DISCUSSION PAPER SERIES

Discussion paper No. 165

International Environmental Agreement and the Timing of Domestic Lobbying

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April 2019
Second version

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International Environmental Agreement and the Timing of Domestic Lobbying

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Abstract

We incorporate domestic lobbying activities into a policymaker's decision making on whether or not to sign a cooperative bilateral environmental agreement and, if not, how much pollution a country emits. There are environmental and industrial lobbyists who attempt to sway the policymaker's decision toward their respectively favored policies. As is usually the case with a common agency model, lobbyists present contribution schedules that are tied to resulting policy choices. In this article, we focus on the impacts of the timing of lobbying activities. The first type of lobbying occurs on the signing of a cooperative agreement, and the second when each nation chooses its own non-cooperative emission level after the agreement was not signed or one of the signatories has reneged on its promise. We compare the outcomes of the four different cases: (i) no lobbying activity; (ii) lobbying conducted at the agreement signing stage; (iii) lobbying conducted when non-cooperative choice is made; and (iv) lobbying at both occasions. Our results suggest that the different timings of domestic lobbying have quite contrasting impacts on the signing of a cooperative agreement, and also that increasing the number of lobbying opportunities can even contribute to the emergence of international cooperation.

Keywords: common agency, compensating equilibrium, environmental agreement, global pollution, lobbying

JEL Codes: D72, H41

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1 Introduction

It is widely considered that international cooperation is crucial in addressing certain environmental issues, such as global warming and transnational acid rain pollution. However, we often observe serious failures for countries to cooperate over these international environmental issues and even witness a defection of a major nation from a politically highlighted agreement, such as the Kyoto Protocol and the Paris Agreement for tackling with climate change. The crux of the problem is typically illustrated by a Prisoners' Dilemma-type situation: in a simple two country case, non-cooperation is the outcome supported by the strictly dominant strategy and, therefore, a rational sovereign nation would never cooperate in a one-shot game.

Although in a slightly different context of domestic voluntary environmental agreements among profit-maximizing oligopoly firms, Dowson and Segerson (2008) argue that, if a player anticipates that the other player will not cooperate once the player himself chooses not to cooperate in the first place, it will be the weakly dominant strategy for each player to stick to the cooperative behavior even in a two-person Prisoners' Dilemma game. They claim that, since the two players both end up losing in the non-cooperative outcome, compared to the cooperative outcome, full cooperation is actually self-enforcing even in a one-shot Prisoners' Dilemma.[1] In our context of a bilateral international environmental agreement, if a nation can immediately detect the other nation's defection from a cooperative agreement and, furthermore, costlessly retract its cooperative promise under such a circumstance, the actual strategic relationship is no longer a Prisoners' Dilemma, but should be perceived as a type of coordination game with full cooperation being the weakly dominant solution, hence a Nash equilibrium in this converted game.[2]

In a highly politicized international issue, such as global warming, it would be more plausible that a defection of one country from a cooperative agreement should induce

[1] This is typically referred to as the "stability" argument in the Industrial Organization literature (d'Aspremont, Jacquemin, Gabszewicz and Waymark, 1983). The idea has been adopted widely in the later works on international environmental agreements (Carraro and Siniscalco, 1993; Barrett, 1994; Diamantoudi and Sartzetakis, 2006; Benchekroun and Chaudhuri, 2015). These previous studies usually deal with N-country cases and focused on the existence of free-riding incentive for sovereign nations in maintaining full-scale cooperation to tackle with international issues.

[2] We will see this later in 3.1.

greater reactions by the other nations. It seems often the case that a defection of a major country from a cooperative agreement makes the agreement quite ineffectual by inducing relatively inept pollution control efforts by the remaining countries if not further defections. For instance, the defection of the U.S. from the Kyoto Protocol made the efforts of the remaining nations, most notably, the EU and Japan, less committed and also less stringent.[3] More recently, the defection of the U.S. from the Paris Agreement has created significant uncertainty on the efforts of the remaining signatories.

From a different viewpoint, the collapse of an agreement in the cases where a certain number of nations do not adhere to the terms of the agreement can be considered as the working of a so-called minimum-participation rule (MPR) included in the treaty. A common type of MPR requires that a minimum number of countries ratify the agreement before it becomes effective, as was incorporated in the Kyoto Protocol (Altamirano-Cabrera, Wangler, Weikard and Kroll, 2013), and the MPR in our two-country model is equivalent to full cooperation between the two nations. In the same way to the argument above, the introduction of an MPR essentially transforms a social dilemma game into a coordination game where cooperation constitutes the dominant strategy solution.

Provided that such a reasoning is legitimate, an immediate question would be why we often find it difficult for nations to cooperate in an international environmental issue and even witness a defection of a major nation from a high-profile international environmental agreement? To answer this question, we include the effects of domestic lobbying in the picture. Lobbying is almost universally a legal activity in modern democracies and is considered to be a means for a policymaker to gather information on the preferences of the general public. On the other hand, lobbying can provide an opportunity for only politically motivated and often privileged citizens to sway policymaker's decision-makings toward their own political interests, which sometimes conflict with the welfare of the general public.

Recently, it has been suggested in the environmental economics literature that lobbying activities have significant impacts on the formation of international environmental agreements and also on the national environmental policy (Habra and Winkler, 2012,

[3]There are several proposed rationales that this is the case (see, for instance, Buchner, Carraro, and Cercosimo, 2002, and Böhringer and Vogt, 2004).

Hagen, Altamirano-Cabrera and Weikard, 2016, and Marchiori, Dietz and Tavoni, 2017). These studies portray strategic interactions featuring domestic lobbying activities as a "common agency" game between multiple lobbyists as principals and a single policymaker as an agent, which has been popularized mainly in the international trade and public economics arenas by Grossman and Helpman (1994 and 2001), following the seminal work of Bernheim and Whinston (1986).

In this paper, we derive a political equilibrium of the same spirit among a policymaker and environmental and industrial interest groups, and, based on this outcome, examine whether a cooperative international agreement can be signed and sustained by the policymakers of the two nations or not. In particular, we consider two different types of lobbying, depending on its timing. The first type of lobbying takes place at the occasion of signing the cooperative agreement, and the second takes place afterward when each nation chooses its own emission level in the cases where the agreement was not signed or if the other country has subsequently reneged on its cooperative promise. The framework where these two stage games are played sequentially is similar to Hagen et al. (2016) and Marchiori et al. (2017), but they do not consider a situation where lobbying activities take place at the both stages, and, more significantly, do not explore the differences in the effects of the lobbying activities at these two stages and the consequences of their interplay.

Our analytical result indicates that, depending on their timing, lobbying activities have very different implications with respect to their impacts on the resulting equilibrium outcomes. The lobbying activities at the non-cooperative emission choice stage have a detrimental effect in terms of posing an obstacle to a successful cooperative agreement, whereas the lobbying activities at the agreement-signing stage always promote the cooperation under certain assumptions. Furthermore, when the lobbying activities at the non-cooperative stage can potentially prevent the signing of the agreement, the additional lobbying opportunity at the signing stage helps recuperate the cooperative agreement. We also illustrate that introducing asymmetry in the lobby organization rates between the two opposing interests within each nation has qualitatively different implications, depending on the timing of lobbying activities.

In section 2, we set up a non-cooperative game theoretical model of a bilateral inter-

national environmental agreement which incorporates lobbying competitions within each country. In the ensuing section, we derive the equilibrium outcomes of the model, particularly focusing on the timings of possible lobbying activities, and examine their effects on the signing of a cooperative agreement. In section 4, we discuss the implications of introducing asymmetries among nations and lobbyists. The final section concludes the paper.

