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Endogenous Environmental Policy when Pollution is Transboundary

by

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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 respect to their environmental policies, but too small to affect world market prices. We show how governments systematically deviate from socially optimal environmental policies. Taxes may be too high if environmental interests and pollution-intensity of production are very strong; under different constellations they may be too low. Governments may actually subsidize the production of a polluting good. Politically motivated environmental policy thus may be more harmful to the environment as compared to the benevolent dictators' solution. In other cases it may enhance environmental quality and welfare beyond what a benevolent government would achieve.

JEL classification*:* Q 58, F 5

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

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1. Introduction

This paper examines how lobby groups in pluralistic societies affect the determination of environmental policy when countries are linked through transboundary pollution and their political support maximizing governments are unable to alter prices on the global goods markets through their policies.

It is widely recognized that environmental policy formation is influenced by lobby groups. Environmental lobby groups are present at international conferences for instance at Kyoto, Copenhagen or Cancún; they also affect the formulation of national policies such as regulation of air or water pollution. While environmental lobby groups advocate stricter environmental standards, industry associations often lobby for lower standards in order to retain competitiveness in international markets. Governments seeking to maximize political support respond systematically to such lobbying.[1] The resulting equilibrium regulation differs considerably from the Pigouvian rule, thus creating a politically motivated distortion of environmental policy (Aidt 1998).

Due to the scale of economic activity, pollution often spills over to neighboring countries making national environmental policies relevant for adjacent countries as well. Transboundary pollution has become a serious challenge over the past decades, especially in East Asia: In China sulphur oxide emissions increased by 53% between 2000 and 2006 and spilled over to Southwest Japan (Lu et al. 2010). Ichikawa and Fujita (1995) estimate that China's contribution to wet sulphate deposition in Japan represent 50% of the total. Furthermore, anthropogenic NOx emissions over Asia have more than doubled since 1985 (Akimoto 2003). This increase in emissions has created atmospheric brown clouds. They are fuelled by emissions of two or more countries in the region and affect those countries negatively. Brown clouds “start as indoor and outdoor air pollution consisting of particles and pollutant gases, such as nitrogen oxides (NOx), carbon monoxide (CO), sulphur dioxide (SO_2), ammonia (NH_3), and hundreds of organic gases and acids” (Ramanathan et al. 2008). They affect many small countries. Their hotspots are in East Asia, Indo-Gangetic Plain in South Asia, Southeast Asia, Southern Africa, and the Amazon Basin. They have severe environmental impacts as, for instance, they accelerate the meltdown of Himalayan glaciers, decrease crop yields by as much as 20%, or result in over 330.000 deaths per year in China

[1] Cf. Binder and Neumayer (2005) and Fredriksson et al. (2005) for empirical evidence on the political influence of environmental lobby groups and List and Sturm (2006) on the relative importance of voters and lobby groups for environmental policies of US states.

and India alone, as their particles cause pulmonary illnesses and chronic respiratory problems (Ramanathan et al. 2008).

Another example for multi-directional transboundary pollution affecting small countries is Scandinavian SO_2 depositions, which are dependent to a high degree on the emission activity in neighboring countries. While all Scandinavian countries apply emission taxes, actual tax rates differ very strongly. Cansier and Krumm (1997) find that tax rates in Sweden are three times higher than in Denmark, which is only partly due to abatement cost differentials and therefore is hardly explained by welfare-maximizing behavior alone. [2]

Such transboundary pollution gives rise to a second distortion (in addition to the political distortion described above), if national environmental policies remain non-cooperative: even welfare maximizing governments would internalize the externalities only to the extent that they affect their own country (Markussen 1975). Yet, how do these two distortions interact? How do politically-motivated, self-interested governments set environmental policies in the presence of transboundary pollution? Governments respond to lobbying efforts of opposing lobby groups and at the same time are in a situation of strategic interaction with neighboring governments that are likewise seeking to maximize their political support. This is the concern of our paper.

Our study adds to the literature on endogenous environmental policy. Fredriksson (1997) analyzes the effects of world price changes and lobbying on the politically optimal environmental tax rate. He shows that pollution may increase in presence of an 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 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 and demonstrates how a politically optimizing government deviates from the social optimum in deciding on its environmental policy.[4] Fredriksson and Svensson (2003) analyze the effects of interaction of corruption and political instability on endogenous environmental policy. They show that political instability has a negative effect on the stringency of environmental policy if

[2] A related example is the environmental degradation of the Baltic Sea: It is affected by fishing, riverine pollution, and atmospheric nitrogen deposition from the neighboring states (Helcom 2010). Gren (2001) demonstrates the inefficiency of uncoordinated environmental policy for the Baltic Sea.

[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.

corruption is low and a positive effect if corruption is high. Damania et al. (2003) show *inter alia* that the effect of trade liberalization on environmental regulation is affected by corruption levels.

These papers 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, the environmental policies within such a framework are determined by domestic considerations alone.[5] A notable exception is Conconi (2003) who portrays two large open economies, which jointly determine their trade and environmental policies. In her model, strategic interaction occurs as environmental policies alter the world market prices for the traded goods. When a large country taxes the production of a polluting good, the world market price rises and as a consequence foreign production and foreign emissions increase (thus giving rise to 'emission leakages'). Conconi shows that under free trade and in the presence of strong emission leakages, environmental lobbying might actually lower emission taxes as unilaterally formulated taxes will tend to increase degradation.[6]

Our paper deviates from her approach in the assumption that the economies are small on the globalized world markets and cannot affect world market prices through their environmental or trade policies. While there are countries that may affect world market prices for certain goods, or even a range of goods, we believe that the majority of countries do not have the capacity to influence their terms of trade through a choice of policies. Nonetheless, transboundary pollution remains to be an important policy issue for a number of countries. We thus model two small open economies which produce a pollution intensive good with pollution spilling over to the other country.[7] National governments set their environmental policies in order to maximize their political support, which is composed of voter support and lobbying contributions. We employ a common agency model developed by Bernheim and Whinston (1986) and introduced by Grossman and Helpman (1994) in the literature on endogenous policy formation and assume functionally specified interest groups

[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. For a comprehensive analysis of the interaction between trade and environmental policy cf. Rauscher (1997), for surveys of the literature see Rauscher (2005).

[6] 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.

[7] We exclude thus environmental regulation of *global* pollutants which can be analyzed only in a multi-country setting (cf. Barrett 2003).

(environmentalists and industrialists). The strategic interaction between the countries results from transboundary pollution – foreign environmental regulation is a substitute for domestic policy for environmental quality, but it places the burden on foreign rather than domestic producers. Countries may be structurally different in their preferences for environmental quality and their political process, that is, in the strength of lobby groups and in the importance of social welfare for the governments' support.

In this framework, we show that politically optimal tax rates can be either lower or higher than the tax rates that welfare maximizing governments would set, depending on the relative strength of the lobby groups and the intensity of damage that is caused by production. Furthermore, we demonstrate that – contrary to the benevolent dictators' equilibrium – tax rates can be negative in equilibrium, for one country or for both. Countries may actually subsidize the polluting good rather than tax it. The distortion created by the political process may exacerbate the damage to the environment. Under different constellations, it may offset the inefficiency created by strategic interaction of the two governments, thereby leading to a higher welfare than non-cooperative social planners would be able to achieve. Our paper is the first to study the political economy of environmental policy formation for small open economies in the presence of transboundary pollution and thus fills an important gap in the literature on endogenous environmental policy.

The 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, which serve as a reference point. Section 4 introduces the common agency approach, derives the politically optimal tax rate, characterizes the equilibrium and simulates it for various parameter constellations, and derives comparative-static results. Section 5 concludes.

2. Transboundary Pollution in a Two Country Model

The model consists of two countries, which produce a good that creates environmental pollution. They are small open economies on the goods market but are nevertheless in a situation of strategic interaction, as their pollution spills over to the other country.

2.1 The economy

Each economy has two sectors. The first sector produces the non-polluting numeràire good z 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 produces the polluting good *x* with labor and a sector-specific factor, which is non-tradeable and inelastically supplied. *S* denotes environmental pollution, which is assumed to affect both countries equally and to be quadratic in total production:

$$S=\beta(X+X^{*})^{2} \tag{1}$$

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 each domestically produced unit of *x* on the producer (if home production of *x* is positive). The production costs are assumed to be quadratic in the produced quantity. Sector-specific income from the production of *x* is hence defined as:

$$\Pi(X)=(p-t)X-X^{2} \tag{2}$$

where *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* to maximize (2):

$$X=\frac{1}{2}(p-t) \tag{3}$$

Foreign production is obtained symmetrically. Obviously, the countries only produce positive amounts of *x*, if the respective production tax does not exceed the world market price of good *x*. Countries are in a situation of strategic interaction with respect to their production tax rates as they affect production and thereby pollution in both countries.

