Strategic Delegation and Centralised Climate Policy

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Abstract: We analyse a principal-agent relationship within the context of international environmental agreements. First, the principals of the two countries decide whether to link their domestic emission permit markets to an international market and delegate, in either case, the decision on permit issuance to an agent who acts on their behalf. In the case of linking, the delegated agents decide cooperatively on the total level of emissions and the allocation of permits. In the last stage, emission permits are traded. Solving by backwards induction and employing a Nash-Bargaining Solution, we ask whether emissions are in fact lower in the cooperative outcome given the strategic considerations in the choice of the delegates. In addition, we explore whether the prospect of cooperation makes linking less probable.

Keywords: cooperative climate policy, political economy, emissions trading, linking of permit markets, strategic delegation, strategic voting

JEL-Classification: D72, H23, H41, Q54, Q58

1 Introduction

In this paper, we ask whether and under which circumstances countries which are represented by their principal, have an incentive to form an international environmental agreement, specifically an international permit market. We assume that under such an agreement, agents selected by the respective principal in each country negotiate the overall number of permits. As the delegates that are sent to the negotiations are chosen independently by each country, we conjecture that the centralised solution may not necessarily fare better than decentralised solutions to the problem of global climate change. The reason is that, under some circumstances, governments have an incentive to send delegates to the negotiation table that have different preferences than their own. Even when welfare is still higher in the centralised solution due to the gains from permit trading, global emissions may be higher than under non-cooperative climate policies where the incentive to strategically delegate is absent (under linear damages). We emphasise that centralised policies are not first-best from the principals' point of view - they are only first-best from their selected agents' point of view.

Our paper contributes to several strands of literature. It builds on and extends the literature on non-cooperative international permit markets, developed in Helm (2003), Carbone et al. (2009), Holtsmark and Sommervoll (2012) and Helm and Pichler (2015). While these papers assume that countries are represented by one welfare-maximising decision maker (the government), we explicitly account for the principal-agent relationship between different bodies involved in international policy making within a single country, for example, an incumbent government or president that serves as the principal and a selected executive or government agency that serves as an agent. In this regard, we heavily draw on the strategic delegation literature.

The first papers on strategic delegation can be found in the Industrial Organization literature analyzing the delegation of managerial decisions from shareholders to chief executive officers. Vickers (1985), Fershtman and Judd (1987) and Sklivas (1987) consider a managerial compensation scheme that is based not only on profits but also on sales respectively revenues. They show that in a duopoly or oligopoly with quantity-setting firms, the profits of the owner who designs such a contract exceed those of her rivals who just prescribe their managers to maximize profits, because the additional incentive device is common knowledge (or can be inferred in repeated games) and thus serves as a credible commitment to a particular strategy. This reasoning does not only apply to markets in which the performance of each firm depends on the choices of all firms (for an excellent survey in this context see Kopel and Pezzino, forthcoming). It is relevant for *all* environments of strategic interdependence in which one player's payoff depends on the decisions of other players. It comes as no surprise that the concept of strategic delegation subsequently found its way into the literature on negotiation and cooperation (Crawford and Varian 1979; Sobel 1981; Jones 1989; Burtraw 1992, 1993; Segendorff 1998) where it has been utilized in various contexts with inter-agent spillovers, such as environmental policy or the provision of public goods more generally. In contrast to the early IO papers, the principal in these papers does not misrepresent her own preferences by incentivizing the agent with an additional instrument. Instead, she is able to raise her payoff by delegating the task at hand to an agent with preferences different from her own. It is also worth mentioning that the literature on strategic delegation sometimes goes under the name "strategic voting" (Persson and Tabellini 1992). In the latter case, we can interpret the electorate or, to be precise, the median voter as the principal and the elected government as the agent.

Siqueira (2003), Buchholz et al. (2005), Roelfsema (2007) and Hattori (2010) analyze strategic voting in the context of environmental policy. While the first three contributions exclusively focus on environmental taxation, Hattori (2010) also examines the outcome of strategic voting under emissions caps. Siqueira (2003) and Buchholz et al. (2005) both find that voters' selection of agents is biased toward politicians who are less green than the median voter. By electing a more "conservative" politician, the home country commits itself to a lower tax on pollution, shifting the burden of a cleaner environment to the foreign country. By contrast, Roelfsema (2007) accounts for emissions leakage through shifts in production and finds that median voters may delegate to politicians who place greater weight on environmental damage than they do themselves, whenever their preferences for the environment relative to their valuation of firms' profits are sufficiently strong. However, this result breaks down in the case of perfect pollution spillovers, such as the emission and diffusion of greenhouse gases. Hattori (2010) allows for different degrees of product differentiation and alternative modes of competition, i.e., competition on quantities but also on prices. His general finding is that, when the policy choices are strategic substitutes (complements), a less (more) green policy maker is elected in the non-cooperative equilibrium. [1] Our work is closely related to Habla and Winkler(2017) however they only consider non-cooperative policies. In contrast, we study the case where total emissions and country specific permits are decided on a centralised level, employing a Nash Bargaining solution. Therefore, we ex-

[1] Strategic delegation in the provision of public goods is examined by Harstad (2010), Christiansen (2013) and Kempf and Rossignol (2013). Harstad (2010) analyzes the incentives to delegate to more conservative or more progressive politicians. While delegation to conservatives improves the conservatives' bargaining position, the progressives are more likely to be included in majority coalitions and hence increase the political power of the jurisdiction they represent. The direction of delegation in this model is found to depend on the design of the political system. Using a model of legislative bargaining, Christiansen (2013) shows that voters strategically delegate to "public good lovers". In Kempf and Rossignol (2013), the electorates of two countries each delegate to an agent who then bargains with the delegate of the other country over the provision of a public good that has cross-country spillovers. The choice of delegates is highly dependent on the distributive characteristics of the proposed agreement.

plore whether the prospect of cooperation makes linking to an international permits market more plausible.

