Domestic politics and the formation of international environmental agreements

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Abstract

We investigate the effect of domestic politics on international environmental policy by incorporating into a classic stage game of coalition formation the phenomenon of lobbying by special-interest groups. In doing so, we contribute to the theory of international environmental agreements, which has overwhelmingly assumed that governments make decisions based on a single set of public-interest motivations. Our results suggest that lobbying on emissions may affect the size of the stable coalition in counterintuitive ways. In particular, a powerful business lobby may increase the government's incentives to sign an agreement, by providing it with strong bargaining power with respect to that lobby at the emission stage. This would result in lower total emissions when the number of countries involved is not too large. We also show that things change radically when lobbying bears directly on the membership decisions, suggesting that both the object and timing of lobbying matter for the way in which membership decisions, emissions and welfare are affected.

Keywords: game theory, international environmental agreements, lobbying, special- interest groups, strategic cooperation

JEL codes: C7, H41, K33, Q2, Q54

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1   Introduction

Drawing from the literature on cartel formation, the economic theory of international environmental agreements (IEAs) typically models the formation of an agreement to protect the global environment as a two-stage game. In the first stage, countries simultaneously decide upon their membership; in the second stage they choose their emissions based on their payoff functions, which comprise benefits from individual emissions and damage costs from global emissions. In its simplicity, this framework has provided us with important insights about the nature of the problem, the strong free-rider incentives involved, and the challenges of securing cooperation that is at the same time broad and deep (Barrett, 1994; Carraro and Siniscalco, 1993; Chander and Tulkens, 1992; Hoel, 1992; Maeler, 1989).

Over the years, the approach set out in the pioneering works cited above has been extended along several dimensions to account for a wide range of relevant issues. These include, to name but a few, commitment of signatories (Botteon and Carraro, 1997; Petrakis and Xepapadeas, 1996); reputation effects (Jeppesen and Andersen, 1998; Hoel and Schneider, 1997); concerns for fairness (Lange and Vogt, 2003); linkage strategies (Barrett, 1997; Carraro and Siniscalco, 1997); minimum participation constraints (Weikard, Wangler, and Freytag, 2015; Carraro, Marchiori, and Oreffice, 2009); asymmetries and transfers (Fuentes-Albero and Rubio 2005; Barrett 2003); and the possibility that countries agree on modest instead of ambitious abatement targets (Finus and Maus 2008).

Surprisingly, one critical dimension of the problem that has remained largely unexplored and is yet to be systematically analysed is the role that (domestic) politics play in shaping international environmental policy; in particular, how special-interest groups affect countries' decisions to cooperate for the protection of the global environment. With the exception of Habla and Winkler (2013), who have recently provided an interesting analysis of the influence of lobbying on emissions trading, virtually all works in the IEA literature assume that nation-states are monolithic entities making choices based on a single set of public interest motivations. Yet, both the empirical evidence and the contemporary literature on political economy suggest that public officials are not solely motivated by the public interest, rather they are also motivated by their own private interests; this, in turn, makes them vulnerable to the influence of national political competition (e.g. Besley, 2006; Grossman and Helpman, 2001; Persson and Tabellini, 2000).

The importance of lobby groups in making environmental policies has also been emphasized by economists such as Oates and Portney (2003) and by scholars in environmental politics (e.g. Bryner, 2008, and Kamieniecki, 2006, on the US; Markussen and Svendsen, 2005, and Michaelowa, 1998, on Europe). Often policymaking is characterised as a battle between business lobby groups, on the one hand, and environmental lobby groups, on the other. Business lobby groups generally seek to

limit the scope of costly environmental measures, while environmental lobby groups do the opposite. Importantly, this body of work has shown that neither the business lobby nor environmental groups can be said to have won the battle in general (Fouquet, 2012; Kraft and Kamieniecki, 2007).

In this paper, we therefore seek to enrich the theory of IEA formation by relaxing the overwhelming assumption that governments are immune to the influence of national political competition. Specifically, we consider the possibility that incumbent politicians not only maximize national social welfare, but are also susceptible to the influence of lobby groups, which try to sway policies in their favour by offering financial resources to elected officials.[1] In particular, we assume that there are two lobby groups operating in each country. Lobby 1 has a stake in the benefits from emissions and can be thought of as representative of the interests of producers and/or consumers; indeed, the benefits from emissions come from activities directed towards the production of some final good and generating emissions as by-product. Lobby 2 is assumed to have a stake in the damages caused by emissions and represents the interests of environmental groups.

Our primary aim is to investigate how domestic pressure by special-interest groups influences governments' incentives to sign an IEA, and what the effects of lobbying are on the breadth and depth of cooperation. To this end, we extend the classic IEA stage model by introducing a lobbying game in each country. The resulting structure is as follows. First, governments in all countries play a *membership stage*, in which they simultaneously choose whether to be signatories to a stylised agreement for the protection of the global environment. After the membership stage, an emission stage is played. In the present paper, as opposed to the classic model, the emission stage is itself divided in three substages: *(i)* first, domestic lobby groups independently and simultaneously present their own government with contribution schedules, to which they fully commit; *(ii)* faced with these contribution schedules, governments (both signatories and non-signatories) simultaneously decide on their emission levels; *(iii)* lobby groups in each country pay contributions contingent on policy choices.

We study the "truth-telling subgame perfect equilibria" of this game (see Grossman and Helpman, 1994). As previously mentioned, we are interested in the effect of lobbying on the size of the stable IEA and on the resulting level of aggregate emissions. Our analysis focuses, in particular, on the effect of three parameters, expressing respectively the degree of organization (or representativeness) of the two lobbies, and the government's "taste for money", which measures the weight that lobbies' contributions have in the government's objective function. Our first result in Proposition 1 shows that the effect of a higher taste for money is that of enlarging the size of the IEA when the stake in the benefits from emissions outweighs the stake in the damages caused by

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[1]As explained in Grossman and Helpman (2001), the offering of resources on the part of lobby groups is not to be equated with corruption. Rather, the idea is that contributions are made to boost the electoral prospects of politicians whose proposed policies best reflect the preferences of the lobby group.

emissions. Put differently, a powerful business lobby and/or a weak environmental lobby provide a government characterised by a high taste for money with stronger incentives to sign an IEA. Key to this apparently counterintuitive result is the effect that the decision to join the agreement has on the expected contributions at the emission stage. Specifically, the emission reduction implied by the decision to become a member of the IEA has the effect of worsening the reservation utility of the business lobby. This would, in turn, increase the lobby's willingness to pay to affect the government's decision at the emission stage (the more, the larger the stake in the benefits). In contrast, joining an IEA has the effect of increasing the environmental lobby's reservation utility, thereby lowering its equilibrium contributions (the more, the larger the stake in the damages). As a result, a government that is very sensitive to campaign contributions would have strong incentives to sign an IEA when the business lobby has large stakes and/or the environmental lobby has small stakes. Similar arguments lead to the other two results in Proposition 1 about the effect of the lobbies' respective stakes on the equilibrium size of the IEA. In particular, we show that increasing the stake in the benefits from emissions never reduces the size of the IEA, and leads to the grand coalition when this stake is sufficiently high. Also, increasing the stakes in the damages caused by emissions never increases the size of the IEA.

In Proposition 2 we look at the effect of political pressure on total emissions. Here, the relative stakes of the lobbies affect total emissions in two ways: by affecting the size of the IEA and by changing the preferences of the government at the emission stage. Specifically, when the business lobby is relatively strong, increasing governments' taste for money results in lower emissions by coalition members, due to the larger size of the IEA, and in higher emissions by non-members, whose governments are conditioned by strong pro-emissions political pressures. When the total number of countries is large, this second effect prevails, and total emissions increase as a result. The opposite holds when the total number of countries is small. By similar arguments, a relatively weak business lobby leads to lower emissions when the total number of countries is large, since the effect of a smaller IEA is outweighed by the reduction of emissions by non-members.

We complement the analysis by comparing this framework and results with the case in which lobbying bears directly on the membership decision. More precisely, lobby groups announce their contribution schedules before the membership decision is taken, and make these schedules a function of the regime chosen by the government. This framework differs from the previous one in one crucial aspect: the government lacks the power to commit to a cooperation regime *before* contributions are announced. Lacking commitment power with respect to the lobbies, governments can no longer use their membership decision to extract resources from domestic lobbies, and the mechanism behind the results of Propositions 1 and 2 is lost. In this case, we find that increasing the stake in the damages caused by emissions results in both a larger IEA and lower total emissions. By the same logic, an increase in the government's taste for money results in a larger IEA and lower emissions when the stake in the benefits is low compared to the stake in the damages. One important insight

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is therefore that both the object and the timing of lobbying matter for the way in which membership decisions, emissions and welfare are affected. A joint analysis of the two types of lobbying seems like an interesting avenue to pursue, and is left for future research.