As we substitute *X* from Eq. (3), and symmetrically X^{*}, into Eq. (1), we obtain pollution contingent on the tax rates:

$$S(t,t^{*})=\frac{\beta}{4}(2p-t-t^{*})^{2} \tag{4}$$

Pollution increases with the world market price, and decreases with the tax rates. Sector specific income is derived by substituting Eq. (3) in Eq. (2):

$$\Pi(t)=\frac{1}{4}(p-t)^{2} \tag{5}$$

Sector specific income decreases with *t* while it increases with the world market price. Total domestic revenue from production taxes, $\tau(t)=tX$, is:

$$\tau(t)=\frac{1}{2}t(p-t) \tag{6}$$

τ is redistributed uniformly to all citizens of the respective country.[8] Since an increase in the world market price leads to a higher production of *X*, tax revenue increases with the world market price. However, the effect of an increase of the tax rate is ambiguous. On the one hand, a higher tax rate leads to more tax income per unit produced. On the other hand, it leads to fewer units produced as the production of *X* becomes less profitable. Hence, tax revenue τ increases (decreases) with *t*, iff $\frac{p}{2} - t > (<) 0$.

2.2 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 of environmentalists in the population and α_I (α_W) be the share of industrialists (workers). Environmentalists have disutility from pollution while industrialists and workers are not concerned with pollution. Environmentalists and workers derive income from labor only; industrialists also obtain specific factor's income from production of good *x*.

Individual maximization problems are defined as follows:

Each environmentalist solves:

$$\max_{c^z, c^x} U_E = c^z + u(c^x) - S$$
$$\text{s.t. } l + \tau = c^z + pc^x \tag{7}$$

c^z is consumption of the numeràire good *z* and c^x is consumption of good *x*. $u(c^x)$ is the concave, differentiable utility function from consumption of *x*. The utility of all environmentalists is equally affected by total pollution.

Each industrialist solves

$$\max_{c^z, c^x} U_I = c^z + u(c^x)$$
$$\text{s.t. } l + \tau + \frac{\Pi}{\alpha_I} = c^z + pc^x \tag{8}$$

[8] If taxes are negative, all individuals are taxed uniformly. The assumption of uniform redistribution of the tax revenue is in line with the literature and made for simplicity reasons. Cf. Aidt (2010) for an analysis of different refunding schemes.

The term $\frac{\Pi}{\alpha_I}$ in Eq. (8) expresses that sector-specific income is equally proportioned to all industrialists. Finally, workers solve

$$\begin{aligned} &\max_{c^z, c^x} U_W = c^z + u(c^x) \\ &\text{s.t.} \quad l + \tau = c^z + pc^x \end{aligned} \tag{9}$$

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

$$\Omega_E(t, t^*) \equiv \alpha_E[-S + \tau + l] \tag{10}$$

$$\Omega_I(t, t^*) \equiv \Pi + \alpha_I\,[\tau + l] \tag{11}$$

$$\Omega_W(t, t^*) \equiv \alpha_W[\tau + l] \tag{12}$$

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

$$\Omega_A(t, t^*) \equiv \Omega_E + \Omega_I + \Omega_W = \tau + l + \Pi - \alpha_E S \tag{13}$$

The term $\alpha_E S$ represents aggregate disutility of the environmentalists from pollution and thus to the society as a whole. It is 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 among how many industrialists the sector-specific income is divided. To obtain gross aggregate welfare –contingent on the tax rates – we substitute Eqs. (4), (5), and (6) in Eq. (13). Rearrangements yield:

$$\Omega_A(t, t^*) = \frac{p^2 - t^2}{4} - \alpha_E \beta \left[\frac{(t + t^*)^2}{4} + p(p - t - t^*)\right] + l \tag{14}$$

3. Benevolent Dictators' Solution

As a reference point for our further analysis, we derive the benevolent dictators' solution for tax rates that are set non-cooperatively.[9] Each government seeks to maximize its country's aggregate welfare.

[9] We index this solution with 'BD' for **b**enevolent **d**ictator.

3.1 Governments' Reaction Functions

The domestic government chooses *t* in order to maximize Eq. (14), taking the foreign tax rate as given:

$$\frac{\partial \Omega_A}{\partial t} = \alpha_E \beta (2p - t - t^*) - \frac{t}{2} \overset{!}{=} 0 \tag{15}$$

Solving Eq. (15) for *t* gives the domestic government's reaction function for positive production of both firms:

$$\tilde{t}^{BD} = \frac{\alpha_E \beta (2p - t^*)}{1 + \alpha_E \beta} \tag{16}$$

The reaction function is linear in t^*, and it is downward sloping. Intuitively, if the foreign tax rate increases, the home country is less affected by the negative externality of foreign pollution and can thus reduce its own tax rate. The foreign country's reaction function is isomorphous. For positive values of foreign production , $t^* < p$, and thus $\tilde{t}^{BD}$ is positive.

Eq. (16) defines the reaction function only for positive production of both firms, hence for $p > t$ and $p > t^*$. However, we cannot exclude corner solutions. They occur if one country produces so large an amount of the polluting good, thereby producing large quantities of pollution in both countries, that it is optimal for the other country not to add to this pollution by setting a prohibitive tax rate. Any further pollution damage created by own production would exceed the welfare gains from the profits of its firm.

For instance, if the foreign country sets its tax rate equal or below a lower threshold, t_{lb}^{BD*}, it is optimal for the home country to set its own tax rate prohibitively high so that its production becomes zero. Algebraically t_{lb}^{BD*} is derived by setting Eq. (16) equal to p and solving for t^*: $t_{lb}^{BD*} = \left(1 - \frac{1}{\alpha_E \beta}\right) p$.[10] Conversely, if the foreign country imposes a prohibitive tax, $t^* \geq p$, the home country will set a tax $t_{low}^{BD} = \frac{\alpha_E \beta p}{1 + \alpha_E \beta}$, which is derived by setting $t^* = p$ in Eq. (16). In other words, if foreign competition is absent, the home country will optimize its own production and pollution by setting a strictly positive tax rate t_{low}^{BD}.

The domestic reaction function is thus defined by:

[10] As t* is strictly positive (cf. the foreign equivalent of Eq. (16)) such a situation can only occur if $\alpha_E \beta > 1$.

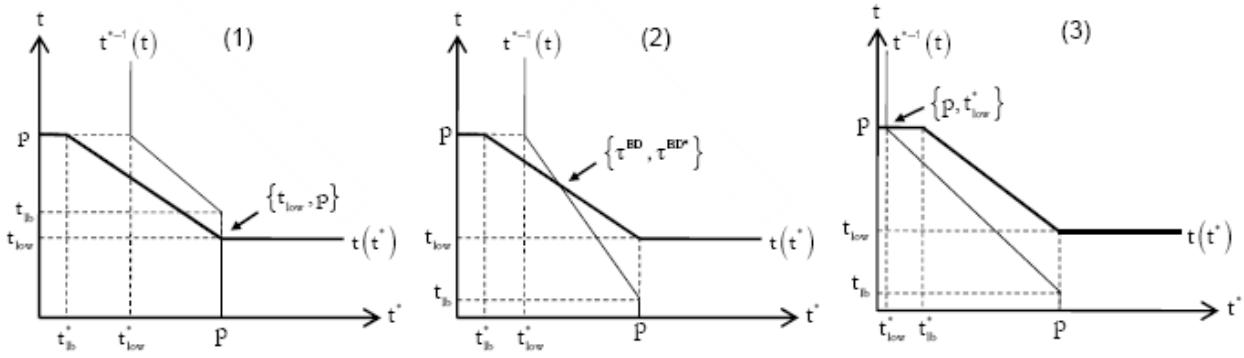
$$t^{BD}=\begin{cases} t_{low}^{BD}, & \text{for } t^* \geq p \\ \tilde{t}^{BD}, & \text{for } t_{lb}^{BD*} < t^* < p \\ p, & \text{for } t^* \leq t_{lb}^{BD*} \end{cases} \tag{17}$$

The foreign reaction function is isomorphous.

3.2 Equilibrium

The three types of possible equilibria are depicted in Figure 1.[11] Either one country sets a prohibitive tax rate and the other country sets its best response tax rate (t_{low}^{BD} or t_{low}^{BD*}, respectively) or both countries set non-prohibitive tax rates thereby creating an inner solution with both countries producing the polluting good.

Figure 1: The Equilibrium with Benevolent Dictators



Panel (1) depicts the situation in which the foreign country sets its prohibitive tax rate and the home country reacts by setting its tax rate equal to t_{low}^{BD}. This situation requires that $t_{lb}^{BD} > t_{low}^{BD}$,[12] which amounts to the condition $\alpha_E{}^* - \alpha_E > \frac{1}{\beta}$. Panel (3) depicts the opposite corner solution with the home country setting the prohibitive tax with $t_{lb}^{BD*} > t_{low}^{BD*}$ and $\alpha_E - \alpha_E{}^* > \frac{1}{\beta}$. In other words, corner solutions occur if the marginal damages from pollution differ strongly between countries – the country with the higher valuation of environmental quality introduces a prohibitive tax while the other keeps producing with a tax rate equal to the marginal damage from production.

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[11] In Figure 1, we have assumed that $\alpha_E\beta > 1$ and $\alpha_E^*\beta > 1$. If for instance $\alpha_E^*\beta < 1$, t_{lb}^{BD} would be negative and therefore the foreign government would never set a prohibitive tax rate. Graphically, the foreign reaction curve would not have a kink at $t_{lb}^{BD*} = p$, but $t_{lb}^{BD*}(t^* = 0) < p$. The equilibrium depicted in panel (1) could not exist.