The broader literature on linking offers several explanations for why "bottom-up" (or non-cooperative in our terminology) approaches to permit trading have not been successful. Among the obstacles that have been identified are different levels of ambition, competing domestic policy objectives, objections to financial transfers and the difficulty of regulatory coordination (Green et al. 2014). We contribute to this literature by suggesting that the hierarchical structures underlying environmental policy may well be a reason for the rejection of otherwise beneficial policies. With respect to hierarchical policy structures within countries, our paper is related to Habla and Winkler (2013) and Marchiori et al. (2017), in which the influence of legislative lobbying on the formation of international permit markets and international environmental agreements, respectively, is analyzed.

2 The model

We consider two countries, indexed by $i = 1, 2$ and $-i = \{1, 2\} \setminus i$.[2] In each country i, emissions e_i imply strictly increasing and concave country-specific benefits from the productive activities of a representative firm, $B(e_i)$, while global emissions $E = e_1 + e_2$ cause strictly increasing and (weakly) convex country-specific damages, $D_i(E)$.

In the first part of the paper, we assume the following functional forms for benefits and damages:

$$B_i(e_i) = \frac{1}{\phi_i} e_i(\epsilon_i - \frac{1}{2} e_i) \ , \quad B_i'(e_i) = \frac{\epsilon_i - e_i}{\phi_i} \ , \quad B_i''(e_i) = -\frac{1}{\phi_i} \ , \tag{1}$$

$$D_i(E) = \delta_i E \ , \quad D_i'(E) = \delta_i \ , \quad D_i''(E) = 0 \ , \tag{2}$$

where $\epsilon_i, \delta_i, \phi_i > 0$, and $\epsilon_i \geq e_i$ denotes business-as-usual emissions in the absence of any climate policy. We will employ the following abbreviations: $\epsilon \equiv \epsilon_i + \epsilon_{-i}$ and $\phi \equiv \phi_i + \phi_{-i}$. We only resort to these functional forms where necessary and keep to the more general notation elsewhere.

The above assumptions allow for analytical tractability and highlight the mechanism underlying our results. Moreover, they are not unrealistic. Klepper and Peterson (2006) show that abatement cost curves (which, in our model, correspond to the benefits of unabated emissions) can well be approximated by quadratic functions. The linear damage specification is in line with the assumptions made in complex integrated assessment or general equilibrium

[2] All our results can be generalized to n countries in a straightforward manner.

climate-economy models (see, e.g., Nordhaus and Boyer 2000, Golosov et al. 2014) in which climate damage is approximately linear in the GHG concentration in the atmosphere. This is because, typically, temperature is assumed to increase logarithmically with concentrations, whereas damage is assumed to be exponential or polynomial in temperature.[3] We discuss and relax these assumptions later on.

2.1 International climate policy

We assume that both countries can either agree on forming a perfectly competitive international permit market or carry out domestic policies. In case they fail to agree, they establish perfectly competitive domestic permit markets. In either regime, the number of permits issued to their representative domestic firms amounts to ω_i. As firms in all countries i require emission permits for an amount equal to the emissions e_i they produce, global emissions are given by the sum of emission permits issued, $E = \omega_1 + \omega_2$.

Restricting emissions imposes a compliance cost on the representative firms and thus reduces profits. If permits are traded internationally, firms have an opportunity to either generate additional profits by selling permits or reduce the compliance cost by buying permits from abroad. Thus, the profits of the representative firm read:

$$\pi_i(e_i) = B_i(e_i) + p(\omega_i - e_i) \ , \qquad i = 1, 2 \ , \tag{3}$$

where p is the price of permits on an international market. If countries decide against the formation of an international permit market, $\omega_i = e_i$ holds in equilibrium and the second term vanishes.

2.2 Agency Structure

In each country i there is a principal whose utility is given by:

$$V_i = \pi_i(e_i) - \theta_i^M D_i(E) \ . \tag{4}$$

Without loss of generality, we normalize θ_i^M to unity. In addition, there is a continuum of agents j of mass one in each country i, whose utility is given by:

$$W_i^j = \pi_i(e_i) - \theta_i^j D_i(E) \ , \tag{5}$$

[3] See also Burke et al. (2015) as one of the very few empirical papers estimating macroeconomic damages due to temperature increases. They find that damages, measured as deviations of economic productivity from a country-specific temperature optimum, are convex in *temperature*.

where θ_i^j is a preference parameter that is continuously distributed on the bounded interval $[0, \theta_i^{\max}]$.[4] To ensure that, in both countries, the principal's preferences are represented in the continuum of agents, we impose $\theta_i^{\max} > 1$.

In each country, all agents and the principal thus have equal stakes in the profits of the domestic firm but differ with respect to environmental damage. This may be either because damages are heterogeneously distributed or because the monetary valuation of homogenous physical environmental damage differs. We assume that all individuals (principals and agents) are selfish in the sense that they maximize their respective utilities, i.e., the principal in country i chooses *her* actions to maximize V_i, while agent j in country i makes decisions to maximize *his* utility W_i^j.