The paper is organized as follows. We begin in Section 2 by presenting the key elements and stages of the IEA formation game with lobbying on emissions. In Section 3, we solve the model and discuss its main insights. In particular, we start by solving for the non-cooperative equilibrium of the game in Section 3.1 and proceed to analyse the partial agreement Nash equilibrium and the equilibrium of the membership stage in Sections 3.2 and 3.3, respectively. In Section 4, we compare this framework and results with the case in which interest groups lobby directly on the membership stage, and discuss important differences in terms of underlying forces and equilibrium implications between these alternative types of lobbying. Some concluding remarks are provided in Section 5.

2   The model

2.1   Economic and political setting

Consider a set I consisting of n symmetric countries, with $n \geq 2$. Each country i engages in some productive activities that generate emissions e_i as a by-product. The benefits associated with emission level e_i are denoted by $B(e_i)$. We assume that $B(e_i)$ is twice differentiable with $B'(e_i) > 0$ and $B''(e_i) < 0$ for all e_i. Global emissions $E = \sum_{i=1}^{n} e_i$ cause strictly increasing and convex damages $D(E)$ to each country, with $D'(E) > 0$ and $D''(E) \geq 0$. Social welfare in country i is given by

$$W_i(e_i, E) = B(e_i) - D(E) \quad \forall i \in I. \tag{1}$$

In deciding on their environmental policy, governments in each country may be subject to the influence of domestic special-interest groups, who are strongly affected by environmental policy and therefore have an interest to offer contributions so as to sway policy choices in their favour. We assume that there are two lobby groups $l = 1, 2$ in each country. Lobby group 1 exhibits a stake $0 \leq \beta \leq 1$ in the benefits from emissions; while lobby group 2 exhibits a stake $0 \leq \delta \leq 1$ in the damages caused by emissions. The gross utilities of the lobby groups operating in country i are as follows:

$$W_{i1}(e_i) = \beta B(e_i), \tag{2a}$$

$$W_{i2}(E) = -\delta D(E). \tag{2b}$$

Consistent with Grossman and Helpman (1994), we interpret a lobby's utility as the aggregate utility of its individual members. In this sense, the weights β and δ express the degree to which

the corresponding lobby represents the stakes of those who benefit and suffer from emissions, respectively. In particular, a higher value of the weight indicates a higher degree of representation and organization of the specific interest group.

Lobby groups in each country present their own government with prospective countributions in order to affect emission policy decisions. The utility of lobby group l in country i is given by W_{il} minus lobbying contribution C_{il}. Specifically

$$U_{i1}(e_i, e_{-i}) = W_{i1}(e_i) - C_{i1}(e_i, e_{-i}), \tag{3a}$$

$$U_{i2}(e_i, e_{-i}) = W_{i2}(E) - C_{i2}(e_i, e_{-i}), \tag{3b}$$

where e_{-i} denotes the vector of emissions of all countries except i. In the above expressions, the contribution function $C_{il}(e_i, e_{-i})$ specifies the proposed contribution of lobby group l in country i, contingent on the domestic policy choice e_i. Note that we are allowing for the possibility that such contribution schedules also depend on the level of foreign emissions e_{-i}. As we shall see, the class of equilibrium contributions on which we focus in this paper display this property in the case of lobby $l = 2$ (environmental lobby). The exact form of the equilibrium contribution schedules will be derived in Section 3.

Each country is represented by a government, which cares about both social welfare and lobbying contributions. Specifically, we define government i's political utility as

$$G_i(e_i, e_{-i}) = (1 - \gamma)W_i(e_i, E) + \gamma[C_{i1}(e_i, e_{-i}) + C_{i2}(e_i, e_{-i})], \tag{4}$$

where $\gamma \in (0, 1)$ measures the government's weighting of a dollar of campaign contributions compared to a dollar of social welfare.

2.2 Structure of the game

Non-cooperative coalition theory typically models the formation of an IEA as a two-stage game, where countries decide upon their membership in the first stage, and choose their emission levels in the second stage. We extend the classic IEA model by introducing a lobbying game in each country, which gives rise to several consecutive sub-stages at the emission policy decision-stage. The resulting structure is as follows:

I. *Membership stage:* Governments in all countries simultaneously choose whether to be signatories to a stylised agreement for the protection of the global environment.

II. *Emission policy stage:*

    (a) Domestic lobby groups independently and simultaneously present their own government with contribution schedules, to which they fully commit.

(b) Faced with these contribution schedules, governments (both signatories and non-signatories) simultaneously decide on their emission levels.

(c) Lobby groups pay contributions contingent on policy choices.

The game is solved using backward induction. The second stage of the game is parametrised by an integer $k > 0$ denoting the number of signatories.[2] We begin in section 3.1 by considering the case of $k = 1$; that is, the emission policy stage in the absense of cooperation. This is the extension to political decision-making of the standard non-cooperative emission game.

3 Solving the model

3.1 The non-cooperative equilibrium with lobbying

In our model setup, the emission policy sub-game for $k = 1$ (which we will refer to as the *non-cooperative emission game with lobbying*) is as follows: first, all lobby groups in all countries independently and simultaneously offer contribution schedules $C_{il}(e_i, e_{-i})$ to their governments, which specify the lobby contributions contingent on the domestic and (possibly) foreign emission policy choices e_i and e_{-i}; then, taking as given the contribution schedules offered by each lobby group in each country, governments independently and simultaneously set their emission policies; finally, lobby groups in all countries pay contributions to their governments according to the choice of emission levels.

An equilibrium of this game is a set of contribution schedules, one for each lobby group in each country, such that each one maximises the utility of the lobby's members, taking as given the schedules of the other lobby groups. In calculating their optimal schedules, the lobbies recognize that governments will set policy to maximize their own welfare, given the emission policy choices of the other countries. The Nash-equilibrium contribution schedules implement an equilibrium emission policy vector (Grossman and Helpman, 1994).

To determine the equilibrium outcome, we apply concepts and results from Bernheim and Whinston (1986). Specifically, we start by introducing the concept of a *truthful contribution schedule*. Bernheim and Whinston (1986) define a truthful contribution schedule as a contribution schedule that offers, for any change of the government's policy, the corresponding change in the respective lobby's gross utility relative to some base level of utility, except when the contribution would be negative. In this case, a zero contribution is offered instead. Formally, a truthful contribution

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[2]Given symmetry, this integer fully characterises the outcome of the participation stage.

function for lobby group $l = 1, 2$ in country i takes the form

$$C_{i1}(e_i) = \max[0, \ W_{i1}(e_i) - \overline{W}_{i1}], \tag{5a}$$

$$C_{i2}(e_i, e_{-i}) = \max[0, \ W_{i2}(E) - \overline{W}_{i2}], \tag{5b}$$

for some base levels of utility $\overline{W}_{i1}$ and $\overline{W}_{i2}$.[3] Notice that truthful contribution schedules are differentiable (except possibly where the contribution becomes nil) because the gross utility functions are differentiable. In particular, for the case of strictly positive contribution schedules, marginal contributions do not depend on $\overline{W}_{il}$, and are given by $\partial C_{i1}(e_i)/\partial e_i = \partial W_{i1}(e_i)/\partial e_i = \beta B'(e_i)$ and $\partial C_{i2}(e_i, e_{-i})/\partial e_i = \partial W_{i2}(E)/\partial e_i = -\delta D'(E)$.

Bernheim and Whinston (1986) have shown that lobby groups bear essentially no cost from playing truthful strategies because each lobby group's set of best-responses to any contribution schedules of all other lobby groups includes a truthful strategy; moreover, all equilibria supported by truthful contribution schedules − and only those equilibria − are robust to coalitional renegotiation (i.e., "coalition-proof"). For these reasons, they argue that equilibria supported by truthful contribution functions may be focal among the set of Nash equilibria. In the remainder of the paper, we will restrict our attention to truthful (and strictly positive) contribution schedules.

In the non-cooperative emission game with lobbying, the government of country i chooses the level of emissions e_i that solves the following problem

$$\max_{e_i} G_i(e_i, e_{-i}) = (1 - \gamma)W_i(e_i, E) + \gamma[C_{i1}(e_i) + C_{i2}(e_i, e_{-i})], \tag{6}$$

subject to Eqs. (5a) and (5b), and given the emissions choices e_{-i} of all other countries.

Assuming truthful and strictly positive contribution schedules of all lobby groups in all countries, the first-order condition of government i's maximization problem is given by

$$FOC_i : (1 - \gamma + \gamma\beta)B'(e_i) - (1 - \gamma + \gamma\delta)D'(E) = 0. \tag{7}$$

Notice that, $G_i''(e_i, e_{-i}) = (1 - \gamma + \gamma\beta)B''(e_i) - (1 - \gamma + \gamma\delta)D''(E) < 0$, given the assumptions $B''(e_i) < 0$ and $D''(E) \geq 0$. This guarantees that the problem defined in Eq. (6) is strictly concave. Furthermore, it can be shown that, for truthful and strictly positive contribution functions, there exists a unique Nash equilibrium $(e_1^0(\gamma), ..., e_n^0(\gamma))$ of the non-cooperative emission game, in which all countries set emission levels e_i to solve Eq. (7), given the emission policy choices e_{-i} of all other countries.[4]

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[3]We will return to and further specify the baseline utilities $\overline{W}_{i1}$ and $\overline{W}_{i2}$ at the end of section 3.2.