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2 The Model

In this section, we set up an analytical model with two symmetric countries, i and j. In each country, there is a national government which is assumed to be represented by a single policymaker. The policymaker is typically considered as a ruling party of the nation, and the policymaker is concerned with the social welfare of the general public of that country partly because it would affect the prospect of his or her re-election. For simplicity, we suppose that the policymakers make their decisions concerning a particular international environmental issue we are focusing on, independently of the other political agendas.

In each country, there exist producers and consumers of goods which emit a particular pollutant in their production and/or consumption, and they respectively derive the benefits of the pollutant emissions in a country i, denoted by e_i, during their production and consumption processes in terms of cost savings, for example. We write the benefit of the pollutant emission, in the aggregate, as $B_i(e_i)$ for country i. As for a type of the pollution issue, we consider a case of global pollution, and suppose that the magnitude of environmental damages in country i from this pollution problem is determined simply by the sum of the amounts of the pollutant emitted by the two countries, i.e., $e_i + e_j$. We denote the damage cost of country i by $D_i(e_i, e_j)$. Thus, the social welfare of the citizens in country i, $W_i(e_i, e_j)$, is given by

$$W_i(e_i, e_j) = B_i(e_i) - D_i(e_i, e_j). \tag{1}$$

Following the standard assumption in the literature (c.f., Hagen et al., 2016, and Marchiori et al., 2017), we suppose that the benefit function is quadratic in e_i as follows:

$$B_i(e_i) = \alpha e_i - \frac{1}{2}\beta e_i^2, \tag{2}$$

where α and β are both positive parameters. On the other hand, the damage cost of country i is assumed to be linear in the total pollutant emissions of the two counties, $e_i + e_j$:

$$D_i(e_i, e_j) = \delta(e_i + e_j), \tag{3}$$

where $\delta(> 0)$ is the constant marginal damage cost of the pollutant. Admittedly, this assumption is rather restrictive in that it causes the marginal damage cost to be independent of the emission levels of both countries i and j, which significantly reduces the depth of strategic interactions between the two nations. Nonetheless, we suppose this particular functional form as it makes our results comparable to the ones in the literature and, more importantly, it renders the following analysis much more tractable and allows us to focus on the effects of lobbying activities. We also assume throughout this paper that the parameters, α, β and δ, are symmetric across the countries. Thus, except for certain political parameters which we introduce below, these two countries share the same environmental and economic characteristics.

Let us first consider the case where the policymaker of each country maximizes its domestic social welfare defined in (1) by choosing its own emission level, e_i, while taking the other country's emission level, e_j, as given. Such a non-cooperative emission level, e_i^N, can be easily obtained as

$$e_i^N = \frac{\alpha - \delta}{\beta}. \tag{4}$$

If the two countries can cooperate and coordinate their respective emission levels so that the joint social welfare of the two symmetric counties is maximized, such a cooperative emission level, $e_i^C (= e_j^C)$, is given by

$$e_i^C = \frac{\alpha - 2\delta}{\beta}. \tag{5}$$

Starting from the next section where we consider the possibility of implementing a co-

operative agreement between the nations, we consider that e_i^C is the level of abatement required in the agreement. This assumption reflects a possible scenario that, upon signing an international agreement, the participating countries will face emission quotas proposed by an international scientific body, such as the Intergovernmental Panel on Climate Change (IPCC) for the global warming problem.

The setups of the underlying environmental and economic situations up to this point render the agreement-signing choices by the policymakers of the two nations a standard Prisoners' Dilemma if the signing decision is irreversible and no country can renege on its cooperative promise later on. As we discussed in Introduction, however, we consider that it is quite probable for a country to renege on its original cooperative promise in international environmental issues, as was exemplified in the case of climate change negotiations, and also that it is plausible that a country's defection from the cooperation is immediately detected by the other country and leads to a weakening of the efforts made by the other country, and even to a collapse of the entire agreement. This consideration essentially transforms a Prisoner's Dilemma situation into a type of a coordination game in the absence of other elements such as domestic lobbying activities, as we will see in the next section.

Now, we introduce lobbyists in respective countries into the model. In each nation, we suppose that there exist one industrial (indexed by a superscript P) and one environmental (G) lobbies which are both concerned only with their own welfare.[4] The payoff of the industrial lobby in country i excluding the potential lobby contributions, $R_i^P(e_i)$, is given by

$$R_i^P(e_i) = \omega_i^P B_i(e_i), \tag{6}$$

where $\omega_i^P \in [0,1]$ denotes the organization ratio of the industrial lobby and indicates how much of the benefit from emitting the pollutant is represented by this lobbyist in country i.[5] In an extreme case, if $\omega_i^P = 1$, the benefit of pollution that could fall on both

[4]How lobbyists organize themselves in the first place is in itself an intriguing research question. In his early survey of the literature, Persson (1998) considers exogenous supposition of lobby groups a crucial and difficult question to which there is no satisfactory answer. In his more recent survey, van Winden (2008) considers it one of strong assumptions of existing common agency models to suppose that "interest groups are exogenously given, of fixed size and are assumed to behave as unitary actors." For simplicity, though, we take the above structure of lobby organizations for granted in this article.

[5]Thus, the industrial lobby can include not only the producers of the pollution emitting products but

producers and consumers of the associated products is fully reflected in the lobbying activities of the industrial lobbyist.

Since we suppose that the environmental lobby is concerned primarily with the status of the environment and not particularly with the source of the pollution, its payoff excluding the potential lobby contributions, $R_i^G(e_i, e_j)$, depends not only on the emission level of country i but also on the emission level of the other country and is written as

$$R_i^G(e_i, e_j) = -\omega_i^G D_i(e_i, e_j), \tag{7}$$

where $\omega_i^G \in [0, 1]$ is the organization ratio of the environmental lobby.

In the presence of lobbying contributions, the payoffs of the policymaker is given by the weighted sum of the social welfare of its own citizens, given by $W_i(e_i, e_j)$, and the amount of contributions provided by the lobbyists. We suppose that the parameter, $\theta_i \in [0, \frac{1}{2}]$, is the weight attached to the social welfare, net of the contributions by the lobbies, and $(1 - \theta_i)$ is the weight attached to the contribution amounts in the mind of the policymaker.[6] Our setup indicates that a decrease in θ_i represents an increase in the susceptibleness of country i's policymaker to lobby contributions.

Let us suppose that the policymaker obtains the total contribution amount of c from the lobbyists. Noting that the contributions by the domestic lobbyists imply a decrease in the net welfare of the citizens by the same amount, the policymaker's payoff function can be written as

$$\theta_i \{W_i(e_i, e_j) - c\} + (1 - \theta_i) c = \theta_i W(e_i, e_j) + (1 - 2\theta_i) c. \tag{8}$$

As for strategic interactions between the two national policymakers, we consider a two-stage dynamic game, following Habra and Winkler (2012), Hagen et al. (2016), and Marchiori et al. (2017). In the first stage, the policymakers of the two countries respectively choose whether to sign a cooperative international agreement or not. Only when both countries' policymakers choose to sign the agreement and stick to its terms, the

also their consumers.

[6] We suppose that the maximum possible value of the parameter θ_i is $\frac{1}{2}$ since, if θ_i exceeds $\frac{1}{2}$, the policymaker values the welfare of the citizens higher than the lobby contributions, and so never accepts any contributions from lobby groups.

cooperative treaty is officially implemented. In the event that the cooperative agreement was not signed by the two countries or if one of the countries has reneged on its promised emission level, the game proceeds to the subsequent stage where the policymaker of each nation decides on its own emission level independently of the other nation.