[12] This condition is intuitive and follows from the definition of these threshold values: Only if the foreign country sets a prohibitive tax rate, which requires $t < t_{lb}^{BD}$, will the home country set its best response at t_{low}^{BD}. For a corner solution to exist and the reaction functions to intersect at $t^* = p$, it is required that $t_{low}^{BD} < t_{lb}^{BD}$. Otherwise an interior solution would result.

Panel (2) shows the case in which both countries produce, create externalities from pollution, and tax their production. It requires that the two countries do not differ too much in their marginal damage from pollution: $|\alpha_E - \alpha_E{}^*| < \frac{1}{\beta}$. The more polluting production is (i.e. the larger β), the more similar the valuations of environment need to be for an interior solution.

The interior equilibrium $\{\tilde{T}^{BD}, \tilde{T}^{BD*}\}$ is given by the intersection of the reaction functions $\tilde{t}^{BD}$ (from Eq. (16)) and $\tilde{t}^{BD*}$, as shown in Figure 1, Panel (2). The domestic tax rate amounts to

$$\tilde{\mathrm{T}}^{\mathrm{BD}} = \frac{2\alpha_{\mathrm{E}}\beta\mathrm{p}}{1 + \beta\,(\alpha_{\mathrm{E}} + \alpha_{\mathrm{E}}{}^*)} \tag{18}$$

$\tilde{T}^{BD*}$ is calculated accordingly.

We can now define the equilibrium for the benevolent dictator setting in the following Proposition.

Proposition 1:

The equilibrium tax rates on production for two welfare-maximizing governments, T^{BD}, T^{BD*}, are given by

$$\{\mathrm{T}^{\mathrm{BD}}, \mathrm{T}^{\mathrm{BD}*}\} = \begin{cases} (1)\{\mathrm{t}_{\mathrm{low}}^{\mathrm{BD}}, \mathrm{p}\}, & \text{for } \alpha_{\mathrm{E}}{}^* - \alpha_{\mathrm{E}} > \frac{1}{\beta} \\ (2)\{\tilde{\mathrm{T}}^{\mathrm{BD}}, \tilde{\mathrm{T}}^{\mathrm{BD}*}\}, & \text{for } |\alpha_{\mathrm{E}} - \alpha_{\mathrm{E}}{}^*| < \frac{1}{\beta} \\ (3)\{\mathrm{p}, \mathrm{t}_{\mathrm{low}}^{\mathrm{BD}*}\}, & \text{for } \alpha_{\mathrm{E}} - \alpha_{\mathrm{E}}{}^* > \frac{1}{\beta} \end{cases} \tag{19}$$

with $t_{low}^{BD} = \frac{\alpha_E \beta p}{1+\alpha_E \beta}$ and $\tilde{T}^{BD}$ defined by Eq. (18)*.*

Equilibrium tax rates are strictly positive.

The equilibrium is unique and stable.

Proof: See Appendix 1. ■

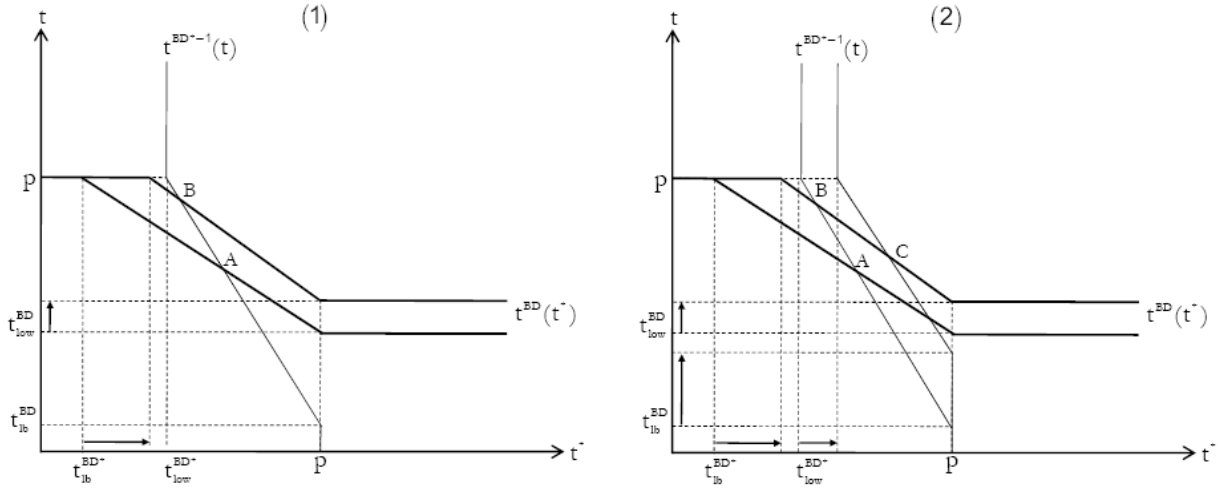
3.3 Comparative Statics

Comparative static effects of variations in all exogenous variables (α_E, $\alpha_E{}^*$, β, and p) are straightforward. An increase in α_E raises t_{lb}^{BD*} and t_{low}^{BD}, and it shifts the domestic reaction

curve (bold line) upwards while the foreign reaction curve (thin line) is unaffected. [13] This is depicted in Panel 1 of Figure 2 for an inner solution. The equilibrium shifts from A to B.

The equilibrium shifts to the Northwest: as a consequence, for large enough variations in α_E, an interior equilibrium may change into a corner equilibrium with the home country setting a prohibitive tax rate. Conversely a corner solution with the foreign country setting a prohibitive tax rate may turn into an inner solution. This follows immediately from differentiating Eq. (18) w.r.t. α_E.[14] An equilibrium in which the domestic tax rate was already prohibitive remains unaffected.

Figure 2: An increase in α_E (panel 1) and in β (panel 2)



An increase in the damage parameter β raises $t_{lb}^{BD*}, t_{lb}^{BD}, t_{low}^{BD}, t_{low}^{BD*}$.[15] This is shown in Panel 2 of Figure 2. Qualitatively, the domestic reaction curve shifts, as depicted in Panel 1. The main difference is that the foreign reaction curve shifts in the same way. This is intuitive: As the marginal environmental damage increases in both countries, countries raise their best response tax rates. As a result, the range of the corner solutions is enlargened on both ends; for the interior solution the resulting new equilibrium (at point C) is characterized by higher foreign and domestic tax rates. Analytically, this can be seen by differentiating (18) w.r.t. β.

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[13] This is seen from $\frac{\partial t_{lb}^{BD*}}{\partial \alpha_E} = \frac{p}{{\alpha_E}^2 \beta} > 0$ and $\frac{\partial t_{low}^{BD}}{\partial \alpha_E} = \frac{p\beta}{[1+\alpha_E\beta]^2} > 0$. The increase of t_{lb}^{BD*} is not proportional to that of t_{low}^{BD}, which implies that the slope of the reaction function changes.

[14] $\frac{\partial \tilde{T}^{BD}}{\partial \alpha_E} = \frac{2\beta p(1+\alpha_E{}^*\beta)}{(1+\beta(\alpha_E+\alpha_E{}^*))^2} > 0$. Analogously, $\frac{\partial \tilde{T}^{BD}}{\partial \beta} > 0$, $\frac{\partial \tilde{T}^{BD}}{\partial p} > 0$, and $\frac{\partial \tilde{T}^{BD}}{\partial \alpha_E{}^*} < 0$.

[15] For instance, $\frac{\partial t_{lb}^{BD*}}{\partial \beta} = \frac{p}{\alpha_E(\beta)^2} > 0$ and $\frac{\partial t_{low}^{BD}}{\partial \beta} = \frac{\alpha_E p}{[1+\alpha_E\beta]^2} > 0$.

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. The political support function is a weighted sum of social welfare and contributions offered by political interest groups.

4.1 The Political Setting

We assume that individuals with similar interests form national lobby groups in both countries and offer campaign contributions to their governments. Environmentalists form environmental lobby groups, industrialists form industry lobby groups while workers do not organize.[16] 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 $\Lambda_i(t)$.[17] Their intention is to influence the government's choice of environmental policy: These contribution schedules are contingent on the pollution tax rate selected by the government and reward the policy choice. Each lobby group's strategy consists of a continuous function $\Lambda_i: T \to \mathbb{R}_+$. Lobby groups offer a monetary payment Λ_i to the government for choosing the tax rate $t \in T, T \in \mathbb{R}$. All contribution schedules are assumed to be non-negative and differentiable around the equilibrium point.[18] Lobby groups at home and abroad act independently from each other. The foreign pollution tax rate will be taken as given when lobby groups decide on their lobby schedules.[19]

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[16] 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.

[17] The offers of campaign contributions 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. 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).

[18] 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 $\Lambda_i = 0$.

[19] 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.

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

$$\upsilon = \sum_{i \in L} \Lambda_i + a\Omega_A \tag{20}$$

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.[20] 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.

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. 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 the corresponding contribution from the lobby groups in their country.[21] The lobby groups offer contribution schedules anticipating the optimization calculus of their governments in the second stage.

4.2.1 General Characterization of the Political Equilibrium

In the two country common agency setup, the equilibrium is characterized by governments setting tax rates that maximize their respective political support functions, taking the other country's policy and their national lobby groups' contribution schedules as given. The lobby groups maximize their respective utilities, contingent on national policies, by offering feasible

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We also disregard the possibility that interest groups lobby across the border. For such an analysis cf. Hillman and Ursprung (1988), Aidt (2005).