[4]Solving Eq. (7) for e_i we obtain

$$e_i = B'^{-1}\left[\frac{1 - \gamma + \gamma\delta}{1 - \gamma + \gamma\beta}D'(E)\right], \forall i.$$

Given symmetry, at the unique Nash equilibrium $e_i^0(\gamma) = e^0(\gamma)$, $\forall i = 1, ..., n$, and $E^0(\gamma) = ne^0(\gamma)$. Totally differentiating condition (7) we obtain

$$\frac{de^0(\gamma)}{d\gamma} = \frac{(1-\beta)B'\left(e^0\right) - (1-\delta)D'\left(E^0\right)}{(1-\gamma+\gamma\beta)B''\left(e^0\right) - n(1-\gamma+\gamma\delta)D''\left(E^0\right)}. \tag{8}$$

By virtue of our assumptions about the benefit and damage functions, and the parameter space, the denominator of Eq. (8) is strictly negative. To determine the sign of $\frac{de^0(\gamma)}{d\gamma}$, we solve the first-order condition, Eq. (7), for $B'(\cdot)$ to obtain

$$B'\left(e^0\right) = \left(\frac{1-\gamma+\gamma\delta}{1-\gamma+\gamma\beta}\right)D'(E^0); \tag{9}$$

substituting this into the numerator of Eq. (8), and after a few algebraic steps, we obtain

$$\frac{de^0(\gamma)}{d\gamma} = \frac{-(\beta-\delta)D'\left(E^0\right)/(1-\gamma+\gamma\beta)}{(1-\gamma+\gamma\beta)B''\left(e^0\right) - (1-\gamma+\gamma\delta)D''\left(E^0\right)}. \tag{10}$$

From Eq. (10), we can conclude that the effect of a change in governments' taste for money, for a given set of lobby weights $\{\beta, \delta\}$, is

$$\frac{de^0(\gamma)}{d\gamma} \gtreqless 0 \iff \beta \gtreqless \delta. \tag{11}$$

That is, starting from a given $\gamma > 0$, any increase in governments' taste for money yields an increase in the equilibrium level of emissions, as long as the degree of representation/organization of the lobby representing the stakes of those who benefit from emissions (as measured by β) is higher than the degree of representation/organization of the lobby representing the stakes of those who suffer from emissions (as measured by δ). This also implies that the non-cooperative emission game with lobbying results in a more (less) stringent emission policy — i.e., in lower (higher) levels of emissions — than the standard 'a-political' game, if and only if β is smaller (larger) than δ.[5]

Summing up over all $i = 1, ..., n$ yields

$$E = \sum_{i=1}^{n} B'^{-1}\left[\frac{1-\gamma+\gamma\delta}{1-\gamma+\gamma\beta}D'(E)\right].$$

The left-hand side of the above equation is strictly increasing in E. Turning to the right-hand side, we notice that, since the marginal benefit function B' is strictly and monotonically decreasing, the inverse function B'^{-1} exists and is also strictly and monotonically decreasing (for all i). This, combined with the assumption that the damage function D is convex, implies that the right-hand side of the above equation is strictly decreasing in E. Hence, there exists a unique level of aggregate emissions E in the Nash equilibrium. Substituting this unique level of E back into governments' first-order conditions (FOC_i, $\forall i$) yields the unique Nash equilibrium $(e_1^0, ..., e_n^0)$.

[5]The only case in which lobbying has no effect is when $\beta = \delta$, that is when both lobbies display the same degree of representation/organization.

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This conclusion is consistent with intuition and in line with Habla and Winkler (2013)'s predictions about a domestic permit market under lobby group pressure.

3.2 The partial agreement Nash equilibrium

In this section, we seek the partial agreement Nash equilibrium of the game; that is, the equilibrium of the emission policy sub-game for a history with $k > 1$. The partial agreement emission sub-game is as follows: first, domestic lobby groups, in both signatory and non-signatory countries, independently and simultaneously choose their contribution schedules; then, the k signatories set their level of emissions to jointly maximize the aggregate payoff to their coalition; whereas each of the $n-k$ non-signatories acts non-cooperatively by maximizing its own payoff; finally, lobby groups in all countries pay contributions to their own governments, according to the choice of emission levels.

As before, we restrict our attention to truthful and strictly positive contribution schedules. Moreover, we introduce the assumption of linear damages $D(E) = \omega E$, with $\omega > 0$. This assumption implies that players have a dominant strategy. Specifically, for each k, the optimal emission level of a signatory is independent of the emission levels chosen by non-signatories, and vice versa. Using linear damages considerably simplifies the analytical structure of the problem and is common to most works in the IEA literature.

Let I^S and I^N denote the set of signatories and non-signatories, respectively; with $I^S \cup I^N = I$. A signatory $i \in I^S$ sets its emission level to solve the following problem

$$\max_{e_i} \sum_{j \in I^S} G_j(e_j, e_{-j}) = \sum_{j \in I^S} \left\{ (1-\gamma)W_j(e_j, E) + \gamma[C_{j1}(e_j) + C_{j2}(e_j, e_{-j})] \right\}, \qquad (12)$$

subject to Eqs. (5a) and (5b). The first-order condition for a signatory is given by

$$FOC_S : (1 - \gamma + \gamma\beta)B'(e_i) - (1 - \gamma + \gamma\delta)\omega k = 0. \qquad (13)$$

The assumptions $\gamma \in (0,1)$, $\beta \in [0,1]$, and $B''(e_i) < 0$ imply $(1 - \gamma + \gamma\beta)B''(e_i) < 0$, which guarantees that the signatory's maximization problem is strictly concave.

A non-signatory $i \in I^N$ simply solves the maximization problem defined in Eq. (6). With linear damages, this leads to the first-order condition

$$FOC_N : (1 - \gamma + \gamma\beta)B'(e_i) - (1 - \gamma + \gamma\delta)\omega = 0. \qquad (14)$$

Signatories' emissions $e_i^S(k, \gamma)$ follow from Eq. (13) and decrease in the number of participants k. Non-signatories' emissions $e_i^N(\gamma)$ follow from Eq. (14) irrespective of k. The optimal choices of

both signatories and non-signatories depend on γ. Thus, aggregate emissions, $E(k,\gamma) = ke_i^S(k,\gamma) + (n-k)e_i^N(\gamma)$, are also a function of γ, and decrease in the number of signatories.

For the effect of a change in governments' taste for money, we find similar results as in the case of no cooperation ($k = 1$). Specifically, by totally differentiating Eq. (13) and (14), we obtain

$$\frac{de_i^S(k,\gamma)}{d\gamma} = \frac{(1-\beta)B'\left(e_i^S\right) - (1-\delta)\omega k}{(1-\gamma+\gamma\beta)B''\left(e_i^S\right)}; \tag{15}$$

$$\frac{de_i^N(\gamma)}{d\gamma} = \frac{(1-\beta)B'\left(e_i^N\right) - (1-\delta)\omega}{(1-\gamma+\gamma\beta)B''\left(e_i^N\right)}. \tag{16}$$

Taking similar steps to Section 3.1 $-$ i.e., solving FOC_S and FOC_N for $B'\left(e_i^S\right)$ and $B'\left(e_i^N\right)$ and substituting these into Eqs. (15) and (16), respectively $-$ we find

$$\frac{de_i^S(k,\gamma)}{d\gamma} \gtreqless 0 \ , \ \frac{de_i^N(\gamma)}{d\gamma} \gtreqless 0 \Leftrightarrow \beta \gtreqless \delta. \tag{17}$$

That is, starting from a given $\gamma > 0$, any increase in governments' taste for money yields an increase in the partial agreement Nash equilibrium level of emissions of both signatories and non-signatories, as long as β is strictly larger than δ.

We now proceed to determine the equilibrium lobbying contributions in the second stage. As in Grossman and Helpman (1994), we consider the equilibrium contributions that arise when the government has the power to extract all the surplus from the lobbies.[6] In this case, for any change of the government's policy, lobby group l offers the corresponding change in its gross utility relative to the benchmark utility level that this lobby would get if only the other lobby was active. We denote the emission levels in the presence of lobby 1 alone by $\overline{e}_i^S(k,\gamma)$ and $\overline{e}_i^N(\gamma)$, and the emission levels in the presence of lobby 2 alone by $\overline{\overline{e}}_i^S(k,\gamma)$ and $\overline{\overline{e}}_i^N(\gamma)$. Depending on country i's decision to sign or not to sign, the equilibrium contributions of lobby group 1 are respectively as follows:

$$C_{i1}(e_i^S(k,\gamma),k,\gamma) = \beta B(e_i^S(k,\gamma)) - \beta B(\overline{\overline{e}}_i^S(k,\gamma); \tag{18a}$$

$$C_{i1}(e_i^N(\gamma),\gamma) = \beta B(e_i^N(\gamma)) - \beta B(\overline{\overline{e}}_i^N(\gamma). \tag{18b}$$

Lobby 2's contribution is a function of aggregate emissions, which are a pure public bad, and are therefore suffered equally by signatories and non-signatories. Hence, in equilibrium, lobby 2's schedule is independent of country i's membership decision and given by

$$C_{i2}(E(k,\gamma),k,\gamma) = -\delta\omega E(k,\gamma) + \delta\omega\overline{E}(k,\gamma). \tag{19}$$

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[6]This seems a natural assumption when there are two or more lobbies competing domestically with one another.