We assume that preference parameters of all individuals are common knowledge. Thus, we abstract from all issues related to asymmetric information.[5]

2.3 Structure and timing of the game

We model the hierarchical structure of climate policy in the following way. In the first stage, the "choice of regime", the principals in both countries simultaneously determine whether to choose a centralized or decentralized solution to the problem of global climate change. In the case of a centralized solution, an international permit market will be formed. Because countries are sovereign, an international permit market only forms if the principals in both countries consent to doing so. In the second stage, the principals simultaneously select an agent from the continuum of available agents. In stage three, these selected agents decide on the number of emission allowances either in a cooperative manner, i.e., through Nash bargaining, or in a non-cooperative manner. In the final stage, emission permits are traded. The complete structure and timing of the game is summarized as follows:

1. Choice of Policy Regime:
   Principals in both countries simultaneously decide whether to form an international permit market. In case they fail to agree, they will each carry out domestic policies by setting up a domestic permit market.[6]

[4] Our results also go through if the lower bound of this interval is negative. However, we believe that it is more realistic that the damages from climate change are either perceived to be non-existent or strictly positive.

[5] Although this may seem restrictive at first glance, it is not in the context of our model framework. One principal's incentive to strategically delegate to an agent stems exclusively from the other principal's ability to observe the principal's and agent's preferences. Moreover, the assumption is not unrealistic, as high-level political delegates have, in general, well-known political agendas.

[6] Our results do not hinge on the domestic policy being a permit market. A domestic emissions tax would be an equivalent instrument in this setting.

2. Strategic Delegation:
   Principals in both countries simultaneously select an agent. We distinguish between two delegation regimes - weak and strong delegation. Weak delegation implies that, in case of a breakdown of the agents' negotiations in the third stage, principals will choose the policies that are optimal from their point of view. Under strong delegation, the outside option in the negotiations is determined by the agents, not the principals.

3. Emission Allowance Choices:
   Selected agents in both countries choose the number of emission permits issued to the domestic firms either in a non-cooperative manner or through Nash bargaining, depending on the regime established in the first stage.

4. Permit Trade:
   Depending on the established regime, emission permits are traded on perfectly competitive domestic *or* international permit markets.

Despite being highly stylised, this model captures essential characteristics of the hierarchical structure of domestic and international environmental policy as it is compatible with various delegation mechanisms present in modern democratic societies. For example, the principal might be the median voter of the electorate while the agent represents the elected government. Alternatively, the principal might be the parliament that delegates a decision to an agent, for example, to the minister of the environment.

We solve the game by backward induction. Therefore, we first determine the equilibrium levels of emission permits for the two different regimes, which depend on the preferences of the selected agents in both countries. Second, we determine the preferences of the agents whom the principals select. These will differ across the two policy regimes and the two delegation regimes. Finally, we analyze under which conditions the principals in both countries consent to the formation of an international permit market and compare this to the case when there is no possibility for the principals to delegate strategically.

3 Permit market equilibrium and delegated permit choice

In the last stage and in the case of domestic emission permit markets, the market clearing condition implies that $\omega_i = e_i$ for both countries $i = 1, 2$. Profit maximization of the representative firm leads to an equalization of marginal benefits with the country-specific equilibrium permit price:

$$p_i(\omega_i) = B_i'(e_i) = \frac{\epsilon_i - \omega_i}{\phi_i} \ , \quad i = 1, 2 \ . \tag{6}$$

In the case of an international permit market, there is only one permit market price, which implies that, in equilibrium, the marginal benefits of all participating countries are equalized:

$$p(E) = B_1'(e_1(E)) = B_2'(e_2(E)) = \frac{\epsilon_i - e_i(E)}{\phi_i} \ . \tag{7}$$

In addition, the market clearing condition:

$$\omega_1 + \omega_2 = B_1'^{-1}(p(E)) + B_2'^{-1}(p(E)) = e_1(E) + e_2(E) = E \ , \tag{8}$$

implicitly determines the permit price $p(E)$ in the market equilibrium as a function of the total number of issued emission allowances E

$$p(E) = \frac{\epsilon - E}{\phi} \tag{9}$$

Existence and uniqueness follow directly from the assumed properties of the benefit functions B_i. Equation (7) and $e_i(E) = B_i'^{-1}(p(E))$ imply:

$$p'(E) = p' = \frac{B_i'' B_{-i}''}{B_i'' + B_{-i}''} = -\frac{1}{\phi} < 0 \ , \quad e_i'(E) = e_i' = \frac{B_{-i}''}{B_i'' + B_{-i}''} = \frac{\phi_i}{\phi} \in (0, 1) \ . \tag{10}$$

Naturally, the permit price goes down as global supply increases, and this increase is absorbed by all countries.

3.1 Delegated permit choice under domestic permit markets

In case no international permit market has been formed in the first stage of the game , the delegated agent of country i sets the level of emission permits ω_i to maximize:[7]

$$W_i^D = B_i(\omega_i) - \theta_i D_i(E) \ , \tag{11}$$

subject to equation (6) and given the permit choice ω_{-i} of the other country. Then, the reaction function of the selected agent i is implicitly given by:

$$B_i'(\omega_i) - \theta_i D_i'(E) = 0 \ , \tag{12}$$

implying that the delegate in country i trades off the marginal benefits of issuing more permits against the corresponding environmental damage costs. The following proposition

[7] Superscript "D" stands for "domestic", indicating the regime in which only domestic permit markets exist.

holds:

Proposition 1 (Unique NE in stage three under domestic permit markets) *For any given vector* $\Theta = (\theta_1, \theta_2)$ *of preferences of the selected agents under a domestic permit market, there exists a unique Nash equilibrium of the subgame beginning at stage three, in which both countries simultaneously set the levels of emission permits* ω_i *to maximize* (11) *subject to equation* (6) *and taking the permit level* ω_{-i} *of the other country as given.*

The proofs of all propositions and corollaries are relegated to the Appendix.