Concerning the lobbying activities, we suppose two different possible occasions when the lobbyists propose their contribution schedules which directly depend on the actions taken by the policymaker of its own country. The first type of lobbying can take place at the timing of a policymaker's deciding on whether to sign an international cooperative agreement or not, and the second takes place afterward when each nation chooses its own emission level if the agreement was not signed or if the other country has reneged on its promise. We refer to the first possible lobbying occasion as the "signing stage" and the second as the "non-cooperative stage." In the next section, focusing on the case of two countries with identical characteristics, we identify the equilibrium outcomes of different institutional settings which are defined by the four cases depending on whether lobbying activities are possible or not at the signing and non-cooperative stages.

3 Analysis of the Political Equilibrium

3.1 Benchmark Case: No Lobbying

If there is no lobbying activity at both the signing and non-cooperative stages, the payoff matrix for the policymaker of country i at the signing stage looks as follows:

		Country j	
		Sign	*Not Sign*
Country i	*Sign*	$W_i(e_i^C, e_j^C)$	$W_i(e_i^N, e_j^N)$
	Not Sign	$W_i(e_i^N, e_j^N)$	$W_i(e_i^N, e_j^N)$

Figure 1: The policymaker's payoffs without any lobbying activities

Here, the respective payoffs are computed by inserting (4) and (5) into (1) under (2) and (3):

$$W_i(e_i^N, e_j^N) = \frac{(\alpha - \delta)(\alpha - 3\delta)}{2\beta}, \tag{9}$$

and

$$W_i(e_i^C, e_j^C) = \frac{(\alpha - 2\delta)^2}{2\beta}. \tag{10}$$

In assigning the payoffs to each outcome in Figure 1, we have supposed that the cooperation entails the achievement of the joint welfare maximization and also that a country can immediately detect a defection by the other country and, if it wishes, can costlessly switch its choice of emissions (similarly to d'Aspremont, Jacquemin, Gabszewicz and Waymark, 1983). Since $W_i(e_i^C, e_j^C) - W_j(e_i^N, e_j^N) = \frac{\delta^2}{2\beta} > 0$, "*Sign*" is, indeed, the weakly dominant strategy for country j of the game in Figure 1. The same is true for country j as well. Hence, the game at the signing stage is essentially a coordination game, and the most plausible equilibrium outcome of this game is for both countries to sign the cooperative agreement, and cooperation will be sustained if each nation recognizes that one's defection would lead to an immediate collapse of the agreement.[7] It should be noted that this result holds, irrespective of the values of the environmental parameters, α, β and δ.

3.2 Lobbying Only at the Signing Stage

Now we introduce the lobbying activities. In this subsection, we consider the possibility of lobbying only at the agreement-signing stage. Within this stage, lobbyists and the policymaker play a sequential game where the respective lobbyists offer to the policymaker fully-committed contribution schedules, which depend on the subsequent policy decision made by the policymaker, and then the policymaker chooses whether or not to join the cooperative international environmental agreement.

As for the payoffs, the industrial lobby always prefers the non-cooperative outcome to the cooperative outcome, and, therefore, has an incentive to promise some contribution to the policymaker only when he/she does not sign up for the cooperative agreement. Let us suppose that the industrial lobby provides the policymaker with the contribution amount of N_i only for the choice of "*Not Sign*". In such a case, the lobbyist's net payoff, $U_i^P(e_i, N_i)$, becomes

[7] Following the convention, throughout the paper, we dismiss Nash equilibria which are only attainable by weakly dominated strategies of the both players.

$$U_i^P(e_i, N_i) = \omega_i^P B_i(e_i) - N_i, \tag{11}$$

whereas, if the policymaker signs the agreement, the industrial lobby's payoff is given by (6) since it does not supply any contribution.[8]

On the other hand, the environmental lobby always prefers the cooperative outcome to the non-cooperative outcome, and is willing to pay some contribution only when the cooperative agreement is signed by its own government. If the lobby provides the policymaker with the contribution amount of S_i for the choice of "*Sign*", the environmental lobbyist's net payoff, $U_i^G(e_i, e_j, S_i)$, is

$$U_i^G(e_i, e_j, S_i) = -\omega_i^G D_i(e_i, e_j) - S_i, \tag{12}$$

and, if the policymaker does not sign the agreement or reneges on its promise to cooperate before the other nation does, the environmental lobby's payoff is given by (7).

Here, we assume that the provision of the contributions by the lobbyists at the signing stage depends solely on the behavior of its own policymaker, and not the actual emission level that the country undertakes eventually. Especially, when country i has signed the cooperative agreement but it subsequently implements the non-cooperative action due to the other country's non-signing or defection from the agreement, the environmental lobby still provides the policymaker of country i with a promised contribution amount of S_i.[9]

As we defined in the previous section, the payoff of the policymaker is given by (8) in the presence of the contribution amount of c. Here, c is one of N_i and S_i, depending on the policymaker's actual decision. Then, the payoff matrix for the policymaker of country i at the signing stage looks as follows:

[8] As is usually the case with the literature, we suppose that it is impossible for a lobbyist to provide a negative amount of lobby contribution.

[9] The alternative assumption, i.e., supposing that the environmental lobby withholds the contribution in the case of non-cooperation initiated by the other country, is also plausible. In such a case, the outcome (*Not Sign*, *Not Sign*) will always be a Nash equilibrium of the game in Figure 2. Still, we have the other Pareto-dominating Nash equilibrium, i.e., (*Sign*, *Sign*), under $\omega_i^G = \omega_i^P$, as we argue below. This observation also applies to the case where lobbying activities are possible at both signing and non-cooperative stages.

		Country j: *Sign*	Country j: *Not Sign*
Country i	*Sign*	$\theta_i W_i(e_i^C, e_j^C) + (1-2\theta_i)\, S_i$	$\theta_i W_i(e_i^N, e_j^N) + (1-2\theta_i)\, S_i$
	Not Sign	$\theta_i W_i(e_i^N, e_j^N) + (1-2\theta_i)\, N_i$	$\theta_i W_i(e_i^N, e_j^N) + (1-2\theta_i)\, N_i$

Figure 2: The policymaker's payoffs with lobbying activities only at the signing stage

In order to derive the equilibrium outcome of this signing stage, we first identify the maximum amounts of respective lobbyists' contributions that are contingent on the choice made by the policymaker of each country. Let us define $\bar{N}_i$ to be the industrial lobby's maximum willingness to pay to get its policymaker not to sign the cooperative agreement. The value of $\bar{N}_i$ is given by the difference between the lobbyist's payoff under the non-cooperative regime and its payoff under the cooperative agreement, i.e., $\omega_i^P B_i(e_i^N) - \omega_i^P B_i(e_i^C)$. Here, we obtain

$$\bar{N}_i = \omega_i^P \cdot \frac{3\delta^2}{2\beta}. \tag{13}$$

Let us also define $\bar{S}_i$ to be the environmental lobby's maximum willingness to pay to get the policymaker to sign the cooperative agreement. As opposed to $\bar{N}_i$, $\bar{S}_i$ is given by the difference between the lobbyist's payoff under the cooperative agreement and its payoff under the non-cooperative regime, i.e., $\omega_i^G D_i(e_i^N, e_j^N) - \omega_i^G D_i(e_i^C, e_j^C)$.[10] Then, we obtain

$$\bar{S}_i = \omega_i^G \cdot \frac{2\delta^2}{\beta}. \tag{14}$$

For the time being, we suppose $\omega_i^G = \omega_i^P$ as a benchmark case, and write $\omega_i^G = \omega_i^P = \omega_i \in [0, 1]$. Thus, the value of ω_i indicate how significantly citizens of country i is generally involved in this policy-making process through their lobbying activities. In 4.2, we discuss the alteration of this symmetry assumption. Under this assumption, we have

$$\bar{S}_i - \bar{N}_i = \omega_i \cdot \frac{\delta^2}{2\beta} > 0, \tag{15}$$

which implies that the environmental lobby always has a higher maximum willingness to pay for the lobby contribution at the signing stage than the industrial lobby does.