The number of signatories k, which has been taken as given thus far, is endogenous to the model. In the next section, we shall solve the membership stage and derive the equilibrium coalition size and levels of emissions.

3.3 The membership stage

Let us start by deriving the payoff functions of signatories and non-signatories for each possible size k of the cooperating coalition. A signatory's payoff is given by

$$G_i^S(k, \gamma) = (1 - \gamma)W_i(e_i^S(k, \gamma), E(k, \gamma)) + \gamma \left[C_{i1}(e_i^S(k, \gamma), k, \gamma) + C_{i2}(E(k, \gamma), k, \gamma) \right]. \quad (20)$$

A non-signatory's payoff is

$$G_i^N(k, \gamma) = (1 - \gamma)W_i(e_i^N(\gamma), E(k, \gamma)) + \gamma \left[C_{i1}(e_i^N(\gamma), \gamma) + C_{i2}(E(k, \gamma), k, \gamma) \right]. \quad (21)$$

In the first stage, the equilibrium number of signatories follows from the conditions of internal and external stability, which respectively guarantee that no signatory is better off leaving the coalition, and that there is no incentive for a non-signatory to join the coalition (d'Aspremont et al., 1983; Hoel, 1992; Carraro and Siniscalco, 1993; Barrett, 1994). Formally

$$\text{internal stability:} \quad G_i^S(k, \gamma) \geq G_i^N(k - 1, \gamma) \ \forall i \in I^S, \text{ and}$$
$$\text{external stability:} \quad G_i^N(k, \gamma) > G_i^S(k + 1, \gamma) \ \forall i \in I^N.$$

For further analysis it is helpful to define as in Hoel and Schneider (1997) the stability function $\Phi_i(k, \gamma) = G_i^S(k, \gamma) - G_i^N(k - 1, \gamma)$, noting that the internal and external stability conditions respectively imply $\Phi_i(k, \gamma) \geq 0 \ \forall i \in I^S$, and $\Phi_i(k + 1, \gamma) < 0 \ \forall i \in I^N$. As we shall see, the size of the equilibrium coalition depends on the properties of this function.

In the reminder of the paper, we will work with the following functional form for the benefit function:

$$B(e_i) = \sigma e_i - \frac{(e_i)^2}{2}, \quad (22)$$

with $\sigma > 0$. Although specific, this has been adopted by many works in the IEA literature, and will allow us to explicitly identify and assess the effect of lobbying on the formation and environmental effectiveness of an IEA.

Under the assumption of linear-quadratic benefits, equilibrium emissions of signatories and non-signatories − as determined by Eqs. (13) and (14) − are as follows:

$$e_i^S(k, \gamma) = \sigma - \frac{1 - \gamma + \gamma\delta}{1 - \gamma + \gamma\beta}\omega k; \quad (23a)$$

$$e_i^N(\gamma) = \sigma - \frac{1 - \gamma + \gamma\delta}{1 - \gamma + \gamma\beta}\omega. \quad (23b)$$

Similar calculations lead to the following expressions for the emissions that determine the benchmark utility levels used to compute the equilibrium contributions of the lobbies:

$$\bar{e}_i^S(k,\gamma) = \sigma - \frac{1-\gamma}{1-\gamma+\gamma\beta}\omega k, \tag{24a}$$

$$\bar{e}_i^N(\gamma) = \sigma - \frac{1-\gamma}{1-\gamma+\gamma\beta}\omega, \tag{24b}$$

$$\bar{\bar{e}}_i^S(k,\gamma) = \sigma - \frac{1-\gamma+\gamma\delta}{1-\gamma}\omega k, \tag{25a}$$

$$\bar{\bar{e}}_i^N(\gamma) = \sigma - \frac{1-\gamma+\gamma\delta}{1-\gamma}\omega. \tag{25b}$$

Using Eqs. (23a)-(25b), and after a few algebraic steps, we obtain the following expression for the stability function:

$$\Phi_i(k,\gamma) = (k-1)\frac{2\omega^2[(1-\gamma+\gamma\delta)^2 - \gamma\delta(1-\gamma)]}{(1-\gamma+\gamma\beta)} - (k^2-1)\frac{\omega^2(1-\gamma+\gamma\delta)^2[(1-\gamma)^2 - \gamma\beta(1-\gamma+\gamma\beta)]}{2(1-\gamma+\gamma\beta)(1-\gamma)^2}. \tag{26}$$

Expression (26) is quadratic in k. For $\gamma < 1$ it is finite, and it admits two distinct roots for $\beta \neq (\frac{1-\gamma}{2\gamma})(\sqrt{5}-1)$, and the unique root $k=1$ when $\beta = (\frac{1-\gamma}{2\gamma})(\sqrt{5}-1)$. For $\beta < (\frac{1-\gamma}{2\gamma})(\sqrt{5}-1)$, (26) is strictly concave in k, with roots $k=1$ and $k^* > 1$. For $\beta > (\frac{1-\gamma}{2\gamma})(\sqrt{5}-1)$, (26) is strictly convex in k, with roots $k=1$ and $k^* < 1$. For all parameter values, (26) is strictly increasing in k at $k=1$ and strictly decreasing in k at all $k=k^*$. These facts are recorded in the next Lemma.

LEMMA 1 *Let $k^*(\gamma,\delta,\beta) \neq 1$ be the second root of (26).*

1. *Φ is strictly decreasing in k at $k^*(\gamma,\delta,\beta)$;*

2. *If $\beta < (\frac{1-\gamma}{2\gamma})(\sqrt{5}-1)$, then $k^*(\gamma,\delta,\beta) > 1$ and the following properties hold:*

   (a) *Φ is strictly concave in k;*

   (b) *$k^*(\gamma,\delta,\beta)$ is increasing in β;*

   (c) *$k^*(\gamma,\delta,\beta)$ is increasing in δ if and only if $\gamma \geq \frac{1}{1+\delta}$;*

   (d) *$k^*(\gamma,\delta,\beta)$ is increasing in γ when $\beta \geq \delta$.*

3. *If $\beta = (\frac{1-\gamma}{2\gamma})(\sqrt{5}-1)$, then Φ is linear in k, and $k=1$ is the unique root of (26);*

4. *If $\beta > (\frac{1-\gamma}{2\gamma})(\sqrt{5}-1)$, then Φ is strictly convex in k and increasing at $k=1$.*

By Lemma 1, the size of the stable coalition is equal to the largest integer number smaller than or equal to k^*. This comes as a result of two facts. First, the stability function is concave and

strictly decreasing at k^* when $\beta < (\frac{1-\gamma}{2\gamma})(\sqrt{5}-1)$; this implies that the stability function is always negative for all $k > k^*$. Second, Φ is convex when $\beta \geq (\frac{1-\gamma}{2\gamma})(\sqrt{5}-1)$; this, together with the fact that Φ is strictly increasing at $k = 1$, implies that the grand coalition is stable. The whole set of implication of Lemma 1 for the size of the stable coalition k^s in the membership stage are presented in the next Proposition 1.

PROPOSITION 1 *Consider the membership stage of the game.*

1. *The size k^s of the stable coalition weakly increases with the stake in the benefits from emissions β. The grand coalition is stable for all $\beta \geq (\frac{1-\gamma}{2\gamma})(\sqrt{5}-1)$;*

2. *The size k^s of the stable coalition weakly decreases with the stake in the damages caused by emissions δ if $\gamma \leq \frac{1}{1+\delta}$, and weakly increases if $\gamma \geq \frac{1}{1+\delta}$;*

3. *An increase in the taste for money γ weakly increases the size k^s of the stable coalition when the stake in the benefits from emissions is at least as large as the stake in the damages caused by emission ($\beta \geq \delta$). For all $\beta \leq 1$, the grand coalition is stable when $\gamma \geq \frac{2-(\sqrt{5}-1)\beta}{2(1+(1-\beta)\beta)}$.*

Let us try to summarise the main insights of Proposition 1. Point 1 states that the larger the stake in the benefits from emissions, the larger the size of the cooperating coalition. The intuition behind this apparently counterintuitive result is best understood by considering the effect that joining a cooperating coalition has on the contributions paid by lobby 1 (the lobby with stake β in the benefits from emissions). In equilibrium, lobby 1's contributions are larger the smaller its reservation utility level; which is measured by the utility that lobby 1 derives in the hypothetical scenario where only lobby 2 exerts pressure on the government. This reservation level is decreased by the decision to join the coalition simply because emissions will reduce as a consequence; the larger β, the larger the effect perceived by lobby 1, and the increase in its equilibrium contributions (see left panel of Figure 1). Since the government is interested in such contributions in measure γ, for large enough γ this mechanism is strong enough to make the grand coalition stable. This result contains a striking economic insight: by joining an IEA, the government commits to lower emissions, and in so doing is able to extract more contributions from lobby 1 at the emission stage. Joining an IEA can be thought of here as the use of commitment power by the government, whose decision provides lobby 1 with larger willingness to pay in order to affect the government's decision at the emission stage.