We denote the total emission level in this Nash equilibrium by $E^D(\Theta)$. Permit choices are dominant strategies due to the linearity of the damage function and the Nash equilibrium of the subgame starting in stage three is denoted by $\Omega^D(\Theta) = (\omega_1^D(\theta_1), \omega_2^D(\theta_2))$. Given our assumption about the functional forms we find that

$$\omega_i^D(\theta_i) = \epsilon_i - \phi_i\theta_i\delta_i \qquad \text{and} \qquad E^D = \epsilon - \phi_1\theta_1\delta_1 - \phi_2\theta_2\delta_2 \tag{13}$$

3.2 Characterization of the threat point under strong delegation

If an international permit market is formed in the first stage but the Nash-bargaining process fails, then countries go back to choosing permits non-cooperatively. This potential non-cooperative outcome serves as a threat point for the negotiations. In the case of strong delegation, country i's selected agent chooses ω_i to maximise:[8]

$$W_i^{NS} = B_i(e_i(E)) + p(E)\left[\omega_i - e_i(E)\right] - \theta_i D_i(E) \ , \tag{14}$$

subject to equations (7) and (8) and given ω_{-i}. Taking into account that $p(E) = B_i'(e_i(E))$, the reaction function of the agent in country i is given by:

$$p(E) + p'\left[\omega_i - e_i(E)\right] - \theta_i D_i'(E) = 0 \ . \tag{15}$$

By summing the reaction functions for both countries, the equilibrium permit price is equal to the average marginal environmental damage costs of the selected agents:

$$p(E) = \frac{1}{2}\left[\theta_i D_i'(E) + \theta_{-i} D_{-i}'(E)\right] \ . \tag{16}$$

Inserting equation (16) back into the reaction function (15) yields:

$$\omega_i - e_i(E) = \frac{1}{2p'}\left[\theta_i D_i'(E) - \theta_{-i} D_{-i}'(E)\right] \ , \tag{17}$$

[8] Superscript "N" stands for no co-operation. Superscript "S" stands for "strong" delegation.

revealing that, in equilibrium, the country whose agent exhibits above-average marginal damages is the permit buyer, whereas the country whose agent's marginal damages are below average is the permit seller.

Again, there exists a unique Nash equilibrium of the subgame beginning at stage three after negotiations have failed:

Proposition 2 (Threat Point with Strong Delegation)
For any given vector $\Theta = (\theta_1, \theta_2)$ *of preferences of the selected agents under an international permit market, there exists a unique Nash equilibrium of the subgame beginning at stage three after negotiations have failed , in which both countries simultaneously set the levels of emission permits* ω_i *to maximize* (14) *subject to equations* (7) *and* (8) *and taking the permit level* ω_{-i} *of the other country as given.*

Denoting the Nash equilibrium by $\Omega^{NS}(\Theta) = (\omega_1^{NS}(\Theta), \omega_2^{NS}(\Theta))$ and the total equilibrium emissions by $E^{NS}(\Theta)$, this non-cooperative outcome serves as a threat point for the negotiations: By analysing the influence of the selected agents' preferences on the equilibrium permit choices, we can examine the strategic incentives of agents to affect their own threat point as well as the threat point of the other agents, in an attempt to improve their bargaining position.

Using equation (15), we can characterise the level of emissions, permits, the permit market price and welfare in the Nash equilibrium as follows:

$$\omega_i^{NS} = \epsilon_i + \frac{1}{2}\phi_{-i}(\theta_{-i}\delta_{-i} - \theta_i\delta_i) - \phi_i\theta_i\delta_i \ , \qquad e_i^{NS} = \epsilon_i - \frac{1}{2}\phi_i(\theta_i\delta_i + \theta_{-i}\delta_{-i}) \ , \tag{18a}$$

$$E^{NS} = \epsilon - \frac{1}{2}\phi(\theta_i\delta_i + \theta_{-i}\delta_{-i}), \qquad p^{NS} = \frac{1}{2}(\theta_i\delta_i + \theta_{-i}\delta_{-i}) \ , \tag{18b}$$

$$W_i^{NS} = \frac{\epsilon_i^2}{2\phi_i} - \theta_i\delta_i\epsilon + \frac{1}{8}(\phi_i + 2\phi_{-i})(\theta_i\delta_i + \theta_{-i}\delta_{-i})^2 \ . \tag{18c}$$

A marginal change in θ_i yields the following results.

Corollary 1 (Stage three comparative statics for the threat point)
The following conditions hold for the levels of emission allowances ω_i^{NS}, ω_{-i}^{NS}, *emissions* e_i^{NS}, e_{-i}^{NS}, *total emissions* E^{NS} *and welfare* W_i^{NS} *and* W_{-i}^{NS} *in the Nash equilibrium* $\Omega^{NS}(\Theta) =$

$(\omega_1^{NS}(\Theta), \omega_2^{NS}(\Theta))$:

$$\frac{d\omega_i^{NS}(\Theta)}{d\theta_i} < 0 \ , \qquad \frac{d\omega_{-i}^{NS}(\Theta)}{d\theta_i} > 0 \ , \tag{19a}$$

$$\frac{de_i^{NS}(\Theta)}{d\theta_i} < 0 \ , \qquad \frac{de_{-i}^{NS}(\Theta)}{d\theta_i} < 0 \ , \qquad \frac{dE^{NS}(\Theta)}{d\theta_i} < 0 \ , \tag{19b}$$

$$\frac{dW_i^{NS}(\Theta)}{d\theta_i} \gtreqless 0 \ , \qquad \frac{dW_{-i}^{NS}(\Theta)}{d\theta_i} > 0 \ . \tag{19c}$$