[10]Here, we consider that the two countries are completely symmetric and thus, $e_i^N = e_j^N$ and $e_i^C = e_j^C$.

Since $W_i(e_i^C, e_j^C) > W_i(e_i^N, e_j^N)$ and $\theta_i \in [0, \frac{1}{2}]$, therefore, the following inequality necessarily holds:

$$\theta_i W_i(e_i^C, e_j^C) + (1 - 2\theta_i)\,\bar{S}_i \geq \theta_i W_i(e_i^N, e_j^N) + (1 - 2\theta_i)\,\bar{N}_i. \tag{16}$$

The above inequality implies that, any $N_i(\leq \bar{N}_i)$ chosen by the industrial lobby will be successfully overwhelmed by some $S_i(\leq \bar{S}_i)$, inducing the policymaker to sign the agreement as the unique Nash equilibrium of the game in Figure 2.[11] Thus we can state the following:

Proposition 1. *Under $\omega_i^G = \omega_i^P$, the lobbying at the signing stage alone would never disrupt the international environmental agreement.*

To be more exact, the actual outcome of the unique subgame-perfect Nash equilibrium of the signing stage is given by the promised contribution amounts of $\omega_i \cdot \frac{3\delta^2}{2\beta}$ and $\frac{3\omega_i(1-2\theta_i)-\theta_i}{1-2\theta_i} \cdot \frac{\delta^2}{2\beta}$ by the industrial and environmental lobbies, respectively, and the policymaker's signing the cooperative agreement.

3.3 Lobbying Only at the Non-cooperative Stage

If a cooperative agreement is rejected or reneged by one of the two countries afterward, the game enters the "non-cooperative" stage, where the policymaker of each nation choose its own emission level independently of the other country. In order to obtain a sharp prediction on the outcome of this stage game, we focus on a so-called compensating equilibrium,[12] as is also the case with previous studies (Habra and Winkler, 2012, Hagen et al., 2016, and Marchiori et al. 2017). A compensating equilibrium is based on the idea that, if there were a change in the policy, the change in contribution should compensate a

[11] It is also true under $\omega_i^G = \omega_i^P$ that $\theta_i W_i(e_i^N, e_j^N) + (1 - 2\theta_i)\,\bar{S}_i \geq \theta_i W_i(e_i^N, e_j^N) + (1 - 2\theta_i)\,\bar{N}_i$.

[12] This equilibrium concept was originally called a truthful equilibrium, following the seminal work of Bernheim and Whinston (1986), and used widely under its original name (Grossman and Helpman, 1994). The term "compensating" reflects the relationship between the contribution level and the economic concept of Hicksian compensating variation. Grossman and Helpman (2001) provide some rationales in focusing on the compensating equilibrium in a more general setting, such as its characteristics of being uniquely both Pareto-efficient and coalition-proof.

lobbyist for that change in the policy, so that its payoff remains the same. The derivation of the compensating equilibrium is detailed in Grossman and Helpman (1994) and Grossman and Helpman (2001), and we adapt their procedure to the issue of international environmental pollution.[13]

Similarly to the agreement-signing stage in the previous subsection, the two lobbyists and the policymaker play a sequential game within the non-cooperative stage. At the beginning of the non-cooperative stage, the two lobbies respectively present their own contribution schedules to the policymaker of their own country. Such schedules are given by $C_i^P(e_i)$ for the industrial lobby and $C_i^G(e_i)$ for the environmental lobby. These contribution schedules are based only on the domestic emission level chosen subsequently by the policymaker, and their provisions are fully committed by the lobbies. Such contributions can benefit the policymaker in several ways, including helping him/her to be reelected in the next election. Thus, the policymaker's payoff only for the non-cooperative stage with lobbying, denoted by $Z_i(e_i, e_j)$, is written as

$$Z_i(e_i, e_j) = \theta_i \left(B_i(e_i) - D_i(e_i, e_j) - C_i^P(e_i) - C_i^G(e_i) \right) + (1 - \theta_i) \left(C_i^P(e_i) + C_i^G(e_i) \right), \tag{17}$$

where $\theta_i \in [0, \frac{1}{2}]$ is the weight attached to the social welfare, net of the contributions by the lobbyists, and $(1 - \theta_i) \in [\frac{1}{2}, 1]$ is the weight attached to the contribution amounts.

In the political equilibrium, whose emission levels are denoted by e_i^L and e_j^L for the respective nations, the equilibrium outcome must be jointly efficient for the government

[13] In fact, political equilibrium concepts used in the two most closely related studies to this paper are somewhat different from the "compensating" equilibrium defined in Grossman and Helpman (2001). Hagen et al. (2016) suppose that their industrial lobby's reservation payoff is given by the payoff associated with the fully cooperative emission level, arguing that the industrial lobby calculates with the worst case scenario as a benchmark since it does not know the true emission level in the absence of its lobby activities. As for the environmental lobby, they suppose the reservation payoff is the one associated with a business-as-usual scenario, again assuming the worst case possible for this particular lobbyist. Similarly, Marchiori et al. (2017) consider that the policymaker has the power to extract all the surplus from the lobbies, arguing that the assumption of such reservation payoffs is natural when there are two or more lobbies competing domestically with one another. In these two models, consequently, in order to derive the equilibrium contribution by a certain lobbyist, the lobbyist is made indifferent between the political equilibrium and the potential case where a policymaker chooses a policy outcome in the absence of any contribution from this particular lobby alone. However, in a compensating equilibrium proposed by Grossman and Helpman (2001), it is a policymaker who is made indifferent between the equilibrium outcome and each case where one of the lobbies is missing from a list of contributors. We detail their procedure below in order to sort out the differences.

and the two lobbies.[14] In order to derive such an emission level, let us fix the payoffs of the lobbies at certain pre-determined levels. In particular, the two lobby groups respectively achieve the payoffs of $U_i^P(e_i^L, C_i^P(e_i^L))$ and $U_i^G(e_i^L, e_j^L, C_i^G(e_i^L))$ in the political equilibrium. Thus, we use the following equality as the constraint in the problem to find the jointly efficient emission level:

$$C_i^P(e_i)+C_i^G(e_i) = \omega_i^P B_i(e_i) - U_i^P(e_i^L, C_i^P(e_i^L)) - \omega_i^G D_i(e_i, e_j^L) - U_i^G(e_i^L, e_j^L, C_i^G(e_i^L)). \quad (18)$$

Inserting (18) into (17), the policymaker's payoff under this constraint becomes

$$\begin{aligned} Z_i(e_i, e_j^L) = &\left\{\theta_i + (1-2\theta_i)\,\omega_i^P\right\} B_i(e_i) - \left\{\theta_i + (1-2\theta_i)\,\omega_i^G\right\} D_i(e_i, e_j^L) \\ &+ (1-2\theta_i)\left(U_i^P(e_i^L, C_i^P(e_i^L)) + U_i^G(e_i^L, e_j^L, C_i^G(e_i^L))\right). \end{aligned} \quad (19)$$

The first-order condition for maximizing (19) with respect to e_i under (2) and (3) is

$$\left\{\theta_i + (1-2\theta_i)\,\omega_i^P\right\}(\alpha - \beta e_i) - \left\{\theta_i + (1-2\theta_i)\,\omega_i^G\right\}\delta = 0. \quad (20)$$

Solving (20) for e_i, we obtain the following jointly-efficient level of emissions, e_i^L, which arises in the political equilibrium of this common agency game under lobbying activities:[15]

$$e_i^L = \frac{\alpha}{\beta} - \frac{\left\{\theta_i + (1-2\theta_i)\,\omega_i^G\right\}\delta}{\left\{\theta_i + (1-2\theta_i)\,\omega_i^P\right\}\beta}. \quad (21)$$

It can be easily seen that e_i^L coincides with e_i^N in (4) if industrial and environmental interests are represented in the exactly same proportion, i.e., $\omega_i^P = \omega_i^G$.

