,A^2\,\alpha_E\,\beta + \alpha_I^2\,A^2\,\beta\,A_E + 2\,a\,A_E\,\alpha_E\,A_I + a^2 \\
& A_E^2\,\beta\,\alpha_E + a\,A_E^2\,\alpha_I\,\beta + 3\,a\,A_E\,\alpha_E\,A + 2\,a\,A_E\,\alpha_I\,A_I + 3\,a\,A_E\,\alpha_I\,A \\
& + 3\,a\,\alpha_I\,A\,\beta\,A_E + 5\,A_I\,a\,\beta\,\alpha_E\,A_E + A_I\,\alpha_E\,A\,\beta\,A_E + A_I\,\alpha_I\,A\,\beta\,A_E \\
& + \alpha_I\,a\,\beta\,\alpha_E\,A_E + \alpha_I\,a\,\beta\,\alpha_E\,A_I + 3\,\alpha_I\,a\,\beta\,\alpha_E\,A + \alpha_I\,\alpha_E\,\beta + a\,\alpha_I\,A_I \\
& + a\,\alpha_I\,A + a\,\alpha_I\,A_E + 2\,a\,A^2\,\alpha_I\,\beta\,A_E + A_I\,\alpha_I\,A_E\,\beta + 3\,A_I\,\alpha_E\,A_E\,\beta \\
& + \alpha_I\,a\,\beta\,\alpha_E + 3\,\alpha_I\,\alpha_E\,\beta\,A + \alpha_I\,\alpha_E\,\beta\,A_I + a\,\alpha_I\,A_E\,\beta + a\,A_I\,\alpha_I\,A_E\,\beta \\
& + a\,A_I\,\alpha_E\,A\,\beta\,A_E + a\,A_I\,\alpha_I\,A\,\beta\,A_E + 2\,a\,A^2\,\alpha_E\,\beta\,A_E + 3\,\alpha_E\,\alpha_I\,A_E\,\beta \\
& - a\,A \Big)^{1/2} \Big) \Big/ \Big(\Big(\alpha_E + A + A_I + A_E + \alpha_I + a + \alpha_E\,A + \alpha_I\,A + a\,A_E \\
& + a\,A_I + 2\,a\,A \Big)\,\beta \Big);
\end{aligned}
$$

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