A decrease in θ_i increases the domestic equilibrium permit level and overall emissions, but decreases the equilibrium allowance choice of the other country, i.e., the international permit market makes countries' permit choices strategic substitutes. Furthermore, note that domestic emissions are not equal to the domestic allowance choices. In fact, equilibrium emissions increase in both countries if θ_i decreases in one of the countries, as an expansion of total emission permits decreases the equilibrium permit price; see equation (10). A marginal decrease in θ_i has a direct and indirect effects on the appointed agent's welfare in country i. It directly increases welfare because an agent with a lower θ_i suffers less from environmental damage. On the other hand, we observe several indirect effects. Global emissions go up, which is detrimental to the agent, production benefits rise, which is beneficial, and permit purchases or permit sales become more or less, which may or may not be beneficial to the agent. Overall, the effect on the appointed agent's welfare is ambiguous and depends on the specific parameter constellation. The welfare of the other country's appointed agent is unambiguously negatively affected by a marginal decrease in θ_i.

The non-cooperative outcome described here serves as a threat point for the negotiations. We now know that a principal can affect her agent's but also the other agent's threat point by choosing an agent with a different θ_i.

3.3 Characterisation of the threat point under weak delegation

Under weak delegation, once the negotiations have failed, the power of deciding over the level of emission permits returns to the principal. The principal chooses permits to maximise

$$V_i = B_i\big(e_i(E)\big) + p(E)\,[\omega_i - e_i(E)] - D_i(E) \ , \tag{20}$$

subject to equations (7) and (8) and given ω_{-i}. In this case, the reaction function yields

$$\omega_i - e_i(E) = \frac{1}{2p'}\left[D_i'(E) - D_{-i}'(E)\right] \ . \tag{21}$$

Again, there exists a unique Nash equilibrium of the subgame beginning at stage three under weak delegation after negotiations have failed:

Proposition 3 (Threat Point with Weak Delegation)
Under weak delegation, there exists a unique Nash equilibrium of the subgame beginning at stage three after negotiations have failed, in which the principals of both countries simultaneously set the levels of emission permits ω_i to maximize (20) *subject to equations* (7) *and* (8) *and taking the permit level ω_{-i} of the other country as given.*

We denote the Nash equilibrium by $\Omega^{NW} = \left(\omega_1^{NW}, \omega_2^{NW}\right)$ and the total equilibrium emissions by E^{NW}. As before, we can characterise the level of emissions, permits, the permit market price and welfare in the Nash equilibrium as follows:

$$\omega_i^{NW} = \epsilon_i + \frac{1}{2}\phi_{-i}(\delta_{-i} - \delta_i) - \phi_i\delta_i \ , \qquad e_i^{NW} = \epsilon_i - \frac{1}{2}\phi_i(\delta_i + \delta_{-i}) \ , \tag{22a}$$

$$E^{NW} = \epsilon - \frac{1}{2}\phi(\delta_i + \delta_{-i}), \qquad p^{NW} = \frac{1}{2}(\delta_i + \delta_{-i}) \ , \tag{22b}$$

$$W_i^{NW} = \frac{\epsilon_i^2}{2\phi_i} - \delta_i\epsilon + \frac{1}{8}(\phi_i + 2\phi_{-i})(\delta_i + \delta_{-i})^2 \ . \tag{22c}$$

We can see that the preference parameters play no role in the outcome, since it is the principals of both countries who have the power to make decisions. However, this "threat point" under weak delegation will affect the bargaining position of each country and therefore the outcome of the negotiations. Note that this non-cooperative outcome represents the optimal outcome from the point of view of the principals when there is an international permit market and no strategic delegation.

3.4 Cooperative permit choice under weak and strong delegation

In the case an international permit market has been formed, the delegated agents of the countries choose permits in a cooperative manner. In particular, we capture the international agreement through the Nash Bargaining Solution.

3.4.1 Strong Delegation

The delegated agents of each country bargain over the total level of emissions E and over the country specific permits. We denote the share for permits for country i and $-i$ with λE and $(1-\lambda)E$ respectively. Then, the Nash Bargaining Solution is given by the levels of E and λ that solve

$$\max_{E,\lambda}(W_i^{CS} - W_i^{NS})(W_{-i}^{CS} - W_{-i}^{NS}) \tag{23}$$

where (W_i^{NS}, W_{-i}^{NS}) is the threat point for negotiations under strong delegations The FOCs for the optimal E and λ give us

$$\begin{aligned}&\Big(p'(E)(\lambda E - e_i(E)) + p(E)\lambda - \theta_i D_i'(E)\Big)\Delta W_{-i} = \\ &-\Big(p'(E)((1-\lambda)E - e_{-i}(E)) + p(E)(1-\lambda) - \theta_{-i} D_{-i}'(E)\Big)\Delta W_i\end{aligned} \tag{24}$$

and

$$\Delta W_i = \Delta W_{-i} \tag{25}$$

respectively, with $\Delta W_i = W_i^{CS} - W_i^{NS}$.