[20] For an analysis that endogenizes the weight of social welfare for the political objective function cf. Fredriksson et al. (2005).

[21] It is assumed that lobby groups keep their promises and thus make the announced payments.

contribution schedules to their governments. They take the other government's policy and the contributions of the other lobby groups in their respective countries as given.

Applying Lemma 2 of Bernheim and Whinston (1986), or Proposition 1 in Grossman and Helpman (1994) to our setup, the equilibrium is characterized as follows.

Proposition 2:

$(\{\Lambda_i\}_{i\in L}, \{\Lambda_i^*\}_{i\in L}, \{T^{PG}, T^{PG*}\})$ *is a Subgame Perfect Nash Equilibrium of the pollution tax game, if and only if:*

(a) Λ_i, Λ_i^* *are feasible for all* $i \in L$*;*
(b) T^{PG} *maximizes* v *on T, and* T^{PG*} *maximizes* v^* *on* T^**;*
(c) T^{PG} *maximizes* $\Omega_j(t) - \Lambda_j(t) + v$ *on* $T \ \forall\, j \in L$*, and* T^{PG*} *maximizes* ${\Omega_j}^*(t^*) - {\Lambda_j}^*(t^*) + v^*$ *on* $T^* \ \forall\, j \in L^*$*;*
(d) $\forall\, j \in L$ *there exists a* $t^{-j} \in T$ *that maximizes* v *on T such that* $\Lambda_j(t^{-j}) = 0$*, and* $\forall\, j \in L^*$ *there exists a* $t^{-j*} \in T^*$ *that maximizes* v^* *on* T^* *such that* ${\Lambda_j}^*(t^{-j*}) = 0$.

A set of policies $\{T^{PG}, T^{PG*}\}$ and the sets of contribution schedules $\{\Lambda_i\}_{i\in L}, \{\Lambda_i^*\}_{i\in L}$ are a subgame perfect Nash equilibrium if conditions (a) to (d) hold. 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 governments set their pollution taxes $\{T^{PG}\}, \{T^{PG*}\}$ to maximize their respective objective functions $\{v\}$ and $\{v^*\}$ taking the contribution schedules offered by their lobby groups and the other country's policy as given. Condition (c) stipulates that the equilibrium tax rate must maximize the joint welfare of the government and each of the national lobby groups, given the contribution schedule offered by the other lobby group. In other words, no lobby group j has a feasible strategy other than the equilibrium strategy that would lead to an increase in the joint surplus of the government and the lobby group, of which it could appropriate a share. Condition (d) requires that for every lobby group j, a tax policy t^{-j} exists that gives the government the same utility as the equilibrium tax rate T^{PG}, if the lobby group j does not contribute. 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). Conditions (c) and (d) ensure that the lobbying schedule is optimal.

4.2.2 Political-economic Reaction Functions

Next we derive the home government's reaction function from Proposition 2. Conditions (b) and (c) characterize the optimization calculus of the government.

$$\text{Condition (b)} \qquad \sum_{i\in L}\frac{\partial \Lambda_i}{\partial t}+a\frac{\partial \Omega_A}{\partial t}\overset{!}{=}0 \tag{21}$$

and

$$\text{Condition (c)} \qquad \frac{\partial \Omega_j}{\partial t}-\frac{\partial \Lambda_j}{\partial t}+\frac{\partial v}{\partial t}\overset{!}{=}0, \forall\, j\in L \tag{22}$$

Eqs. (21) and (22) imply that, in equilibrium, each lobby group sets its contribution schedule such that, the marginal utility from a change in tax rate equals its marginal change in contribution. Thus each lobby group's marginal net utility is zero in equilibrium.

$$\frac{\partial \Omega_i}{\partial t}=\frac{\partial \Lambda_i}{\partial t}, \forall\, i\in L \tag{23}$$

Substituting Eq. (23) into Eq. (21) we obtain the equilibrium characterization:

$$\sum_{i\in L}\frac{\partial \Omega_i}{\partial t}+a\frac{\partial \Omega_A}{\partial t}\overset{!}{=}0 \tag{24}$$

Next we calculate $\frac{\partial \Omega_E}{\partial t}$ and $\frac{\partial \Omega_I}{\partial t}$ to derive the politically optimal tax rate as a function of the other country's tax rate and the parameters of the model. $\frac{\partial \Omega_A}{\partial t}$ is given by Eq. (15). The lobby groups' marginal utilities w.r.t. the tax rate in Eq. (24) are calculated by substituting Eqs. (4), (5), and (6) in Eqs. (10) and (11), and differentiating them with respect to t:

$$\frac{\partial \Omega_E}{\partial t}=\frac{1}{2}\alpha_E\left[\beta\,(2p-t-t^*)+2\left(\frac{p}{2}-t\right)\right] \tag{25}$$

and

$$\frac{\partial \Omega_I}{\partial t}=\alpha_I\left(\frac{p}{2}-t\right)-\frac{1}{2}(p-t) \tag{26}$$

Environmentalists' marginal utility with respect to the home tax rate can have either sign (cf. Eq. (25)). There are two relevant effects. First, when the domestic tax rate increases, home production of *x* decreases, and hence pollution decreases. Second, total tax revenue changes with t and thus the share redistributed to environmentalists. It increases if $\frac{p}{2}-t>0$ and decreases otherwise (cf. Eq. (6)). If the environmentalists' revenue share increases, their marginal utility with respect to the home tax rate is unambiguously positive. Otherwise, the loss in tax revenue may outweigh the effect of reduced pollution – making $\frac{\partial \Omega_E}{\partial t}$ negative.[22]

[22] This may happen only for small β because a further increase in the tax rate reduces pollution only negligibly but may reduce the tax revenue significantly as the tax base diminishes.

Eq. (26) shows that industrialists' marginal utility from an increase in t is strictly negative: sector specific income Π decreases; tax revenue may increase or decrease (see above), but an increase can only partially compensate industrialists for the decline in profits as tax revenue is distributed among all members of the society.

We calculate the reaction function of the home country by substituting Eqs. (15), (25), and (26) in Eq. (24), and solving it for t. This yields:

$$\tilde{t}^{PG} = \frac{\alpha_E \beta(a+1)(2p - t^*) - \alpha_W p}{(a+1)(\alpha_E \beta + 1) - 2\alpha_W} \tag{27}$$

4.3 The Political-economic Equilibrium

Eq. (27) is derived from the first order condition for a maximum of the political support function conditional on the value of the foreign tax rate. As in the benevolent dictator case, the reaction function is linear in the foreign tax rate. The second order condition for an interior maximum, i.e. $\frac{\delta^2 v}{\delta t^2} < 0$, requires that

$$(a+1)(\alpha_E \beta + 1) - 2\alpha_W > 0 \tag{28}$$

If condition (28) was violated, the interior solution given by (27) would characterize a minimum and hence a corner solution would be optimal. Industrialists' marginal utility would increase faster as t is lowered below $\tilde{t}^{PG}$ than the sum of the weighted marginal welfare, and the environmentalists' marginal utility would decrease.[23] It would be optimal for the government to reduce the tax rate to the minimal amount possible. [24]

This corner solution is a degenerate case as it is hard to conceive that society directs all its resources from all members of the society by an 'infinitely' negative tax on production towards the industrialist sector only to increase output, profits and environmental degradation

[23] This is intuitive as Eq. (28) states that the absolute values of the second derivative of the environmentalists' utility function $\Omega_{E,tt} = -\alpha_E - \frac{1}{2}\alpha_E\beta$ plus the weighted second derivative of the welfare function $a\,\Omega_{A,tt} = -a(\frac{1}{2} + \frac{1}{2}\alpha_E\beta)$ exceed the value of the second derivative of the industrialists' utility function $\Omega_{I,tt} = \frac{1}{2} - \alpha_I$.

[24] While the effective tax rate is bounded from above by the value of the price, beyond which production is zero and thus a further increase would be inconsequential, a lower bound exists only to the extent that the negative tax would use up all resources from the society and redirect it to the industrial production. When comparing $v\ (t = p)$ with $v\ (t \to -\infty)$ it is immediately clear that the value of the former corner solution falls short of the latter. [Strictly speaking the latter is not an infinite, but a finite subsidy with a rate implicitly defined by the gross resources of all groups.]

to the maximum extent possible.[25] This is not what we observe and it would require unrealistic parameter values. We thus exclude this uninteresting case by the following assumption:

Assumption 1: $\frac{1}{2}(a+1)(\alpha_E\beta+1) > \alpha_W$ and $\frac{1}{2}(a^*+1)(\alpha_E{}^*\beta+1) > \alpha_W{}^*$

Assumption 1 guarantees a stable interior maximum of the political support function conditional on the value of the foreign tax rate and stable Nash equilibria as shown below.

The sign of the tax rate in Eq. (27) is ambiguous — while the denominator is positive under Assumption 1, the numerator can be positive or negative. Thus in contrast to the benevolent dictator case the reaction function of a political support maximizing government can take on negative values. Given Assumption 1, the reaction function is downward sloping in the foreign tax rate, as in the Benevolent Dictator case.