Point 2 states that a larger stake in the damages from emissions increases the size of the stable coalition when lobbying is very effective (large γ), and decreases it when lobbying is not very effective. This result can be interpreted along similar lines. In particular, by committing to an IEA, the government positively affects the reservation utility of lobby 2, as long as the ensuing reduction
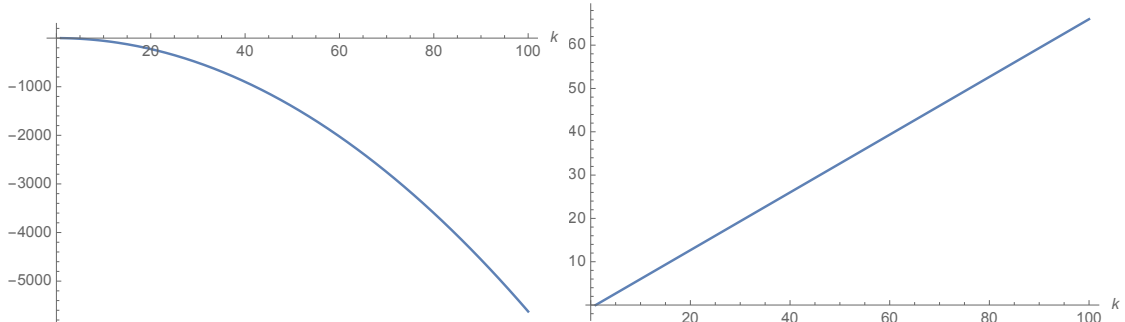
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Figure 1: Change in the reservation utility of lobby 1 (left) and of lobby 2 (right) from joining a IEA, as a function of the size of the IEA ($\gamma = .5$, $\beta = .5$, $\delta = .5$, $n = 100$, $\sigma = 100$, $w = 1$).

in emissions due to cooperative behaviour by one additional country outweighs the negative effect of belonging to a coalition in the hypothetical scenario in which only lobby 1 is active (see right panel of figure 1). This second effect is small when γ is small, leading to higher reservation utilities of lobby 2, little incetive for the government to join and, in turn, a smaller equilibrium coalition. When γ is large, the opposite holds, and the size of the stable coalition increases with δ.

Point 3 refers to the relation between the government's taste for money and the size of the IEA. This result is the joint effect of the two mechanisms described in points 1 and 2: when β is large relative to δ, the effect on lobby 1's equilibrium contributions is stronger than the effect on lobby 2's contributions; as a result, a larger taste for money positively affects the size of the stable IEA. When γ grows large, the two effects align in the direction of increasing the size of the IEA, and the grand coalition becomes stable for all values of β and δ. Formally, this happens when the stability function Φ becomes convex in k, as depicted in Figure 2.
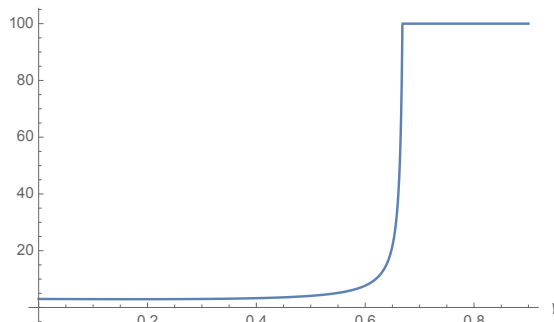

Figure 2: Size of the stable coalition as a function of γ ($\delta = .5$, $\beta = .3$, $n = 100$, $\sigma = 100$, $w = 1$).

Let us now turn our attention to the total level of emissions and how this is affected by the political parameters of our model, γ, β and δ. These parameters affect total emissions both through their effect on the size of the IEA and through the way in which they change governments' prefer-

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ences at the emission stage. We have seen how larger values of the parameter β tend to increase the size of the cooperating coalition. This would, for fixed preferences, reduce emissions by internalising more of the negative externalities. However, an increase in β also has the effect of increasing the weight that the benefits from emissions have in governments' preferences, and this works in favour of larger emissions. The net effect is ambiguous. Similar arguments apply to the parameter δ; while larger values of δ tend to decrease the number of cooperating countries (at least for not-too-high levels of γ), they also assign a larger weight to the environment. The net effect on emissions is, again, ambiguous. By the same token, the effect of increasing the parameter γ depends on the above trade-offs. In the next proposition we show that the solution of these trade-offs depends both on the total number of countries, n, and on the relative magnitudes of δ and β.

PROPOSITION **2** *Consider the membership stage of the game.*

1. *Let* $\gamma < \frac{2-(\sqrt{5}-1)\beta}{2(1+(1-\beta)\beta)}$.

    (a) *If* $\delta > \beta$*, there exists* $\bar{n}(\gamma,\delta,\beta)$ *such that increasing the taste for money* γ *in the government's objective function results in lower aggregate emissions if and only if* $n > \bar{n}(\gamma,\delta,\beta)$;

    (b) *If* $\delta \leq \beta$*, there exists* $\bar{n}(\gamma,\delta,\beta)$ *such that increasing the taste for money* γ *in the government's objective function results in lower aggregate emissions if and only if* $n \leq \bar{n}(\gamma,\delta,\beta)$;

2. *Let* $\gamma \geq \frac{2-(\sqrt{5}-1)\beta}{2(1+(1-\beta)\beta)}$*. Then increasing the taste for money* γ *results in lower aggregate emissions if and only if* $\delta \geq \beta$

The logic behind both points is the following. Increases in γ result in a larger role for β and δ. When $\delta > \beta$ (point a), the effect is to reduce the size of the IEA, and to increase emissions. At the same time, however, non-members tend to decrease emissions as a result of the change in preferences. The net effect is a decrease in emissions when the number of non-members (which grows with n, given that the size k^s is independent of n) is large enough. When $\delta \leq \beta$ (point b), the decrease in emissions of members of the larger IEA dominates the increase of non-members, when there are not too many of these. Point 2 refers to the high range of γ, for which the grand coalition is stable. In this range, any increase in γ has no effect on the size of the IEA, and aggregate emissions are reduced if and only if government's preferences are affected by the stake in damages more than by the stake in the benefits from emissions (that is, when $\delta > \beta$).

Fig 3 illustrates the pattern of total emissions as a function of γ for given values of the other parameters and for $n = 100$. It shows that the effect on preferences of an increased γ is stronger when γ is low, and emissions increase as a result. When γ is high, the positive effect of a high β on the size of the IEA becomes overwhelming, and emissions consequently decrease. When the limit

to coalitional expansion is reached (that is, when $k^s = n$), then further increases in γ only affect preferences, and emissions increase again as a result (see Fig 3). The non monotonicity in figure 3 is not in contradiction with point 1 of Proposition 2. In fact, the threshold $\bar{n}(\gamma, \delta, \beta)$ changes with γ, and $\bar{n}(\gamma, \delta, \beta) = 100$ around $\gamma = .3$; for larger γ we have $\bar{n}(\gamma, \delta, \beta) > 100$, and the pattern switches from increasing to decreasing.
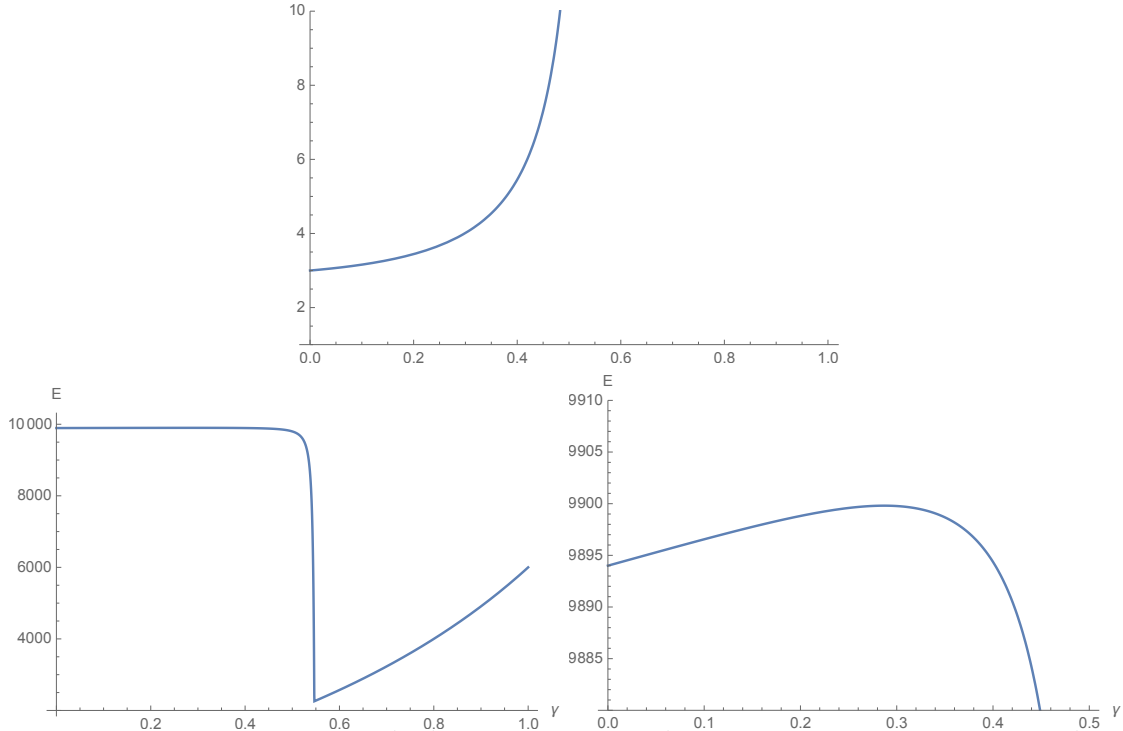