Now, we identify the contribution amounts, i.e., $C_i^P(e_i^L)$ and $C_i^G(e_i^L)$, in this political equilibrium of the non-cooperative stage. Since we suppose that the two countries are completely symmetric concerning the benefits and costs of the pollutant emissions and also that the marginal damage cost is constant, the resulting equilibrium emission levels are the same between the two countries, that is, $e_i^L = e_j^L$, and furthermore they both equal to e_i^N given in (4).

With the lobby contribution, the payoff of the environmental lobby in country i in

[14] The proof can be found at pages 268-269 of Grossman and Helpman (2001).

[15] Throughout the paper, the superscript L indicates the values of variables in the political equilibrium.

this equilibrium of the non-cooperative stage game can be written as

$$U_i^G(e_i^L, e_j^L, C_i^G(e_i^L)) = -\omega_i^G D_i(e_i^L, e_j^L) - C_i^G(e_i^L). \tag{22}$$

Following Grossman and Helpman (2001), we define the compensating contribution schedule to be the one that coincides with a lobbyist's indifference curve through the political equilibrium whenever the contribution amount is positive. The contribution amount is simply zero elsewhere in the compensating schedule. In particular, the compensating contribution schedule of the environmental lobby, denoted by $H_i^G(e_i)$, is

$$H_i^G(e_i) = \max\left\{-\omega_i^G D_i(e_i, e_j^L) - U_i^G(e_i^L, e_j^L, C_i^G(e_i^L)), 0\right\}. \tag{23}$$

On the other hand, the payoff of the industrial lobby in the political equilibrium of the non-cooperative stage game equals

$$U_i^P(e_i^L, C_i^P(e_i^L)) = \omega_i^P B_i(e_i^L) - C_i^P(e_i^L). \tag{24}$$

Similarly to the environmental lobby above, the compensating contribution schedule of the industrial lobby, $H_i^P(e_i)$, can be defined as

$$H_i^P(e_i) = \max\left\{\omega_i^P B_i(e_i) - U_i^P(e_i^L, C_i^P(e_i^L)), 0\right\}. \tag{25}$$

Given the above information, we can find the policy that the policymaker would choose in the absence of contribution from the environmental lobby, e_i^{-G}. In this case, the policymaker would maximize a weighted sum of the net social welfare and the contribution from the industrial lobby alone.[16] This maximization problem leads to

$$e_i^{-G} = \frac{1}{\beta}\left(\alpha - \frac{\theta_i \delta}{\theta_i + (1 - 2\theta_i)\,\omega_i^P}\right). \tag{26}$$

The relationship between the political equilibrium and e_i^{-G} is graphically illustrated in Figure 3.

[16] In deriving e_i^{-G}, the weight attached to the net social welfare is still θ_i while the weight attached to the contribution from the industrial lobby is $1 - \theta_i$, just as in the case of multiple lobbies above. This applies to the derivation of the contribution of the industrial lobby below as well.

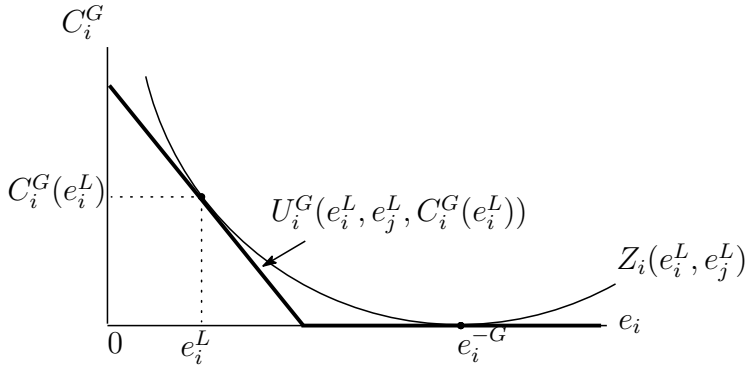

Figure 3: The political equilibrium and the emission level without the environmental lobby

In Figure 3, we have the level of emission on the horizontal axis and the contribution by the environmental lobby on the vertical axis. The indifference curves for the policymaker and the environmental lobby through the political equilibrium are shown as the lines indexed by $Z_i(e_i^L, e_j^L)$ and $U_i^G(e_i^L, e_j^L, C_i^G(e_i^L))$, respectively. The compensating contribution schedule of the environmental lobby, $H_i^G(e_i)$, is given by the bold line. In particular, the contribution level of the environmental lobby in the political equilibrium is $C_i^G(e_i^L)$.

In such an equilibrium, the environmental lobby must give a sufficient contribution to ensure that the policymaker chooses e_i^L, instead of e_i^{-G}. Denoting the payoff of the policymaker in the absence of the environmental lobby by $Z_i^{-G}(e_i, e_j)$, therefore, $Z_i^{-G}(e_i^{-G}, e_j^L) = Z_i(e_i^L, e_j^L)$ must hold. In other words, at the political equilibrium, we have

$$\begin{aligned} &\theta_i \left(B_i(e_i^{-G}) - D_i(e_i^{-G}, e_j^L)\right) + (1-2\theta_i)\left(\omega_i^P B_i(e_i^{-G}) - U_i^P(e_i^L, C_i^P(e_i^L))\right) \\ &\quad = \theta_i \left(B_i(e_i^L) - D_i(e_i^L, e_j^L)\right) + (1-2\theta_i)\left(C_i^P(e_i^L) + C_i^G(e_i^L)\right), \end{aligned} \tag{27}$$

which leads to[17]

$$\begin{aligned} (1-2\theta_i)\, C_i^G(e_i^L) = \theta_i &\left(B(e_i^{-G}) - B_i(e_i^L) - D_i(e_i^{-G}, e_j^L) + D_i(e_i^L, e_j^L)\right) \\ &+ (1-2\theta_i)\,\omega_i^P \left(B(e_i^{-G}) - B_i(e_i^L)\right), \end{aligned} \tag{28}$$

Using the specific benefit and damage cost functions, i.e., (2) and (3), (28) can be written

[17]Here, we make use of the fact $C_i^P(e_i) = \omega_i^P B_i(e_i) - U_i^P(e_i^L)$ whenever $C_i^P(e_i) > 0$.

as[18]

$$\begin{gathered}(1-2\theta_i)\,C_i^G(e_i^L)= \\ \left(e_i^{-G}-e_i^L\right)\left[\alpha\left\{\theta_i+(1-2\theta_i)\,\omega_i^P\right\}-\tfrac{\beta}{2}\left\{\theta_i+(1-2\theta_i)\,\omega_i^P\right\}\left(e^{-G}+e_i^L\right)-\theta_i\delta\right],\end{gathered} \tag{29}$$

where e_i^{-G} is the potentially chosen emission level in the absence of the environmental lobby and specifically given by (26). From (29), we can obtain

$$C_i^G(e_i^L)=\frac{\delta^2}{2\beta}\cdot\frac{(1-2\theta_i)\,\omega_i^P}{\theta_i+(1-2\theta_i)\,\omega_i^P}. \tag{30}$$

From (30), we can see $\frac{\partial C_i^G(e_i^L)}{\partial \omega_i^P}>0$, which implies that an increase in the organization ratio of the industrial lobby leads to an increase in the equilibrium contribution amount by the environmental lobby. When the stake of the other lobby group increases, the environmental lobbyist needs to exert more efforts to offset the other group's increased willingness to pay for the lobby contribution.