Eq. (27) defines the reaction function only for positive production of both firms, not for corner solutions. Analogous to Section 3, we determine the optimal domestic tax rate for zero foreign production, t_{low}^{PG}, by setting $t^* = p$ in Eq. (27). This yields

$$t_{low}^{PG} = \frac{\alpha_E\beta(a+1)p - \alpha_W p}{(a+1)(\alpha_E\beta+1) - 2\alpha_W} \tag{29}$$

The denominator is positive under Assumption 1, the numerator can have either sign: Contrary to the benevolent dictator case, t_{low}^{PG} can take on negative values. A comparison of (27) and (29) shows that $t_{low}^{PG} \leq \tilde{t}^{PG}$.

Next we determine the foreign tax rate t_{lb}^{PG*}, below which it is optimal for the home country to introduce a prohibitive tax rate $t \geq p$.

$$t_{lb}^{PG*} = p\left(\frac{(a+1)\,[\alpha_E\beta - 1] + \alpha_W}{\alpha_E\beta(a+1)}\right) \tag{30}$$

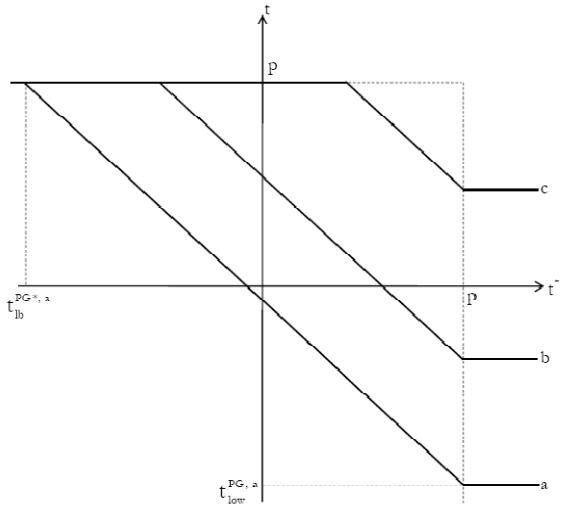
Note that t_{lb}^{PG*} may be positive or negative. The reaction function is thus defined by

$$t^{PG} = \begin{cases} t_{low}^{PG}, & \text{for } t^* \geq p \\ \tilde{t}^{PG}, & \text{for } t_{lb}^{PG*} < t^* < p \\ p, & \text{for } t^* \leq t_{lb}^{PG*} \end{cases} \tag{31}$$

[25] Such a degenerate case could occur only if the environmentalists had little political weight, the pollution damage from production was small, the value of welfare consideration of the government's calculus was low, and if the number of industrialists was small ($\alpha_E, \beta, a, \alpha_I$ were small).

where $\tilde{t}^{PG}$ is defined by Eq. (27). As t_{low}^{PG} and t_{lb}^{PG*} can have either sign and are not bounded from below, the 'interior' reaction function $\tilde{t}^{PG}$ may be only in the first quadrant, in the fourth, first, and second, or not in the first quadrant at all. Three possible reaction curves are depicted in Figure 3 below.[26]

Figure 3: Domestic reaction curves for the political game



Next we analyze the possible equilibria. The slopes of the 'interior' domestic reaction function $\tilde{\mathrm{t}}^{\mathrm{PG}}$ and the inverse of the foreign reaction function $\tilde{\mathrm{t}}^{\mathrm{PG}*-1}$ are

$$\frac{\partial \mathrm{t}}{\partial \mathrm{t}^*} = -\frac{\alpha_{\mathrm{E}}\beta(\mathrm{a}+1)}{(\mathrm{a}+1)(\alpha_{\mathrm{E}}\beta+1)-2\alpha_{\mathrm{W}}}$$

$$\frac{\partial \mathrm{t}^{*-1}}{\partial \mathrm{t}} = -\frac{(\mathrm{a}^*+1)(\alpha_{\mathrm{E}}{}^*\beta+1)-2\alpha_{\mathrm{W}}{}^*}{\alpha_{\mathrm{E}}{}^*\beta(\mathrm{a}^*+1)} \qquad (32)$$

By assumption 1, both reaction curves are downward sloping. Eq. (32) shows that the inverse of the foreign reaction curve can be flatter or steeper than the domestic reaction curve, which implies the possibility of unstable equilibria.

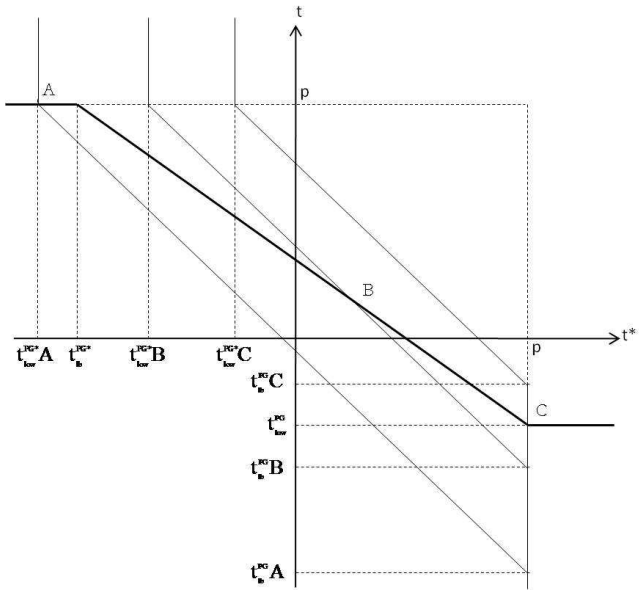
4.3.1 Stable equilibria

We first analyze the case in which $\frac{\partial t}{\partial t^*} > \frac{\partial t^{*-1}}{\partial t}$; i.e. the domestic reaction function is flatter than the inverse of the foreign reaction function. This is depicted in Figure 4. The line in

[26] The reaction functions are depicted for values β=6, $\alpha_I = 0.06, \bar{p} = 5, l = 1, a = 1$ and differ in the value for α_E which takes on the values 0.03, 0.05, and 0.1 for the reaction curves a, b, and c, respectively.

boldface depicts a selected domestic reaction function as shown in Figure 3.[27] The thin lines show three possible inverse of the foreign reaction curve, which results in three different – stable – equilibria. In equilibrium A, the domestic country sets a prohibitive tax rate $t = p$ and the foreign country sets its best response, which is t^*_{low}. Equilibrium C is the mirror case in which the foreign government denies production in its country and the home country sets $t = t^{PG}_{low}$. These corner solutions A and C correspond to the panels 3 and 1 in Figure 1 of Section 3. Yet, while in the benevolent dictator case both tax rates are unambiguously positive, tax rates may (or may not) be negative in the political game. The interior solution B is characterized by both countries producing finite amounts of the polluting good. In Figure 4 this solution is depicted with positive tax rates for both countries; however home and foreign reaction curves could be positioned very differently in the policy space (t, t*) – as shown in Figure 3 for the domestic reaction function – so that any combination between taxes and subsidies is possible in the equilibrium. In other words, it is possible that both countries subsidize the production of the polluting good or that one country taxes the negative externality while the other country subsidizes it.

Figure 4: Stable equilibria in the political game



The conditions for corner solutions versus inner solutions can be seen in Figure 4 by comparing the values of t^{PG}_{low}, t^{PG}_{lb}, t^{PG*}_{low} and t^{PG*}_{lb}:[28]

[27] For the sake of clarity we selected only one domestic reaction function, but it is clear from Figure 3, that depending on parameter values the domestic reaction function could lie entirely outside the first quadrant or the downward sloping part entirely inside the first quadrant. The same is true for the foreign reaction function so that a resulting interior equilibrium could lie anywhere in the policy space.

[28] Note that for $\frac{\partial t}{\partial t^*} > \frac{\partial t^{*-1}}{\partial t}$ the condition $t^{PG*}_{low} < t^{PG*}_{lb}$ implies that $t^{PG}_{low} > t^{PG}_{lb}$.

$$\begin{array}{rcl} X = 0, X^* > 0 & \Leftrightarrow & t_{low}^{PG*} < t_{lb}^{PG*} \\ X, X^* > 0 & \Leftrightarrow & t_{low}^{PG*} > t_{lb}^{PG*} \wedge t_{low}^{PG} > t_{lb}^{PG} \\ X > 0, X^* = 0 & \Leftrightarrow & t_{low}^{PG} < t_{lb}^{PG} \end{array} \quad (33)$$

The three conditions in (33) describe the equilibria A, B, C in Figure 4. For instance, for equilibrium A: $t_{low}^{PG*}A < t_{lb}^{PG*}A$. The first line of (33) corresponds with the tax rates $t = p, t^* = t_{low}^{PG*}$, the second line with $(\tilde{t}^{PG}, \tilde{t}^{PG*})$, and the third line with $t = t_{low}^{PG}, t^* = p$.