Substituting (25) into (24), we get the optimal level of λ

$$\lambda^{CS} = \frac{1}{2Ep(E)}\Big(B_{-i}(e_{-i}(E)) - B_i(e_i(E)) + 2p(E)e_i(E) + \theta_i D_i(E) - \theta_{-i} D_{-i}(E) + W_i^{NS} - W_{-i}^{NS}\Big) \tag{26}$$

and an implicit expression for the optimal level of emissions

$$p(E^{CS}) - \theta_i D_i' - \theta_{-i} D_{-i}' = 0 \tag{27}$$

Given our assumptions about the functional forms, we can characterise the level of emissions, permits, the permit market price and welfare in the Nash equilibrium as follows:

$$\omega_1^{CS} = \lambda^{CS} E^{CS} = \frac{1}{2}\Big(- (\theta_1\delta_1 + \theta_2\delta_2)\frac{(13\phi_1 + 3\phi_2)}{8} + \phi(\theta_2\delta_2 - \theta_1\delta_1) + 2\epsilon_1\Big) \tag{28a}$$

$$\omega_2^{CS} = (1-\lambda^{CS}) E^{CS} = \frac{1}{2}\Big(- (\theta_1\delta_1 + \theta_2\delta_2)\frac{(13\phi_2 + 3\phi_1)}{8} - \phi(\theta_2\delta_2 - \theta_1\delta_1) + 2\epsilon_2\Big) \tag{28b}$$

$$e_i^{CS} = \epsilon_i - \phi_i(\theta_i\delta_i + \theta_{-i}\delta_{-i}) \ , E^{CS} = \epsilon - \phi(\theta_i\delta_i + \theta_{-i}\delta_{-i}) \ , \quad p^{CS} = \theta_i\delta_i + \theta_{-i}\delta_{-i} \ , \tag{28c}$$

$$W_i^{CS} = \frac{\epsilon_i^2}{2\phi_i} - \theta_i\delta_i\epsilon + \frac{1}{16}(3\phi_i + 5\phi_{-i})(\theta_1\delta_1 + \theta_2\delta_2)^2 \tag{28d}$$

A few points are worth mentioning here. The optimal level of emissions, E^{CS}, that the Nash Bargaining Solution dictates, is also the socially optimal level: it is the level of emissions that maximises the aggregate sum of welfare for the two countries. Equation (27) equates the marginal benefit of emissions, which is the same for the two countries and equal to the price, with the social damage associated with emissions. However, we should note that this level of emissions is optimal from the point of view of the delegates but not the principals. On the other hand, equation (25) reveals that the country specific permits are allocated so that the gains from bargaining are split equally between the two countries. In other words, the Nash Bargaining in our framework is rather simple: first countries decide for the optimal level of emissions from an aggregate point of view and then split the bargaining gains. The emission permits, which can be thought of as side payments, reassures that the welfare change is the same for the two countries.

Moreover, we can see the how the threat point affects the bargaining outcome: the higher is the welfare of a country at its threat point, the more permits it is allocated at the NBS. In a sense, the better-off you are without the negotiations, the more you benefit if the negotiations are successful. Hence, it is obvious that there are strategic incentives to alter your threat point in order to improve your bargaining position. On the other hand, the lower the welfare of the other country at the threat point, the more one country benefits. So not only are there incentives for a country to affect its own threat point, but also to affect the threat point of the other country.

As expected, the share of permits is proportional to the country specific emissions as a share of total emissions. Moreover, the share of permits for a country increases the higher are the damages and the lower are the benefits of emissions. In a sense countries are "compensated" through the allocation of extra emission permits. As we shall see later, this is exactly what creates the incentives to "inflate" the country's damage from emissions through the strategic choice of a delegate with a higher preference parameter.

Finally, it remains to specify which country is the permit seller and which the permit buyer. From (28a), we can find

$$\omega_1^{CS} - e_1^{CS} = \frac{1}{2}\Big((\theta_1\delta_1 + \theta_2\delta_2)\frac{3(\phi_1 - \phi_2)}{8} + \phi(\theta_2\delta_2 - \theta_1\delta_1)\Big) \tag{29}$$

Here we can identify three different cases depending on the parameters. If $(\phi_1 - \phi_2) > 0$ and $(\theta_2\delta_2 - \theta_1\delta_1) > 0$, then country 1 is a permit seller: the marginal damage of emissions is lower for country 1 while the marginal benefit falls by less than country 2. Instead, if $(\phi_1 - \phi_2) < 0$ and $(\theta_2\delta_2 - \theta_1\delta_1) < 0$, country 1 is the permit buyer. Finally, in the case where the marginal damage for country 1 is smaller(bigger) than country 2 while the marginal benefit falls by more(less) than country 2, the result is ambiguous and depends on the parameters.

A marginal change in θ_i yields the following results.

Corollary 2 (Stage three comparative statics for Nash Bargaining)
The following conditions hold for the levels of emission allowances ω_i^{CS}, ω_{-i}^{CS}, emissions e_i^{CS}, e_{-i}^{CS}, total emissions E^{CS} and welfare W_i^{CS} and W_{-i}^{CS} in the Nash equilibrium $\Omega^{CS}(\Theta) = (\omega_1^{CS}(\Theta), \omega_2^{CS}(\Theta))$:

$$\frac{d\omega_i^{CS}(\Theta)}{d\theta_i} < 0 \ , \qquad \frac{d\omega_{-i}^{CS}(\Theta)}{d\theta_i} \gtreqless 0 \ , \tag{30a}$$

$$\frac{de_i^{CS}(\Theta)}{d\theta_i} < 0 \ , \qquad \frac{de_{-i}^{CS}(\Theta)}{d\theta_i} < 0 \ , \qquad \frac{dE^{NS}(\Theta)}{d\theta_i} < 0 \ , \tag{30b}$$

$$\frac{dW_i^{CS}(\Theta)}{d\theta_i} \gtreqless 0 \ , \qquad \frac{dW_{-i}^{CS}(\Theta)}{d\theta_i} > 0 \ . \tag{30c}$$

As expected, total emissions as well as country specific emissions decrease when one country becomes greener. The emission permits of the country which becomes greener decrease too. However, the effect on the permits of the other country is ambiguous : for $\phi_i > \phi_{-i}$, permits for country $-i$ increase when country i becomes greener while they decrease in the opposite case. In this case, countries' permit choices can be either strategic substitutes or complements.