We can also find the policy that the policymaker would choose in the absence of contribution from the industrial lobby, e_i^{-P}. In this case, the policymaker would maximize a weighted sum of the social welfare and the contribution from the environmental lobby alone. This maximization problem leads to

$$e_i^{-P}=\frac{1}{\beta}\left\{\alpha-\left(1+\frac{1-2\theta_i}{\theta_i}\omega_i^G\right)\delta\right\}. \tag{31}$$

In a similar way to Figure 3, the relationship between the political equilibrium and e_i^{-P} is depicted in Figure 4.

[18]We can confirm that the value of $C_i^G(e_i^L)$ is strictly positive.

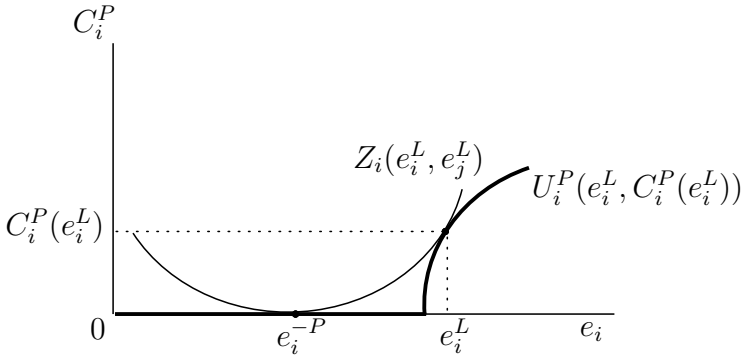

Figure 4: The political equilibrium and the emission level without the industrial lobby

The indifference curves for the policymaker and the industrial lobby through the political equilibrium are depicted as $Z_i(e_i^L, e_j^L)$ and $U_i^P(e^L, C_i^P(e_i^L))$, respectively. Also, the compensating contribution of the industrial lobby, $H_i^P(e_i)$, is given by the bold line. The industrial lobby must give a sufficient contribution, $C_i^P(e_i^L)$, to ensure that the policymaker chooses e_i^L, instead of e_i^{-P}. Denoting the payoff of the policymaker in the absence of the industrial lobby by $Z_i^{-P}(e_i, e_j)$, therefore, $Z_i^{-P}(e_i^{-P}, e_j^L) = Z_i(e_i^L, e_j^L)$ must hold, which is equivalent to

$$\begin{aligned} &\theta_i \left(B_i(e_i^{-P}) - D_i(e_i^{-P}, e_j^L)\right) + (1-2\theta_i)\left(-\omega_i^G D_i(e_i^{-P}, e_j^L) - U_i^G(e_i^L, e_j^L, C_i^G(e_i^L))\right) \\ &\quad = \theta_i \left(B_i(e_i^L) - D_i(e_i^L, e_j^L)\right) + (1-2\theta_i)\left(C_i^P(e_i^L) + C_i^G(e_i^L)\right), \end{aligned} \tag{32}$$

which leads to[19]

$$\begin{aligned} (1-2\theta_i)\, C_i^P(e_i^L) &= \theta_i \left(B(e_i^{-P}) - B_i(e_i^L) - D_i(e_i^{-P}, e_j^L) + D_i(e_i^L, e_j^L)\right) \\ &\quad + (1-2\theta_i)\, \omega_i^G \left(D_i(e_i^L, e_j^L) - D_i(e_i^{-P}, e_j^L)\right), \end{aligned} \tag{33}$$

Using the benefit and damage cost functions, i.e., (2) and (3), (33) can be written as[20]

$$\begin{aligned} &(1-2\theta_i)\, C_i^P(e_i^L) = \\ &\left(e_i^L - e_i^{-P}\right)\left[-\theta_i\alpha + \tfrac{\theta_i\beta}{2}(e_i^L + e_i^{-P}) + \left\{\theta_i + (1-2\theta_i)\,\omega_i^G\right\}\delta\right], \end{aligned} \tag{34}$$

where e_i^{-P} is the potentially chosen emission level in the absence of the industrial lobby

[19]Here, we make use of the fact $C_i^G(e_i) = -\omega_i^G D_i(e_i, e_j^L) - U_i^G(e_i^L, e_j^L)$ whenever $C_i^G(e_i) > 0$.

[20]We can confirm that the value of $C_i^P(e_i^L)$ is indeed strictly positive.

and specifically given by (31). From (34), we obtain

$$C_i^P(e_i^L) = \frac{1-2\theta_i}{2\beta\theta_i}\left(\omega_i^G\delta\right)^2. \tag{35}$$

From (30), we can easily see $\frac{\partial C_i^P(e_i^L)}{\partial \omega_i^G} > 0$, as is the case for $C_i^G(e_i^L)$ above.

In this section, we suppose that the two countries are exactly symmetric with respect to the two political parameters, namely, $\theta_i = \theta_j \in [0, \frac{1}{2}]$ and $\omega_i = \omega_j \in [0, 1]$. Then, the political equilibrium under lobbying activities by the two lobbyists is given by the emission level of (21) and the contribution amounts of (30) and (35). By substituting, (21), (30) and (35) into (17) and considering $\theta_i = \theta_j$ and and $\omega_i^P = \omega_i^G = \omega_i = \omega_j$, the policymaker's payoff in the political equilibrium, $Z_i(e_i^L, e_j^L)$, is given as follows:

$$Z_i(e_i^L, e_j^L) = \theta_i\frac{(\alpha-\delta)(\alpha-3\delta)}{2\beta} + (1-2\theta_i)\left\{\frac{1-2\theta_i}{2\beta\theta_i}\omega_i^2\delta^2 + \frac{\delta^2}{2\beta}\cdot\frac{(1-2\theta_i)\theta\omega_i}{\theta_i+(1-2\theta_i)\omega_i}\right\}, \tag{36}$$

where the first equality reflects the fact that $e_i^L = e_j^L = e_i^N$ under our assumption in this section that the political parameters are symmetric across the two countries, i.e., $\omega_i^P = \omega_i^G = \omega_i = \omega_j$ and $\theta_i = \theta_j$.

Given what will subsequently happen in the non-agreement stage, the payoff matrix for the policymaker of country i at the agreement-signing stage, when there is no lobbying activity at the signing stage, looks as follows:

		Country j	
		Sign	*Not Sign*
Country i	*Sign*	$\theta_i W_i(e_i^C, e_j^C)$	$Z_i(e_i^L, e_j^L)$
	Not Sign	$Z_i(e_i^L, e_j^L)$	$Z_i(e_i^L, e_j^L)$

Figure 5: The policymaker's payoffs with lobbying activities only at the non-cooperative stage

From (10) and (36), $\theta_i W_i(e_i^C, e_j^C) \geq Z_i(e_i^L, e_j^L)$ if and only if

$$\theta_i\frac{\delta^2}{2\beta} \geq (1-2\theta_i)\frac{\delta^2}{2\beta}\left\{\frac{1-2\theta_i}{\theta_i}\omega_i^2 + \frac{(1-2\theta_i)\omega_i}{\theta_i+(1-2\theta_i)\omega_i}\right\}, \tag{37}$$

which can be rewritten as

$$\theta_i^2 \left\{\theta_i + (1-2\theta_i)\,\omega_i\right\} \geq (1-2\theta_i)^2 \left[\omega_i^2 \left\{\theta_i + (1-2\theta_i)\,\omega_i\right\} + \omega_i\theta_i\right]. \tag{38}$$

If the last condition holds, signing the cooperative agreement is still the weakly dominant strategy for the policymaker of country i. Otherwise, not signing the agreement or reneging on the agreement becomes the weakly dominant strategy. The combination of ω_i and θ_i that does not satisfy the condition (38) is graphically shown in Figure 6.