Figure 3: Size of the stable coalition (top) and total emissions (bottom: right panel for low range of γ) as a function of γ ($\beta = .5$, $\delta = .3$, $n = 100$, $\sigma = 100$, $w = 1$).

In Figure 4 we present the pattern of total emissions as a function of δ for given values of the other parameters. It is useful to keep track of the effect of δ on the size of the stable coalition in the left panel. We see that the effect of δ is non monotonic, first increasing emissions and then reducing them. At low values of δ, the decrease in the size of the coalition is marked, so much so that it outweighs the effect of the induced change in preferences; as a result emissions increase. At higher levels of δ, further increases have little effect on the coalitional size, so that the change in preferences tends to dominate and emissions decrease.

Similar insights are given in Figure 5, illustrating the role of β. Here, the effect of larger β on the size of the IEA is more marked when β is large. Therefore, at large values of β we observe that emissions decrease with β as a result of the prevailing effect of a larger coalitional size on

preferences. Opposite arguments explain the positive relation between total emissions and β at low values of β.
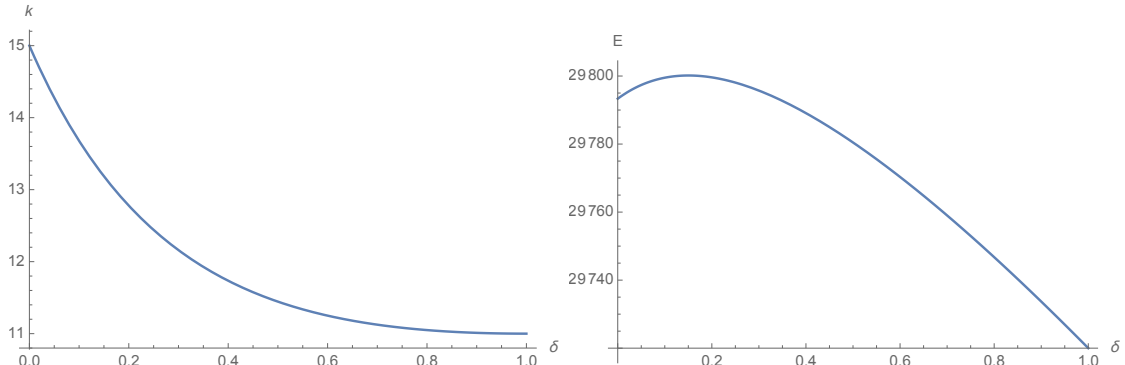

Figure 4: Size of the stable coalition (left) and total emissions (right) as a function of δ ($\gamma = .5$, $\beta = .5$, $n = 100$, $\sigma = 200$, $w = 1$).
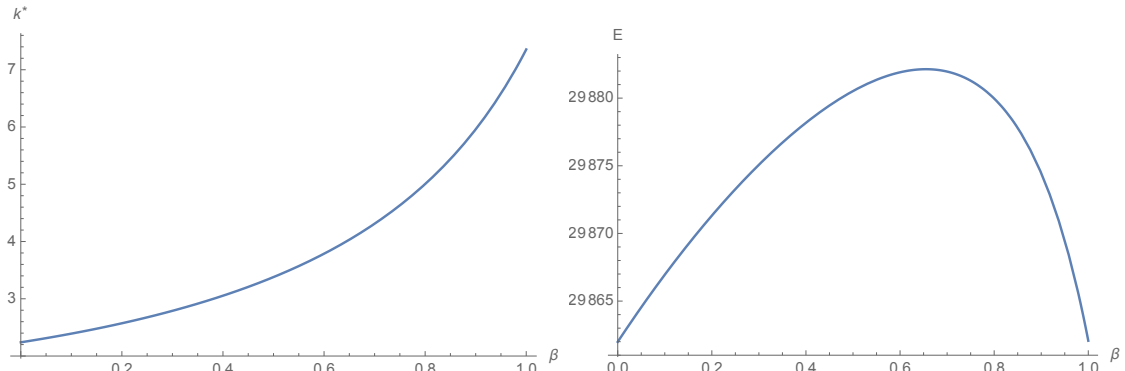

Figure 5: Size of the stable coalition (left) and total emissions (right) as a function of β ($\gamma = .3$, $\delta = .5$, $n = 100$, $\sigma = 200$, $w = 1$).

4   Lobbying on membership

As suggested by Habla and Winkler (2013), the decision process in the first stage may also be affected by lobbies, as domestic special interest groups either gain or lose depending on governments' membership decisions. In this section we introduce an alternative lobbying approach to the one we studied in the previous section, whereby interest groups lobby directly on the membership stage. Our purpose here is not to provide an exhaustive treatment of this type of lobbying, but rather to present a sketched model and use its equilibrium implications to assess how the two types of lobbying differ in terms of their effects on the extent and depth of cooperation.

We study the following game:

I. *Membership stage:*

    (a) First, all organised lobby groups l in all countries independently and simultaneously present their own government with contribution schedules C_{il}^R, which specify the lobbying contributions contingent on the government's membership decision $R = \{S, N\}$. As we shall see, these contribution schedules are also contingent on the other countries' membership decisions through k.

    (b) Second, taking as given the contribution schedules offered by all lobby groups in all countries, governments independently and simultaneously decide whether to sign the agreement.

    (c) Third, lobby groups pay contributions.

II. *Emission policy stage:* Signatories set their emissions to jointly maximize the aggregate payoff to their coalition, while each non-signatory acts non-cooperatively.

The game is solved using backward induction. Hence, we begin in the following subsection by considering the second stage of the game.

4.1 The emission policy stage

The equilibrium of the second stage coincides with the partial agreement Nash equilibrium of the standard emissions policy game with no lobbying. Indeed, since lobbying now bears only on countries' membership decisions, it does not affect the marginal choice about emissions at the second stage. Formally, the first-order conditions of signatories and non-signatories are given by

$$FOC_S : B'(e_i) - \omega k = 0 \tag{27}$$

$$FOC_N : B'(e_i) - \omega = 0. \tag{28}$$

Signatories emissions $e_i^S(k)$ follow from Eq. (27) and decrease in the number of participants k. Non-signatories emissions e_i^N follow from Eq. (28) irrespective of k. The optimal choices of both signatories and non-signatories are independent of γ. Assuming linear-quadratic benefits as specified by Eq. (22), we can solve the first-order conditions to obtain:

$$e_i^S(k) = \sigma - \omega k; e_i^N = \sigma - \omega. \tag{29}$$

Aggregate emissions are given by $E(k) = k(\sigma - \omega k) + (n - k)(\sigma - \omega)$ and decrease in the number of signatories $k \geq 1$.

4.2   The membership stage

Let $(k-1)$ be the number of signatories among all other countries $m \neq i$. If country i joins the agreement, the second stage utilities of lobby groups 1 and 2 in country i are given by $W_{i1}(e_i^S(k)) = \beta B(e_i^S(k))$ and $W_{i2}(E(k)) = -\delta \omega E(k)$, respectively. Similarly, if country i does not join the agreement, given that $(k-1)$ other countries are members, lobby groups' utilities in the second stage are $W_{i1}(e_i^N) = \beta B(e_i^N)$ and $W_{i2}(E(k-1)) = -\delta \omega E(k-1)$. We denote by $\Delta W_{i1}^{S,N} \equiv \beta \left[B(e_i^S(k)) - B(e_i^N) \right]$ and $\Delta W_{i2}^{S,N} \equiv -\delta \omega [E(k) - E(k-1)]$ the difference in second stage utilities that lobby groups 1 and 2 respectively derive as a result of the government switching from non-signing to signing, given that $(k-1)$ other countries are members.