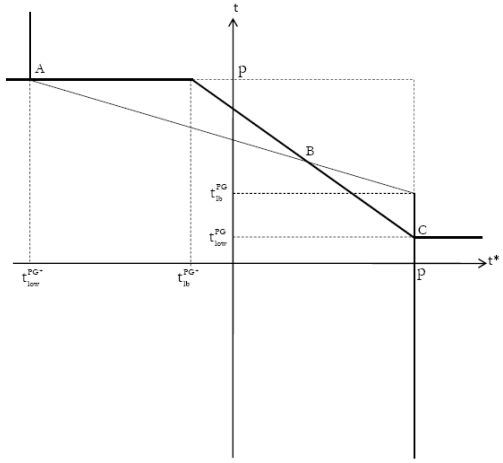
To shed light on the political-economic determinants for the equilibria A, B, and C and their position we analyze how the domestic reaction function shifts in response to changes in α_E, α_I, β and a. All derivations are relegated to Appendix 2. An increase in α_E shifts the domestic reaction function to the Northeast and increases t_{lb}^{PG*} and t_{low}^{PG}. An increasing β shifts the domestic reaction curve upwards in the same way, however the foreign reaction curve shifts as well in the described manner so that a new inner equilibrium, if it exists, must lie to the Northeast of the old inner equilibrium. Thus both shifts are similar to the benevolent dictator case depicted in Figure 2 (with the exception that they are not confined to the first quadrant). Increases in α_I and a reduce t_{lb}^{PG*} and make the reaction curve flatter; they increase t_{low}^{PG} if $\alpha_E\beta<1$ and decreases it otherwise.[29] The new reaction curve may either be entirely below the old reaction curve or intersect with it.

4.3.2 Unstable equilibria

We now turn to the case of the foreign reaction curve being flatter than the domestic reaction curve, i.e. $\frac{\partial t}{\partial t^*} < \frac{\partial t^{*-1}}{\partial t}$. This condition implies that both countries react relatively strongly in their tax setting to changes in the other country's tax rate. This case is depicted in Figure 5. Again the blue line in boldface depicts the domestic reaction function; the thin red line represents the foreign reaction function.

[29] This follows straightforwardly from differentiating (29) and (30) w.r.t. α_I and a.

Figure 5: Unstable equilibria in the political game



Now, the reaction curves intersect three times with intersection B representing an unstable equilibrium and points A and C representing stable corner solutions. That is, if countries react relatively strongly to their opponent's tax setting, initial conditions or coincidence decide about which country will produce the polluting good, possibly under heavy subsidization, and which country will not produce the good at all. In that case it is no longer the political-economic characteristics of the two countries alone which decide about the pattern of production and pollution, but any factor that happens to tip the unstable equilibrium to the left or the right of point B with the consequences being most radical. A government may heavily subsidize the production of the polluting good, which it would have banned under only slightly different circumstances. Overall, the possibility of unstable outcomes makes corner solutions more likely.

For this case the equilibria can be characterized as follows

$$\begin{array}{lll} t_{low}^{PG*} < t_{lb}^{PG*} \wedge t_{low}^{PG} > t_{lb}^{PG} & \Longrightarrow & X = 0, X^* > 0 \\ t_{low}^{PG*} < t_{lb}^{PG*} \wedge t_{low}^{PG} < t_{lb}^{PG} & \Longrightarrow & X = 0, X^* > 0 \; or \; X, X^* > 0 \text{ or } X > 0, X^* = 0 \\ t_{low}^{PG*} > t_{lb}^{PG*} \wedge t_{low}^{PG} < t_{lb}^{PG} & \Longrightarrow & X > 0, X^* = 0 \end{array} \quad (34)$$

The second line refers to the situation depicted in Figure 5. The comparative static properties are the same as described above. Note that increases in a and α_I will make the reaction curve flatter, which may turn an unstable equilibrium into a stable one.

We now turn to the derivation of the equilibrium. For an interior political-economic equilibrium $(\tilde{T}^{PG}, \tilde{T}^{PG*})$ the 'interior' reaction functions $\tilde{t}^{PG}$ and $\tilde{t}^{PG*}$ need to intersect. From Eq. (27) and its foreign equivalent follows

$$\tilde{T}^{PG} = \bar{p}\left(1 + \frac{\alpha_W{}^*[(a+1)(\alpha_E\beta+1) - 2\alpha_W] + (a^*+1)\left[\alpha_W(2-\alpha_E{}^*\beta) - (a+1)\left(1+\beta(\alpha_E-\alpha_E{}^*)\right)\right]}{(a+1)(\alpha_E\beta+1)(a^*+1-2\alpha_W{}^*) + (a^*+1)(\alpha_E{}^*\beta+1)(a+1-2\alpha_W) + 4\alpha_W\alpha_W{}^* - (a+1)(a^*+1)}\right) \quad (35)$$

We can now summarize our main result in the following Proposition.

Proposition 3:

(i) The equilibrium tax rates on production for two political support-maximizing governments, T^{PG}, T^{PG*}, are given by

(1)	$\tilde{\mathrm{T}}^{\mathrm{PG}}, \tilde{\mathrm{T}}^{\mathrm{PG}*}$	for $\mathrm{t}_{\mathrm{low}}^{\mathrm{PG}*} > \mathrm{t}_{\mathrm{lb}}^{\mathrm{PG}*} \wedge \mathrm{t}_{\mathrm{low}}^{\mathrm{PG}} > \mathrm{t}_{\mathrm{lb}}^{\mathrm{PG}}$
(2)	$\mathrm{p}, \mathrm{t}_{\mathrm{low}}^{\mathrm{PG}*}$	for $\mathrm{t}_{\mathrm{low}}^{\mathrm{PG}*} < \mathrm{t}_{\mathrm{lb}}^{\mathrm{PG}*} \wedge \mathrm{t}_{\mathrm{low}}^{\mathrm{PG}} > \mathrm{t}_{\mathrm{lb}}^{\mathrm{PG}}$
(3)	$\mathrm{t}_{\mathrm{low}}^{\mathrm{PG}}, \mathrm{p}$	for $\mathrm{t}_{\mathrm{low}}^{\mathrm{PG}*} > \mathrm{t}_{\mathrm{lb}}^{\mathrm{PG}*} \wedge \mathrm{t}_{\mathrm{low}}^{\mathrm{PG}} < \mathrm{t}_{\mathrm{lb}}^{\mathrm{PG}}$
(4)	Multiple equilibria	for $\mathrm{t}_{\mathrm{low}}^{\mathrm{PG}*} < \mathrm{t}_{\mathrm{lb}}^{\mathrm{PG}*} \wedge \mathrm{t}_{\mathrm{low}}^{\mathrm{PG}} < \mathrm{t}_{\mathrm{lb}}^{\mathrm{PG}}$

where t_{low}^{PG} is defined by Eq. (29) *and t_{lb}^{PG*} by Eq.* (30)*.*

(ii) Equilibria (1) to (3) are unique and stable. In situation (4) there exist two stable corner solutions with (p, t_{low}^{PG*}) and (t_{low}^{PG}, p) and an unstable interior equilibrium with $(\tilde{T}^{PG}, \tilde{T}^{PG*})$.

(iii) Equilibrium tax rates $\tilde{T}^{PG}, \tilde{T}^{PG*}, t_{low}^{PG}, t_{low}^{PG*}$ may be positive or negative. ■

4.4 Comparison of the Political Game with the Benevolent Dictator Solutions

The conditions (1) to (4) in Proposition 3 can be rewritten in terms of the parameter of the model, which allows an easier comparison to the benevolent dictator case as described in Eq. (19). Using Eqs. (29), (30) and the other country's equivalent, we can rewrite the conditions in Proposition 3 as:

(1)	$\tilde{\mathrm{T}}^{\mathrm{PG}}, \tilde{\mathrm{T}}^{\mathrm{PG}*}$	$-\frac{1}{\beta}\left(1-\frac{\delta\ \alpha_{\mathrm{W}}}{\mathrm{a}\ +1}\right) < \alpha_{\mathrm{E}}\delta - \alpha_{\mathrm{E}}{}^{*}\delta^{*} < \frac{1}{\beta}\left(1-\frac{\delta^{*}\alpha_{\mathrm{W}}{}^{*}}{\mathrm{a}^{*}+1}\right)$
(2)	$\bar{\mathrm{p}}, \mathrm{t}_{\mathrm{low}}^{\mathrm{PG}*}$	$\frac{1}{\beta}\left(1-\frac{\delta^{*}\alpha_{\mathrm{W}}{}^{*}}{\mathrm{a}^{*}+1}\right) < \alpha_{\mathrm{E}}\delta - \alpha_{\mathrm{E}}{}^{*}\delta^{*}$ and $\alpha_{\mathrm{E}}\delta - \alpha_{\mathrm{E}}{}^{*}\delta^{*} > -\frac{1}{\beta}\left(1-\frac{\delta\ \alpha_{\mathrm{W}}}{\mathrm{a}\ +1}\right)$
(3)	$\mathrm{t}_{\mathrm{low}}^{\mathrm{PG}}, \bar{\mathrm{p}}$	$\frac{1}{\beta}\left(1-\frac{\delta^{*}\alpha_{\mathrm{W}}{}^{*}}{\mathrm{a}^{*}+1}\right) > \alpha_{\mathrm{E}}\delta - \alpha_{\mathrm{E}}{}^{*}\delta^{*}$ and $\alpha_{\mathrm{E}}\delta - \alpha_{\mathrm{E}}{}^{*}\delta^{*} < -\frac{1}{\beta}\left(1-\frac{\delta\ \alpha_{\mathrm{W}}}{\mathrm{a}\ +1}\right)$
(4)	Multiple equilibria	$-\frac{1}{\beta}\left(1-\frac{\delta\ \alpha_{\mathrm{W}}}{\mathrm{a}\ +1}\right) > \alpha_{\mathrm{E}}\delta - \alpha_{\mathrm{E}}{}^{*}\delta^{*} > \frac{1}{\beta}\left(1-\frac{\delta^{*}\alpha_{\mathrm{W}}{}^{*}}{\mathrm{a}^{*}+1}\right)$

δ is a measure of the political distortion in the home country. It is defined as: $\delta := \frac{a+1}{a+1-\alpha_W} > 1$. The definition of δ^* is analogous.