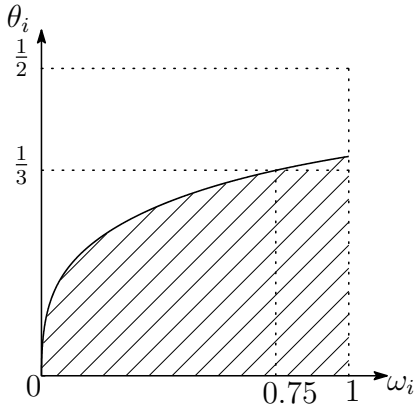

Figure 6: The region where the cooperative deal fails with lobbying at the non-cooperative stage

The inequality in (38) is violated when the combination of ω_i and θ_i falls inside the shaded region in Figure 6. Examining Figure 6, we can observe the following:

Proposition 2. *An increase in ω_i, as well as an decrease in θ_i, contributes to the disruption of the international environmental agreement when the lobbying takes place at the non-cooperative stages alone.*

When lobbying takes place at the signing stage as we examined in the previous subsection, lobbying was never a hindrance to successful cooperation for any $\theta_i \in [0, \frac{1}{2}]$ as long as $\omega_i^P = \omega_i^G$ holds, but, when lobbying occurs at the non-cooperative stage, the cooperative agreement cannot be sustained at $\theta_i = \frac{1}{3}$, for instance, if $\omega_i \geq 0.75$, i.e., the lobbies are sufficiently well-organized.

As was mentioned in Introduction, one popular defense of political lobbying activities

is their information transmission role (Grossman and Helpman, 2001). Without any lobbying activities the policymaker may find it more difficult to gauge $B_i(e_i)$ and $D_i(e_i, e_j)$ correctly. The above proposition suggests that, facing such an information acquisition need, if the political system can somehow restrict the opportunity of lobbying to one out of the two potential stages which we consider in this model, the society would be strictly better off by allowing lobbying to take place only at the signing stage and not at the non-cooperative emission-choice stage.

3.4 Lobbying at Both Stages

Finally, we consider the case where the lobbying activities can take place both at the signing stage and at the non-cooperative stage once the agreement fails.

What will potentially happen in the non-cooperative stage has already been identified in the previous subsection, and the contribution amounts in the signing stage do not affect the lobbyists' contribution behaviors in the non-cooperative stage since such contributions are essentially sunk costs for the two lobbyists at the non-cooperative stage. Thus, by denoting the amount of the lobby contribution provided by the environmental lobby at the signing stage for signing up for the cooperative agreement as S_i and the one provided by the industrial lobbyist for not signing as N_i, we have the payoff matrix for the policymaker of country i at the signing stage as follows:

		Country j	
		Sign	*Not Sign*
Country i	*Sign*	$\theta_i W_i(e_i^C, e_j^C) + (1-2\theta_i)\, S_i$	$Z_i(e_i^L, e_j^L) + (1-2\theta_i)\, S_i$
	Not Sign	$Z_i(e_i^L, e_j^L) + (1-2\theta_i)\, N_i$	$Z_i(e_i^L, e_j^L) + (1-2\theta_i)\, N_i$

Figure 7: The policymaker's payoffs with lobbying activities both at the signing and non-cooperative stages

In a similar manner to the case where lobbying activities are possible only at the signing stage, we can identify respective lobbyists' maximum willingness to pay for the two contribution amounts, S_i and N_i.

Considering the lobbies have to pay contributions at the subsequent non-cooperative stage as well if the game proceeds to that stage, the industrial lobby's maximum will-

ingness to pay for the choice of "*Not Sign*" by the policymaker is now given by $\bar{N}_i = \omega_i B_i(e_i^L) - \omega_i B_i(e_i^C) - C_i^P(e_i^L)$. Using the specific functional forms in this study, we can obtain[21]

$$\bar{N}_i = \frac{\omega_i \delta^2}{2\beta}\left(3 - \frac{1-2\theta_i}{\theta_i}\omega_i\right). \tag{39}$$

Clearly, this value is smaller than $\bar{N}_i$ of the case where lobbying was not possible at the non-cooperative stage, which is given by (13). Since the industrial lobby has to contribute $C_i^P(e_i^L)$ at the non-cooperative stage, its benefit of blocking the cooperative agreement at the signing stage is diminished by that amount.

On the other hand, the environmental lobby's maximum willingness to pay for the choice of "*Sign*" by the policymaker is $\bar{S}_i = -\omega_i D_i(e_i^C, e_j^C) - \left\{-\omega_i D_i(e_i^L, e_j^L) - C_i^G(e_i^L)\right\} = -\omega_i D_i(e_i^C, e_j^C) + \omega_i D_i(e_i^L, e_j^L) + C_i^G(e_i^L)$. Using the specific forms, we can obtain

$$\bar{S}_i = \frac{\omega_i \delta^2}{2\beta}\left(4 + \frac{1-2\theta_i}{\theta_i + (1-2\theta_i)\,\omega_i}\right). \tag{40}$$

Comparing this level of $\bar{S}_i$ with that of the case where lobbying takes place only at the signing state, i.e., (14), we can immediately see that the environmental lobby's willingness to pay for the lobbying contribution at the signing stage increases as its potential loss of moving into the non-cooperative stage expands because of having to engage in the lobbying activities at the non-cooperative stage for the second time. In sum, we have

$$\bar{S}_i - \bar{N}_i = \frac{\omega_i \delta^2}{2\beta}\left(1 + \frac{1-2\theta_i}{\theta_i}\omega_i + \frac{1-2\theta_i}{\theta_i + (1-2\theta_i)\,\omega_i}\right), \tag{41}$$

whose value is necessarily positive. Thus, we can state

Proposition 3. *If the lobbying activities take place both at the signing and the non-cooperative stages, the cooperative agreement will always be achieved under* $\omega_i^G = \omega_i^P$ for each country.

Combining the Propositions 1, 2, and 3, we can also state the following:

[21] Again, we make use of $e_i^L = e_j^L = e_i^N$ stemmed from the symmetry assumptions, i.e., $\omega_i^P = \omega_i^G = \omega_i$ and $\theta_i = \theta_j$ in this subsection.

Corollary 1. *Irrespective of the possibility of lobbying at the non-cooperative phase, the cooperation will be agreed between the two countries' policymakers as long as the lobbying is possible at the signing stage and the organization rates of the lobby groups within each country are sufficiently close.*

Although the lobbying at the non-cooperative stage has the potential of disrupting the cooperative agreement, the additional opportunity of lobbying at the signing stage can always recuperate the cooperation for the following reasons. As we saw in 3.2, under $\omega_i^G = \omega_i^P$, it is always the case that the maximum willingness to pay for lobbying of the environmental lobby, i.e., $\bar{S}_i$, necessarily exceeds that of the industrial lobby, $\bar{N}_i$, in the absence of the lobbying opportunity in the non-cooperative stage. Moreover, the additional possibility of lobbying at the non-cooperative stage has asymmetric effects on these maximum willingness to pay of the two lobbies at the signing stage, quite interestingly, in favor of signing the international agreement: the maximum willingness to lobby at the signing stage will get larger for the environmental lobby with the addition of the lobbying occasion at the non-cooperative stage while it gets smaller for the industrial lobby because of the additional lobby opportunity. This is because the required lobby contributions at the non-cooperative stage make the non-cooperative outcome more unattractive not just for the environmental lobby but also for the industrial lobby, without affecting the resulting level of the non-cooperative emission level under $\omega_i^G = \omega_i^P$. While this additional lobbying occasion can potentially be an incentive for a policymaker to move the game to the non-cooperative stage by providing an extra opportunity to collect lobby contributions, this consideration is effectively overwhelmed by the widening difference between $\bar{N}_i$ and $\bar{S}_i$ at the signing stage.