We will work under the assumption that each lobby group expects the worst regime to be adopted should it give up lobbying altogether. This assumption simplifies the analysis, and has been adopted in Habla and Winkler (2013), where exact conditions on the primitives are spelled out. In particular, this allows us to specify the behaviour of lobby groups in terms of equilibrium contributions as we describe below.

Lobby group $l = \{1, 2\}$ in country i supports membership choice S if and only if $\Delta W_{il}^{S,N} > 0$, which also implies that $\Delta W_{il}^{N,S} < 0$. Note that, since $B'(e_i) > 0$ and $e_i^S(k) < e_i^N$, $\Delta W_{i1}^{S,N}$ is negative; whereas $\Delta W_{i2}^{S,N}$ is positive since aggregate emissions are decreasing in k. As contributions must be non-negative, the contribution of lobby group 1 supporting membership choice $R = \{S, N\}$, C_{i1}^R, is given by

$$C_{i1}^S = 0, C_{i1}^N = \max\{0, \beta[B(e_i^N) - B(e_i^S(k))]\}; \tag{30}$$

and the contribution of lobby group 2 is

$$C_{i2}^S = \max\{0, -\delta \omega [E(k) - E(k-1)]\}, C_{i2}^N = 0. \tag{31}$$

The government' payoff is a weighted sum of social welfare and lobbying contributions. Thus, if the government of country i signs the agreement, given that $(k-1)$ other countries are members, it will obtain

$$G_i^S(k, \gamma) = (1-\gamma) \left[B(e_i^S(k)) - \omega E(k) \right] + \gamma \delta \omega [E(k-1) - E(k)]; \tag{32}$$

if i does not sign, its payoff will be

$$G_i^N(k-1, \gamma) = (1-\gamma) \left[B(e_i^N) - \omega E(k-1) \right] + \gamma \beta [B(e_i^N) - B(e_i^S(k))]. \tag{33}$$

Country i will choose regime S if and only if $G_i^S(k, \gamma) > G_i^N(k-1, \gamma)$. Note that Eqs. (32) and (33) can be interpreted respectively as the payoff of a member of a coalition of size k, and the

payoff that a country would get by leaving the coalition k. We can therefore use these expressions to derive the stability function $\Phi_i(k, \gamma) \equiv G_i^S(k, \gamma) - G_i^N(k-1, \gamma)$. Specifically, we have:

$$\Phi_i(k, \gamma) = \omega\left(1 - \gamma + \gamma\delta\right)\left[E(k-1) - E(k)\right] - \left(1 - \gamma + \gamma\beta\right)\left[B(e_i^N) - B(e_i^S(k))\right]. \quad (34)$$

For linear quadratic benefits as specified by Eq. (22), the above expression becomes

$$\Phi_i(k, \gamma) = -\frac{\omega^2}{2}\left(1 - \gamma + \gamma\beta\right)k^2 + 2\omega^2\left(1 - \gamma + \gamma\delta\right)k - \omega^2\left[2(1 - \gamma + \gamma\delta) - \frac{1}{2}(1 - \gamma + \gamma\beta)\right]. \quad (35)$$

Expression (35) is quadratic in k, and its roots are

$$k = 1; k^*(\gamma, \delta, \beta) = \frac{3 - 3\gamma + 4\gamma\delta - \gamma\beta}{1 - \gamma + \gamma\beta}.$$

It can be shown that Φ is concave in k, and that it is strictly decreasing at $k = k^*(\gamma, \delta, \beta)$. For the same arguments discussed in the previous section, this implies that the size of the largest internally and externally stable coalition is the largest integer k^s such that $k^s \leq k^*(\gamma, \delta, \beta)$. The following proposition records the relation between the taste for money γ and the size k^s of the stable coalition.

PROPOSITION **3** *Consider the membership stage of the game with lobbying on membership. An increase in the government's taste for money (γ) results in a larger equilibrium coalition size if and only if the stake in the damages caused by emissions is higher than the stake in the benefits from emissions. Formally:*

$$\frac{\partial k^*(\gamma, \delta, \beta)}{\partial \gamma} \gtreqless 0 \Leftrightarrow \beta \lesseqgtr \delta.$$

This is an intuitive result; indeed, when $\delta > \beta$, a larger role for political pressure (as captured by the parameter γ) translates into a larger concern for the environment in governments' preferences, which, in turn, results in more countries cooperating.

Some interesting insights emerge when we compare this intuitive result with the opposite conclusion obtained in the case of lobbying on emissions. There, large values of β were shown to always enlarge the size of the IEA. The reason for this stark difference in the effect of the two types of lobbying is to be found in the different commitment power of the government at the membership stage that they entail, and the resulting different extraction possibilities with respect to the two lobbies. In particular, when lobbying bears on emissions, joining an agreement affects the outside options of lobbies at the emission stage and, consequently, the equilibrium contributions extracted by the government. When, in contrast, contributions are a function of governments' membership decisions, a government cannot commit to a regime *before* interacting with the lobbies, and

the somewhat counterintuitive effects outlined in Proposition 1, stemming from this commitment power, are replaced by the more intuitive effects of Proposition 3. We therefore conclude that the object and timing of lobbying matter substantially for the size of the ensuing IEA.

Regarding the equilibrium level of emissions, we have seen that aggregate emissions are determined by the effects of β and δ on governments' preferences *and* on the size of the cooperating coalition. In the case of lobbying on emissions these two effects work in opposite directions, and lobbying leads to lower levels of aggregate emissions when δ is larger (smaller) than β and the number of countries is large (small). In the case of lobbying on membership the effects of γ on preferences are reinforced by the effect on coalitional size, leading to a larger coalition size and lower levels of aggregate emissions whenever δ is larger than β.

5   Concluding remarks

We have studied the effect of domestic lobbying on the extent and depth of international environmental cooperation. Our results suggest that lobbying on emissions may affect the size of the (stable) IEA in counterintuitive ways. In particular, a strong lobby representing the interests of groups that favour high emissions (typically business lobbies) may increase the government's incentives to sign an IEA, by providing it with strong bargaining power with respect to that lobby at the emission stage. In fact, the incentives of the lobby to affect the emission policy would be higher if the government were to join the IEA, as would be the contributions that the government could extract from that lobby. We have shown that this would result in lower total emissions when the number of countries involved is not too large. We have also shown that things change radically when lobbying is transferred to the membership stage, and governments receive contributions that depend on their decision to join (or not join) an IEA. Here, a strong business lobby always results in a smaller size of IEA and in higher emissions overall, as one would expect.

There are several avenues along which the present work could be extended. For example, it would be interesting to study the joint effect of the two types of lobbying considered in this paper; or to enrich the set of actors by including international lobby groups. Another extension could be to include trade, which might shed light on phenomena like the 'California effect': will the threat of trade sanctions to firms exporting a polluting good to a regulated market trigger lobbying for more stringent domestic policies? Lastly, it would be interesting to test the model empirically, estimating the effect of lobbying on environmental policy using, for example, data from US campaign contributions.

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Appendix

PROOF OF LEMMA 1:

Point 1. Let us start by rewriting expression (26) as follows:

$$\Phi(\gamma, k, \delta, \beta) = \frac{A(\gamma, k, \delta, \beta)}{B(\gamma, k, \delta, \beta)},$$

where

$$A(\gamma, k, \delta, \beta) = \omega^2 \left(\gamma \left(-\beta^2 \gamma(\gamma(\delta-1)+1)^2 + \beta(\gamma-1)(\gamma(\delta-1)+1)^2 - 3\gamma(\gamma-1)^2\delta^2 + 2(\gamma-1)^3\delta \right.\right.$$
$$- 3(\gamma-2)((\gamma-2)\gamma+2) + k^2(\gamma(((\beta-1)\beta-1)\gamma+\beta+2)-1)(\gamma(\delta-1)+1)^2 +$$
$$+ 4(\gamma-1)^2 k(\gamma(\gamma((\delta-1)\delta+1)+\delta-2)+1) - 3,$$

and

$$B(\gamma, k, \delta, \beta) = 2(\gamma-1)^2((\beta-1)\gamma+1).$$

Note that for $\gamma = 1$, $B(\gamma, k, \delta, \beta) = 0$ and $A(\gamma, k, \delta, \beta) > 0$ for all $k > 1$. So, for all plausible values of k the expression for Φ tends to infinity. When $\gamma < 1$, the quadratic expression for Φ admits two roots: $k = 1$ and $k(\gamma, \delta, \beta) = \frac{A(\gamma, \delta, \beta)}{B(\gamma, \delta, \beta)}$, where

$$A(\gamma, \delta, \beta) = \gamma \left(-\beta^2 \gamma(\gamma(\delta-1)+1)^2 + \beta(\gamma-1)(\gamma(\delta-1)+1)^2 \right.$$
$$- 3\gamma(\gamma-1)^2\delta^2 + 2(\gamma-1)^3\delta - 3(\gamma-2)((\gamma-2)\gamma+2) - 3,$$

and

$$B(\gamma, \delta, \beta) = \gamma(((\beta-1)\beta-1)\gamma+\beta+2)-1)(\gamma(\delta-1)+1)^2.$$

The derivative of Φ with respect to k is:

$$\frac{\omega^2 \left(2(\gamma-1)^2(\gamma(\gamma((\delta-1)\delta+1)+\delta-2)+1) + k(\gamma(((\beta-1)\beta-1)\gamma+\beta+2)-1)(\gamma(\delta-1)+1)^2\right)}{(\gamma-1)^2((\beta-1)\gamma+1)}.$$

Substituting for $k(\gamma, \delta, \beta)$ we obtain:

$$-\frac{\omega^2 \left(\gamma \left(\beta^2 \gamma(\gamma(\delta-1)+1)^2 - \beta(\gamma-1)(\gamma(\delta-1)+1)^2 + \gamma \left(\gamma^2 + (\gamma-1)^2\delta^2 - 4\gamma + 6\right) - 4\right) + 1\right)}{(\gamma-1)^2((\beta-1)\gamma+1)}.$$

The above expression is negative for all values of γ, δ and β in the intervale $(0, 1)$.