For the inner solution in the benevolent dictator case, countries need to be not too dissimilar in the sense that the disutility from pollution must not differ by more than $\frac{1}{\beta}$ in absolute terms, i.e. $|\alpha_E - \alpha_E{}^*| < \frac{1}{\beta}$, as shown in Eq. (19). For the political game a comparable

condition exists that bounds a weighted difference in the α_Es from above and below for a stable interior equilibrium; yet this difference now takes the political distortions into account and thus the lower and upper limits are different. Comparing the two sets of conditions in the above table and in Eq. (19) shows that it is impossible to determine in general whether the area with interior solutions is larger in the benevolent dictator case or in the political game.

Comparing $\tilde{T}^{PG}$ in Eq. (35) with $\tilde{T}^{BD}$ in Eq. (18) demonstrates that the politically optimal tax rate can be smaller or larger than the tax rate that a benevolent dictator would set for the same economy; the relative magnitudes depend on the structure of the political, economic and ecological system. We illustrate this with the following three examples displayed in Table 1. Columns 2-4 give the values for the political economic equilibrium and for the benevolent dictators' equilibrium (in parentheses) for three different sets of parameter values. All equilibria are interior and stable and represent maxima of the governments' conditional objective functions (i.e., Assumption 1 is fulfilled and the domestic reaction curve is flatter than the inverse of the foreign reaction curve).[30]

Table 1: Simulated equilibria in the benevolent dictator and the political game

	Case (1)	Case (2)	Case (3)
Parameter values	$\alpha_E = \alpha_E^* = 0.1, \alpha_I = \alpha_I^* = 0.1$, $p = 1$, $l = l^* = 1$		
	$a = a^* = 1$ $\beta = 1$	$a = 10, a^* = 1$ $\beta = 1$	$a = a^* = 1$ $\beta = 10$
Variables			
Home tax rate PG (BD)	-0.5 (0.17)	0.21 (0.17)	0.73 (0.67)
Foreign tax rate PG (BD)	-0.5 (0.17)	-0.74 (0.17)	0.73 (0.67)
Home production level PG (BD)	0.75 (0.42)	0.39 (0.42)	0.14 (0.17)
Foreign production level PG (BD)	0.75 (0.42)	0.87 (0.42)	0.14 (0.17)
Total Pollution PG (BD)	2.25 (0.69)	1.59 (0.69)	0.74 (1.11)
Home Welfare PG (BD)	0.96 (1.17)	1.08 (1.17)	1.04 (1.03)
Foreign Welfare PG (BD)	0.96 (1.17)	0.95 (1.17)	1.04 (1.03)

[30] It is straightforward to construct examples in which the political game results in corner solutions and the benevolent dictator game does not and vice versa. Results are available upon request.

Overall Welfare PG (BD)	1.92 (2.34)	2.03 (2.34)	2.08 (2.06)

Note: PG denotes values for the political game; BD denotes values for the benevolent dictator game. They are given in parentheses.

In case 1, both countries are symmetric; the welfare maximizing governments would levy a 17 percent tax on the value of the output of their polluting firms. Under the same parameter values, the political-support maximizing governments, however, would subsidize production at a rate of 50 percent, with the consequence that production and pollution is significantly higher. In this case, the political-economic calculus leads to a sizeable deterioration in welfare and a strong increase in environmental degradation as the governments cater to the industrialist lobby group.

In case 2, both countries have the same parameter values as in case 1 with the exception that the domestic government places a much larger weight on welfare considerations in its political-economic calculus (i.e. the parameter a is higher). The benevolent dictators' equilibrium is thus the same as in case 1, but the political equilibrium is qualitatively different: The domestic government now levies a tax rate, which is even higher than in the benevolent dictator case while the foreign country subsidizes production, yet more strongly than in case 1. The comparison between the two political economic equilibria in case 1 and 2 shows the interdependence of the political support maximizing governments' behaviors: As the domestic government is taxing the production of the polluting good thereby reducing the negative externality, the foreign government can increase its subsidy further thereby enhancing its political support. It is free-riding on the domestic government. Conversely, the domestic government anticipates such behavior and therefore taxes production more heavily than if the foreign government would tax its production as well. The welfare in the political equilibrium in case 2 is higher than in case 1, but it is lower than in the benevolent dictator case.

Case 3 is again completely symmetrical and has the same parameter values as case 1 except for the damage parameter β, which is now much higher. As a result, the benevolent dictators now tax production more heavily than in case 1 and the resulting welfare level is lower. This is intuitive. More striking, however, is the comparison between the political game and benevolent dictators' game. The political support maximizing governments tax production of the polluting good *more* heavily than a benevolent dictator would! As a result environmental degradation is lower and the welfare is higher in the political game. The reason for this result is that the distortion created by the political-economic calculus — "too" high

tax rates — now counteracts the distortion created by the strategic interaction of two benevolent dictators, who set tax rates on transboundary pollution too low.

We summarize these findings in the following corollary.

Corollary 1:

(i) *The tax rates of the benevolent dictator can be either higher or lower than the tax rates set by political support maximizing governments.*

(ii) *The political game may result in higher or in lower welfare than the strategic interaction of non-cooperative benevolent dictators.*

(iii) *The welfare is lower if both tax rates are lower than in the benevolent dictator case. It may be higher if both tax rates exceed the benevolent dictators' tax rates.*

The intuition behind this result is that there are different forces that shift the equilibrium from the benevolent dictator solution to the political game solution. The direction of the political distortion depends on the relative strengths of the interest groups (and the value of a). For instance, if α_E and β are high, an increase in the tax rate reduces production and thus profits, but translates into a large reduction in disutility from pollution. Thus, the environmentalists will be lobbying more strongly for an increase in the tax rate than if the damage coefficient and the size of the environmentalists were lower. The resulting political-economic equilibrium will imply a higher tax rate.[31] The political-economic equilibrium is affected in addition by the redistribution of the tax revenue: While in the benevolent dictator case it is a mere redistribution of income between members of the society that does not affect overall welfare, this redistribution affects the political equilibrium as not all groups of the society will reward additional income from tax proceeds as they are not organized (the workers). The lower a, the stronger the political distortion; for $a \longrightarrow \infty$ the political game solution converges to the benevolent dictator solution.

If the politically optimal tax rates are higher than the benevolent dictators' tax rates, they may reduce a distortion that is created by the strategic interaction of the two welfare-maximizing governments. Non-cooperative governments internalize the externality of transboundary pollution only to the extent that pollution affects domestic welfare. As a result, tax rates are too low compared with joint welfare maximization (Markusen 1975).[32] If tax rates are lower than the in benevolent dictator case, the political distortion reinforces the distortion created by strategic interaction and welfare is even lower.

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[31] Note that both profits and disutility from pollution are convex in the tax rate, however with different signs and magnitudes.

[32] Of course tax rates could be so high that the distortion from strategic interaction is strongly overcompensated, resulting in a lower welfare level than in the benevolent dictator case.

The fact that a political support maximizing government *may* pursue a welfare superior policy compared to a government that seeks to maximize welfare is thus contingent on a situation of international strategic interaction. It cannot arise in the analysis of a small open economy (e.g. Fredriksson 1997), where the political-economic calculus of the government unambiguously reduces overall welfare. Yet it may be relevant for a number of situations in which environmental damage is high and environmental policies affect the environmental quality of neighboring states.

5. Concluding Remarks

In this paper, we have analyzed endogenous environmental policy formation of two countries that are small on the world markets, but are linked through transboundary pollution. Three major results emerge. First, the environmental policy adopted by self-interested governments may or may not be more stringent than by social welfare maximizing, but uncooperative governments. Thus the distortion created by the transboundary pollution may be exacerbated or may be alleviated by the distortion created through the political system. Under certain circumstances, a political process that does not take all individuals into consideration equally, may work in favor of the society at large. Second, the space of optimal policies in the political-economic game is larger than in the game played by benevolent dictators: While uncooperative benevolent governments will always set positive but inefficiently low tax rates (from the perspective of joint welfare maximization), the politically optimal tax rates may be too high to optimally internalize the transboundary externality, but they may also be too low. Political support maximizing governments may indeed subsidize the production of the polluting good rather than taxing it. In equilibrium, it is possible that one government subsidizes the production of the polluting good while the other taxes it. Third, the political distortion might create instability: While the resulting equilibria in the case of social welfare maximizing governments are always unique and stable, the possibility of multiple equilibria in the political game with one equilibrium being unstable cannot be excluded. This increases the probability of corner solutions with one country ceding production to the other.