In conclusion, the opportunity of lobbying *per se* does not necessarily work against the signing of a cooperative international environmental agreement. It makes a critical difference when those lobbying activities take place. Moreover, expanding the lobbying occasions can sometimes restore the cooperation, compared to the case where the lobbying opportunity is restricted to the non-cooperative environmental policy-making alone when the cooperative agreement is not reached.

4 Discussion on Asymmetric Organizations of the Lobbies

In this section, we briefly discuss the implications of introducing different values of the organization rates between the two lobby groups within a country. Specifically, we consider the effects of some deviations of the respective lobby's organization rates from the symmetric case, i.e., $\omega_i^P = \omega_i^G$, which we have examined above. We denote this original value of ω_i^P (and ω_i^G) by ω_i^O. For simplicity, we focus on the second and the third cases of the previous section, i.e., lobbying activities are conducted either at the signing stage or at the non-cooperative stage, and not at both stages[22].

First, we look at a relatively straight-forward case where lobbying takes place at the signing stage. In this case, the outcome of the non-cooperative stage is not affected whatsoever. As we have seen in 3.2, the cooperative agreement has been signed and sustained in the original symmetric case, $\omega_i^P = \omega_i^G = \omega_i^O$, which implies that the initial values of ω_i^P, ω_i^G, and θ_i are such that the policymaker's best response to "*Sign*" by the other country's policymaker is also "*Sign*". Let us now consider that only the value of ω_i^P increases. With $\omega_i^P > \omega_i^G = \omega_i^O$, then, only the industrial lobby's maximum willingness to pay for the contribution is raised according to (13), which leads to a smaller gap in $\bar{S}_i - \bar{N}_i$. If anything, this can only hurt the success of the cooperation if $\bar{S}_i - \bar{N}_i$ becomes negative to a sufficient degree to overturn the policymaker's preference toward the cooperative agreement. So is the case where the value of ω_i^G unilaterally gets smaller as can be seen by (14). On the other hand, when the value of ω_i^P decreases or when the value of ω_i^G increases, the cooperation will be sustained just as before.

Now, we turn to a more complicated case where lobbying takes place at the non-cooperative stage. From the analysis of 3.3 above, we know that, in the presence of lobbying, the political equilibrium of the non-cooperative stage is given by (21). It is obvious from (21) that an increase in ω_i^P results in a higher e_i^L, which is now different from e_i^N since $\omega_i^P > \omega_i^G = \omega_i^O$. This upward deviation of e_i^L from e_i^N necessarily leads to some welfare loss as far as the equilibrium outcome of the non-cooperative stage is concerned.

[22]A full investigation into the impacts of lobbying activities at both stages on the outcome of an international environmental agreement are analytically challenging and remains for future research

However, as we have seen above in (30) and (35), an increase in the organization rate of an lobby group always raises the other group's lobbying contribution amount at the non-agreement stage.[23] Thus, an increase in ω_i^P leads to a larger contribution amount from the environmental lobbyist, which is always attractive to the policymaker. Since an increase in ω_i^P has these two opposing impacts on the payoff of the policymaker, its effects on the sustainability of the cooperation is ambiguous and depends on specific parameter values.

In contrast, an increase in ω_i^G has an unambiguous and rather surprising effect on cooperation as in the following proposition:

Proposition 4. *With lobbying at the non-cooperative stage, when, at the original symmetric situation, the cooperative agreement has been signed and sustained, an increase in ω_i^G may contribute to the failure of the cooperation. Moreover, when the cooperative agreement has not been originally sustainable, an increase in ω_i^G can never restore the cooperative relationship.*

As we can see from (21), an increase in ω_i^G leads to a lower e_i^L, which is smaller than e_i^N since $\omega_i^G > \omega_i^P = \omega_i^O$ now. As long as the size of the increase in ω_i^G is not too significant, this change will result in some welfare gain at the non-cooperative stage because e_i^L will be located between e_i^C and e_i^N. Moreover, an increase in ω_i^G induces the industrial lobbyist to contribute more at the non-cooperative stage as is shown by (35). Thus, the payoff of the policymaker at the non-cooperative stage necessarily improves when the value of ω_i^G increases (at least up to a certain extent). This implies that, when the cooperative agreement has been signed and sustained in the original symmetric case, if anything, an increase in ω_i^G can only contribute to the failure of the cooperation although the welfare consequence of the non-cooperation is better than before due to a lower e_i^L. Moreover, when the cooperative agreement has not been sustainable at the original case, an increase in ω_i^G can never restore the cooperation.

In a similar vein, we can also show that a decrease in ω_i^G also helps the cooperation

[23] It should also be noted from (30) and (35) that an increase in the organization rate of a lobby does not affect its own equilibrium contribution amount at the non-cooperative stage.

to be sustained. In summary, introducing asymmetry in the organization rate has very different and sometimes rather counter-intuitive implications for the resulting equilibrium outcomes, depending on the timing of lobbying activities.

5 Concluding Remarks

Our analytical results indicate that, depending on the timing of lobbying, lobbying activities have very different implications with respect to their impacts on the resulting equilibrium outcomes. Especially, if lobbying activities are directed toward the policymaker's decision on how much pollutant the country emits when such an agreement collapses (i.e., at the non-cooperative stage), they have a detrimental influence on the policymaker's decision making, whereas the lobbying opportunity at the time when the lobbying takes place when the policymaker decides whether or not to sign the cooperative agreement (i.e., at the signing stage) always help the signing as long as the organization rates of the industrial and environmental lobbies are sufficiently close. Furthermore, even when the lobbying activities can potentially occur at the non-cooperative stage, introducing the additional lobbying opportunity at the signing stage necessarily leads to the signing of the cooperative agreement in the symmetric case.

Thus, provided that there is a role for lobbying activities to supply a policymaker with some important information on the preference of the citizens, the society may or may not face a trade-off between such a benefit of lobbying activities and its potential societal cost of being an obstacle to implementing a beneficial environmental treaty on an international scale. Given the forms of the contribution schedules, the lobbying at the non-cooperative stages can provide much finer pieces of information concerning the benefits and the damages of the pollutant emissions for that country. However, lobbying at this stage could prove to be an obstacle in sustaining an international agreement. Moreover, when lobbying occurs at the non-cooperative emission-choice stage, changes in the organization rates of the respective lobbies produces rather counter-intuitive results. Especially, an increase in the organization rate of the environmental lobby always worsens the prospect of a cooperative agreement getting signed. More attentions should be paid to the workings of lobbying activities especially now that such activities are conducted

in an increasingly larger scale.[24]

There are several directions in which this study can be extended. The most immediate extension would be to examine a stable cooperative coalition in a N-country model as has been traditionally practiced in this literature (Carraro and Siniscalco, 1993; Barrett, 1994; Diamantoudi and Sartzetakis, 2006; Benchekroun and Chaudhuri, 2015), but now under the lobbying influences. Indeed, this is a research question that recent studies (Hagen et al., 2016, and Marchiori et al. 2017) try to address although they use somewhat different derivation processes for the non-cooperative stage equilibrium from the one adopted in this study. It would be interesting to see how the alteration of the derivation process and, more importantly, the multiple lobbying opportunities that we have proposed in this article influence the properties of the equilibrium outcomes.

The other important extension would be to conduct a fuller analysis of a model involving two asymmetric countries in different dimensions. Although we discussed the possible impacts of introducing several asymmetries into our model in Section 4, their formal treatments could pose some serious analytical challenges because of the interplay of the two different lobbying opportunities. It would be interesting to investigate into the effects of different characteristics of the nations involved, and they remain for future researches.

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[24]For instance, as for the EU, Dinan and Wesselius (2010) claim that there are about 30,000 lobbyists in Brussels, the same number as the number of EU Commission employees, and it is estimated that lobbyists influence as much as 75% of legislation (The Guardian, 2014).

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