Pont 2a. The second derivative of Φ with respect to k is as follows:

$$\frac{\partial^2 \Phi}{\partial k^2} = \frac{\omega^2(\gamma(((\beta-1)\beta-1)\gamma+\beta+2)-1)(\gamma(\delta-1)+1)^2}{(\gamma-1)^2((\beta-1)\gamma+1)}.$$

The sign of the above expression is independent of δ and ω, and follows the following pattern:

$$\frac{\partial^2 \Phi}{\partial k^2} < 0 \iff \beta < (\frac{1-\gamma}{2\gamma})(\sqrt{5}-1)$$

$$\frac{\partial^2 \Phi}{\partial k^2} = 0 \iff \beta = (\frac{1-\gamma}{2\gamma})(\sqrt{5}-1)$$

$$\frac{\partial^2 \Phi}{\partial k^2} > 0 \iff \beta > (\frac{1-\gamma}{2\gamma})(\sqrt{5}-1)$$

Point 2b. The derivative of Φ with respect to β is:

$$\frac{4(\gamma-1)^2\gamma((2\beta-1)\gamma+1)(\gamma(\gamma((\delta-1)\delta+1)+\delta-2)+1)}{(\gamma(((\beta-1)\beta-1)\gamma+\beta+2)-1)^2(\gamma(\delta-1)+1)^2}.$$

The above expression is positive whenever $0 < \beta < (\frac{1-\gamma}{2\gamma})(\sqrt{5}-1)$.

Point 2c. The derivative of Φ with respect to δ is:

$$\frac{4(\gamma-1)^3\gamma(\gamma\delta+\gamma-1)}{(\gamma(((\beta-1)\beta-1)\gamma+\beta+2)-1)(\gamma(\delta-1)+1)^3}.$$

In the the above expression, the denominator is positive when $0 < \beta < (\frac{1-\gamma}{2\gamma})(\sqrt{5}-1)$. The result comes from the analysis of the numerator. Note also that in order for the desired condition to hold, it has to be that $\gamma \geq \frac{1}{2}$, since δ is at most 1.

Point 2d. The derivative of Φ with respect to γ is $\frac{A}{B}$, where:

$$A = 4(\gamma-1)\left(-\beta^2\gamma(\gamma(2\delta-1)+1)(\gamma(\gamma((\delta-1)\delta+2)+\delta-4)+2)+\beta(\gamma-1)(\gamma(\gamma(\gamma(\delta((\delta-1)\delta+3)-1)+\right.$$
$$+ (\delta-6)\delta+3)+3(\delta-1))+1)+(\gamma-1)^3\delta(\gamma\delta+\gamma-1),$$

and

$$B = (\gamma(((\beta-1)\beta-1)\gamma+\beta+2)-1)^2(\gamma(\delta-1)+1)^3.$$

The numerator is positive for $\beta > \gamma$. The denominator is positive when $\beta > \gamma$ and $0 < \beta < (\frac{1-\gamma}{2\gamma})(\sqrt{5}-1)$.

Point 3. See the proof of point 2a above.

Point 4. See the proof of point 2a above. Moreover, evaluating the first derivative of Φ with respect to k at $k = 1$ we obtain:

$$\frac{\omega^2 \left(\gamma \left(\beta^2\gamma(\gamma(\delta-1)+1)^2 - \beta(\gamma-1)(\gamma(\delta-1)+1)^2 + \gamma\left(\gamma^2 + (\gamma-1)^2\delta^2 - 4\gamma + 6\right) - 4\right) + 1\right)}{(\gamma-1)^2((\beta-1)\gamma+1)},$$

which is a positive expression for all γ, β and δ in the interval $(0,1)$.

PROOF OF PROPOSITION 1:

Point 1. When $\beta < (\frac{1-\gamma}{2\gamma})(\sqrt{5}-1)$, the result follows from point 2b in Lemma 1. When $\beta \geq (\frac{1-\gamma}{2\gamma})(\sqrt{5}-1)$, the stable coalition is the grand coalition, whose size is constant with respect to β (Lemma 1, points 3 and 4).

Point 2. See the proof of Lemma 1, point 2c.

Point 3. See the proof of Lemma 1, point 2d, and note that the condition $\gamma \geq \frac{2-(\sqrt{5}-1)\beta}{2(1+(1-\beta)\beta)}$ is equivalent to the condition $\beta \geq (\frac{1-\gamma}{2\gamma})(\sqrt{5}-1)$.

PROOF OF PROPOSITION 2:

Point 1. In this range of parameters values, the stability function is concave and total emissions are computed by looking at the stable coalition for any given values of the parameters γ, β and δ Total emissions are derived as follows:

$$E(\gamma, \delta, \beta) = ke_i^S(k(\gamma, \delta, \beta), \gamma, \delta, \beta) + (n-k)e_i^N(\gamma, \delta, \beta).$$

Using the expressions for $k(\gamma, \delta, \beta)$ and $e_i^S(.)$, we obtain the following expression:

$$E(\gamma, \delta, \beta) = \frac{A(\gamma, \delta, \beta)}{B(\gamma, \delta, \beta)},$$

where

$$A(\gamma, \delta, \beta) = n(\gamma(\beta(-\beta\gamma+\gamma-1)+\gamma-2)+1)^2(\gamma(\delta-1)+1)^3(\sigma((\beta-1)\gamma+1)+\omega(\gamma(-\delta)+\gamma-1))$$
$$-2\omega\left(\gamma\left(\beta^2\gamma(\gamma(\delta-1)+1)^2 - \beta(\gamma-1)(\gamma(\delta-1)+1)^2 + 3\gamma(\gamma-1)^2\delta^2 - 2(\gamma-1)^3\delta + 3(\gamma-2)((\gamma-2)\gamma+2)\right)\right)$$
$$+3\left(\gamma\left(\beta^2\gamma(\gamma(\delta-1)+1)^2 - \beta(\gamma-1)(\gamma(\delta-1)+1)^2 + \gamma\left(\gamma^2 + (\gamma-1)^2\delta^2 - 4\gamma + 6\right) - 4\right) + 1\right),$$

and

$$B(\gamma, \delta, \beta) = ((\beta-1)\gamma+1)\left(\left(\beta^2-\beta-1\right)\gamma^2 + (\beta+2)\gamma-1\right)^2(\gamma(\delta-1)+1)^3.$$

The derivative of $E(\gamma, \delta, \beta)$ with respect to γ is a long expression. We refer to the additional material for a derivation. Computed at $\gamma = 0$, the derivative takes the following simple form:

$$(n-14)\omega(\beta-\delta).$$

It is immediate that when $\beta > \delta$, total emissions are increasing at $\gamma = 0$ if and only if $n > 14$, and the reverse is true when $\beta < \delta$. In the general case of any arbitrary value of γ, the threshold for n is a non trivial function of γ, and β. However, a result in the same spirit of the one obtained above: when $\beta > \delta$, total emissions are increasing if and only if n is larger than a given threshold, and the other way around when $\beta > \delta$.

Point 2. For this range of parameters values, the stability function is convex, and the stable coalition is the grand coalition. Therefore any increase in γ do not affect the size of the stable coalition ($k = n$), and the change in total emissions is given by:

$$\frac{\partial E(\gamma, \delta, \beta)}{\partial \gamma} = \frac{n^2 \omega (\beta - \delta)}{((\beta - 1)\gamma + 1)^2}.$$

We conclude that total emissions increase in γ if and only if $\beta > \delta$.

PROOF OF PROPOSITION 3: The result is obtained by differentiating with respect to γ the following expression:

$$k^*(\gamma, \delta, \beta) = \frac{3 - 3\gamma + 4\gamma\delta - \gamma\beta}{1 - \gamma + \gamma\beta}.$$

to obtain

$$\frac{4\delta - 4\beta}{((\beta - 1)\gamma + 1)^2}.$$