We believe that the strategic interaction in environmental policy formation of self-interested governments in the presence of transboundary, but non-global pollution has so far not been sufficiently examined. Our theoretical analysis is aimed at improving our understanding of this issue, the scope of which can be broadened in many ways. First, it would be interesting to study what the incentives for political support maximizing governments are to cooperate and what the welfare effects would be. It is obvious that

international cooperation would eliminate the distortion created by strategic interaction (Markussen 1975), but could also lead to a welfare deterioration if the political distortion has an offsetting effect. Second, interest groups could be assumed to lobby across the border. While industrialist lobby groups in both countries have opposing interests with respect to the national regulations; they favor higher regulation abroad and lower at home, environmentalist groups' interests in both countries are aligned. Third, extending the model to a multi-country setup with incomplete spill-overs would provide many important insights on real world applications of regional pollution.

Our model shows how distortions created by the strategic interaction of national governments interact with distortions created by the political processes in both countries. We show that these two sets of distortions could either reinforce or counteract each other. Which scenario is more realistic, however, remains an empirical question. It could be the subject of a fruitful empirical analysis.

Appendices

Appendix 1: Uniqueness and stability of the equilibria in the benevolent dictator case

In this appendix we demonstrate the existence and uniqueness of the welfare maximizing non-cooperative equilibrium of Section 3.

First, we note that both reaction curves $\tilde{t}^{BD}$ and $\tilde{t}^{BD*}$ are linear in the opponent's tax rate (cf. Eq. (16)). In the (t*, t) space, the slope of the 'interior' domestic reaction curve $\tilde{t}^{BD}$, is

$$\frac{\partial\,\tilde{\mathrm{t}}^{\mathrm{BD}}}{\partial \mathrm{t}^{*}} = -\frac{\alpha_{\mathrm{E}}\beta}{1+\alpha_{\mathrm{E}}\beta} > -1,$$

while the slope of the inverse of the 'interior' foreign reaction curve, $\tilde{\mathrm{t}}^{\mathrm{BD}*-1}$, is

$$\frac{\partial\tilde{\mathrm{t}}^{\mathrm{BD}*-1}}{\partial \mathrm{t}^{*}} = -\frac{1+\alpha_{\mathrm{E}}{}^{*}\beta}{\alpha_{\mathrm{E}}{}^{*}\beta} < -1.$$

For $\mathrm{t}^{*} > p$ and for $t^{*} < t_{lb}^{*}$, the domestic reaction function is flat, while the inverse of the foreign reaction function is vertical for $t > p$ and for $t < t_{lb}^{BD}$. That is, the inverse of the foreign reaction curve is always steeper than the domestic reaction curve and thus the reaction curves t^{BD} and $\mathrm{t}^{\mathrm{BD}*}$ intersect exactly once. The resulting equilibrium is thus unique and stable. ■

Appendix 2: Properties of the reaction curve in the political game

We first derive that the reaction function in the political game is downward sloping. This is shown by differentiating Eq. (27) w.r.t. the foreign tax rate.

$$\frac{\partial\tilde{\mathrm{t}}^{\mathrm{PG}}}{\partial \mathrm{t}^{*}} = -\frac{\alpha_{\mathrm{E}}\beta(\mathrm{a}+1)}{(\mathrm{a}+1)(\alpha_{\mathrm{E}}\beta{+}1) - 2\alpha_{\mathrm{W}}} < 0$$

An analogous expression can be derived for the inverse of the foreign reaction function.

Next we analyze the comparative static properties of the domestic reaction function with respect to α_E, α_I, β and a. We calculate the change of t_{lb}^{PG*} and t_{low}^{PG} in response to a change in the relevant parameters using Eqs. (29) and (30).

$$\frac{\partial \mathrm{t}_{\mathrm{lb}}^{\mathrm{PG}*}}{\partial\alpha_{\mathrm{E}}} = \frac{\mathrm{p}(\alpha_{\mathrm{E}}+\mathrm{a})}{\alpha_{\mathrm{E}}{}^{2}\beta(\mathrm{a}+1)} > 0$$

$$\frac{\partial \mathrm{t}_{\mathrm{low}}^{\mathrm{PG}}}{\partial\alpha_{\mathrm{E}}} = \frac{\mathrm{p}(\mathrm{a}+1)(\alpha_{\mathrm{I}}\beta{+}\mathrm{a}\beta{+}1)}{\left((\mathrm{a}+1)(\alpha_{\mathrm{E}}\beta{+}1) - 2\alpha_{\mathrm{W}}\right)^{2}} > 0$$

$$\frac{\partial\tilde{\mathrm{t}}^{\mathrm{PG}}}{\partial\alpha_{\mathrm{E}}} = \frac{\mathrm{a}(\mathrm{p}+1) + (\mathrm{a}+1)\beta[\alpha_{\mathrm{I}}(3\mathrm{p}-2\mathrm{t}^{*}) + \mathrm{p}] + \beta(\mathrm{a}^{2}+1)(2\mathrm{p}-\mathrm{t}^{*})}{\left((\mathrm{a}+1)(\alpha_{\mathrm{E}}\beta{+}1) - 2\alpha_{\mathrm{W}}\right)^{2}} > 0$$

An increase in α_{E} shifts the domestic reaction function to the Northeast; at the same time the range of foreign tax rates increases, for which the domestic government sets prohibitive tax rates as best response. The tax rate for zero foreign production increases as well. The slope of the reaction function can either increase or decrease:

$$\frac{\partial^{2}\tilde{\mathrm{t}}^{\mathrm{PG}}}{\partial \mathrm{t}^{*}\,\partial\alpha_{\mathrm{E}}} = -\frac{\beta(\mathrm{a}+1)(\mathrm{a}+2\alpha_{\mathrm{I}}-1)}{\left((\mathrm{a}+1)(\alpha_{\mathrm{E}}\beta{+}1) - 2\alpha_{\mathrm{W}}\right)^{2}} \lesseqgtr 0$$

If α_I increases, the range of foreign tax rates for which the home country sets prohibitive taxes decreases and the reaction curve becomes flatter. t_{low}^{PG} decreases for $\alpha_E\beta > 1$ and increases otherwise.

$$\frac{\partial t_{lb}^{PG*}}{\partial \alpha_I} = -\frac{p}{\alpha_E\beta(a+1)} < 0$$

$$\frac{\partial t_{low}^{PG}}{\partial \alpha_I} = -\frac{p(a+1)(\alpha_E\beta-1)}{\left((a+1)(\alpha_E\beta+1)-2\alpha_W\right)^2} \lesseqgtr 0$$

$$\frac{\partial^2 \tilde{t}^{PG}}{\partial t^* \, \partial \alpha_I} = \frac{2\alpha_E\beta(a+1)}{\left((a+1)(\alpha_E\beta+1)-2\alpha_W\right)^2} > 0$$

The reaction curve shifts similarly in response to an increase in *a*:

$$\frac{\partial t_{lb}^{PG*}}{\partial a} = -\frac{p\alpha_W}{\alpha_E\beta(a+1)^2} < 0$$

$$\frac{\partial t_{low}^{PG}}{\partial a} = \frac{p\alpha_W(1-\alpha_E\beta)}{\left((a+1)(\alpha_E\beta+1)-2\alpha_W\right)^2} \lesseqgtr 0$$

$$\frac{\partial^2 \tilde{t}^{PG}}{\partial t^* \, \partial a} = \frac{2\alpha_E\beta\alpha_W}{\left((a+1)(\alpha_E\beta+1)-2\alpha_W\right)^2} > 0$$

$$\frac{\partial \tilde{t}^{PG}}{\partial a} = \frac{\alpha_W[p-\alpha_E\beta(3p-2t^*)]}{\left((a+1)(\alpha_E\beta+1)-2\alpha_W\right)^2} \lesseqgtr 0$$

In other words, if *a* increases the new reaction curve is flatter than the old reaction curve and it may lie completely below the old one or may intersect with it.

An increase in β shifts the domestic reaction curve to the Northeast, which is qualitatively the same reaction to an increase in α_E. However, if β rises, the foreign reaction curve shifts as well making the effect of the equilibrium qualitatively different.

$$\frac{\partial t_{lb}^{PG*}}{\partial \beta} = \frac{p(a+1-\alpha_W)}{\alpha_E\beta^2(a+1)} > 0$$

$$\frac{\partial t_{low}^{PG}}{\partial \beta} = \frac{p\alpha_E(a+1)(a+1-\alpha_W)}{\left((a+1)(\alpha_E\beta+1)-2\alpha_W\right)^2} > 0$$

$$\frac{\partial^2 \tilde{t}^{PG}}{\partial t^* \, \partial \beta} = -\frac{\alpha_E(a+1)(a+1-2\alpha_W)}{\left((a+1)(\alpha_E\beta+1)-2\alpha_W\right)^2} \lesseqgtr 0$$

$$\frac{\partial t_{lb}^{PG}}{\partial \beta} = \frac{p(a^*+1-\alpha_W{}^*)}{\alpha_E{}^*\beta^2(a^*+1)} > 0$$

$$\frac{\partial t_{low}^{PG*}}{\partial \beta} = \frac{p\alpha_E{}^*(a^*+1)(a^*+1-\alpha_W{}^*)}{\left((a^*+1)(\alpha_E{}^*\beta+1)-2\alpha_W{}^*\right)^2} > 0$$

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