3.4.2 Weak Delegation

In the case of weak delegation, if negotiations break down, it is the principal of each country that decides non cooperatively over the level of permits. The analysis is similar with the difference that the threat point is now given by (W_i^{NW}, W_{-i}^{NW}). Therefore, the NBS for the level of emissions is the same as in the case of strong delegation while the allocation of country specific permits is now given by

$$\lambda^{CW} = \frac{1}{2Ep(E)}\Big(B_{-i}(e_{-i}(E)) - B_i(e_i(E)) + 2p(E)e_i(E) + \theta_i D_i(E) - \theta_{-i} D_{-i}(E) + W_i^{NW} - W_{-i}^{NW}\Big) \tag{31}$$

We should point out that in the case of weak delegation, the threat point depends on the principal's preference parameter ($\theta_i^M = 1$), therefore the principal cannot affect his country's threat point through the strategic choice of a delegate. On the other hand, with strong delegation, a "strategically" chosen delegate remains in place after negotiations fail which modifies the threat point and finally the bargaining results. To be completed.

4 Strategic delegation

We now turn to the selection of agents by the principals in the second stage of the game. As all agents living in country i are potential candidates to be selected, the principals can always find a delegate for preference parameters in the interval $\theta_i \in [0, \theta_i^{\max}]$.

4.1 Strategic Delegation under Domestic Permit Markets

First, assume that only domestic permit markets have formed. In this case, the principal in country i selects an agent with preference parameter θ_i to maximise

$$V_i^D = B_i(\omega_i^D(\Theta)) - D_i(E^D(\Theta)) \tag{32}$$

given the Nash-Equilibrium $\Omega^D(\Theta)$ of the subgame starting in the third stage and the preference parameter θ_{-i} of the selected agent in the other country. The first order condition gives us

$$B_i'(\omega_i^D(\Theta))\frac{d\omega_i^D(\Theta)}{d\theta_i} - D_i'(E^D(\Theta))\frac{dE^D(\Theta)}{d\theta_i} = 0 \tag{33}$$

which implicitly determines the reaction function of country i, $\theta_i^D(\theta_{-i})$. Taking into account the equilibrium outcome in the third stage and in particular equation (12) , the first-order condition becomes

$$(1-\theta_i)D_i'(E^D(\Theta))\frac{dE^D(\Theta)}{d\theta_i} = 0 \tag{34}$$

which implies that there is no incentive for strategic delegation: principals choose agents with the same preferences as theirs.

Proposition 4 (Unique Nash equilibrium under domestic permit markets) *Given a domestic permit markets regime, there exists a unique Nash-equilibrium of the subgame starting at stage 2 in which the principals in both countries simultaneously choose agents with the same preferences as theirs i.e.* $\theta_i^D = \theta_{-i}^D = 1$*: self-representation is the equilibrium strategy.*

Substituting for $\theta_i^D = \theta_{-i}^D = 1$ in the expressions for the equilibrium permits and total emissions we find

$$\omega_i^D(\theta_i) = \epsilon_i - \phi_i\delta_i \qquad \text{and} \qquad E^D = \epsilon - \phi_1\delta_1 - \phi_2\delta_2 \tag{35}$$

4.2 Strategic delegation under strong delegation

If an international permit market has formed in the first stage, the principal in country i selects an agent with preference parameter θ_i to maximise

$$V_i^{CS} = B_i(e_i(E^{CS}(\Theta))) + p(E^{CS}(\Theta))\left[\omega_i^{CS}(\Theta) - e_i(E^{CS}(\Theta))\right] - D_i(E^{CS}(\Theta)) \ , \tag{36}$$

given the Nash equilibrium $\Omega^{CS}(\Theta)$ of the subgame beginning in the third stage and the preferences θ_{-i} of the selected agent in the other country. The first order condition for country i reads

$$\frac{1}{8}(\theta_i\delta_i + \theta_{-i}\delta_{-i})(5\phi_i + 3\phi_{-i}) = \phi\delta_i(1-\theta_i) \tag{37}$$

The LHS of equation (37) is positive which implies that country i will choose an agent with less green preferences than her own. Solving for θ_i yields the reaction function for country i

$$\theta_i(\theta_{-i}) = \frac{8\phi}{11\phi + 2\phi_i} - \theta_{-i}\frac{\delta_{-i}(3\phi + 2\phi_i)}{\delta_i(11\phi + 2\phi_i)} \tag{38}$$

As expected, the reaction function is negatively sloped.

Proposition 5 (Unique Nash equilibrium under international permit markets)
Given an international permit market regime, there exists a unique Nash-equilibrium of the subgame starting at stage 2 in which the principals in both countries simultaneously choose agents with preferences θ_i to maximise (36) subject to $\Omega^{CS}(\Theta)$ and the given choice θ_{-i} of the principal of country $-i$. The unique NE, Θ^{CS},of the delegation stage is

$$\Theta^{CS} = \begin{cases} (0, \frac{8\phi}{11\phi+2\phi_{-i}}) & \textit{if } \frac{\delta_i}{\delta_{-i}} \leq \frac{3\phi+2\phi_i}{11\phi+2\phi_{-i}} \\ (\frac{\delta_i(11\phi+2\phi_{-i})-\delta_{-i}(3\phi+2\phi_i)}{16\delta_i\phi}, \frac{\delta_{-i}(11\phi+2\phi_i)-\delta_i(3\phi+2\phi_{-i})}{16\delta_{-i}\phi}) & \textit{if } \frac{3\phi+2\phi_i}{11\phi+2\phi_{-i}} < \frac{\delta_i}{\delta_{-i}} < \frac{11\phi+2\phi_i}{3\phi+2\phi_{-i}} \\ (\frac{8\phi}{11\phi+2\phi_i}, 0) & \textit{if } \frac{\delta_i}{\delta_{-i}} > \frac{11\phi+2\phi_i}{3\phi+2\phi_{-i}} \end{cases} \tag{39}$$

The following corollary describes the properties of the equilibria presented above.

Corollary 3 (Properties of the NE under international permit markets)

1. *In all the NE, the principals of both countries choose $0 \leq \theta_i^{CS} < 1$*
2. *In the corner equilibria, the principal with the lower marginal damages is the one that delegates to an agent with the minimum possible θ.*
3. *In the interior equilibrium, the principal delegates more strongly the lower are her marginal damages and the less her marginal benefits decrease. In particular, it holds that*

$$\theta_i^{CS} < \theta_{-i}^{CS} \qquad \Longleftrightarrow \qquad \frac{\delta_i}{3\phi + 2\phi_i} < \frac{\delta_{-i}}{3\phi + 2\phi_{-i}} \tag{40}$$

Corollary 3 implies that self representation can never be an equilibrium as the interaction through the permit markets ensures that there are strategic considerations in the choice of the preference parameter.

The principals delegate more strongly, i.e they choose an agent with a lower θ_i, the lower are their marginal damages and the less their marginal benefits fall. The intuition here is that the country with the lower marginal damages is the one that can afford to take up higher global emissions in return for choosing an agent with a lower θ_i and more domestic permits as a result. Similarly, if marginal benefits fall less steeply, the principal enjoys higher marginal benefits from choosing a lower θ_i because her country will now absorb a bigger share of the additional permits issued by the less green agent; see equation (10). As a consequence, the principal in one country will also delegate more strongly than her counterpart in the other country if her marginal damages are lower and the production benefits fall by less than in the other country.

In fact, when the marginal damages of the two countries differ substantially, we can even reach a corner equilibrium. In this case, the country with the lower marginal damage chooses an agent with the minimum possible concern for the environment: in our case, this is 0. The other country has no choice but to compensate the big increase in total emissions by choosing the highest possible environmental preference. Notice that even though one would expect that the country with no environmental concern would be the permit seller, this still depends on how marginal benefits behave. From equation (29), we can see that in addition to setting a zero θ, the country needs to have the marginal benefit falling less steeply.

4.3 Strategic delegation under weak delegation

4.4 Comparison of equilibrium emissions

5 The choice of regime

6 Conclusion

This paper attempts to gain a better understanding of the complex relationship between national politics (in the form of voting or delegation) and the formation of international policies. It shows that principals will choose delegates that have lower preferences for the environment than they have themselves, both in the non-cooperative and the cooperative outcome. In addition, we conjecture that centralisation of policies, particularly the formation of an international permit market for which the total number of permits is decided upon through Nash bargaining by selected agents, does not necessarily need to lower global emissions. In this regard, we caution against centralising policies at all costs. Instead, the mechanisms behind centralisation play a crucial role in whether the implemented policies will be beneficial or harmful to the environment.

Appendix

Proof of Proposition 1

(i) Existence: The maximization problem of country i's selected agent is strictly concave:

$$\mathrm{SOC}_i^D \equiv B_i'' < 0 \ . \tag{A.1}$$

Thus, for each country $i = 1, 2$, the reaction function yields a unique best response for any given choice ω_{-i} of the other country. This guarantees the *existence* of a Nash equilibrium.

(ii) Uniqueness: Solving the best response functions (12) for e_i and summing up over both countries yields the following equation for the aggregate emissions E:[9]

$$E = B_i'^{-1}\left(\theta_i D_i'\right) + B_{-i}'^{-1}\left(\theta_{-i} D_{-i}'\right) \ . \tag{A.2}$$

As the left-hand side is strictly increasing and the right-hand side is CONSTANT in E, there exists a unique level of total emissions $E^D(\Theta)$ in the Nash equilibrium. Substituting back into the reaction functions yields the unique Nash equilibrium $\left(\omega_1^D(\Theta), \omega_2^D(\Theta)\right)$. □

Proof of Proposition 2

(i) Existence: The maximization problem of country i's delegate is strictly concave:

$$\mathrm{SOC}_i^{NS} = p'[2 - e_i'] < 0 \ . \tag{A.3}$$

Thus, for each country $i = 1, 2$, the reaction function yields a unique best response for any given choice ω_{-i} of the other country, which guarantees the *existence* of a Nash equilibrium.

(ii) Uniqueness: Summing up the reaction function (15) over both countries yields the following condition, which holds in the Nash equilibrium:

$$2p(E) = \theta_i D_i' + \theta_{-i} D_{-i}' \ . \tag{A.4}$$

The left-hand side is strictly decreasing in E, while the right-hand side is CONSTANT in E. Thus, there exists a unique level of total emission allowances $E^{NS}(\Theta)$ in the Nash equilibrium. Inserting $E^{NS}(\Theta)$ back into the reaction functions (15) yields the unique equilibrium allowance choices $\left(\omega_i^{NS}(\Theta), \omega_{-i}^{NS}(\Theta)\right)$. □

[9] As all marginal benefit functions B_i' are strictly and monotonically decreasing, the inverse functions $B_i'^{-1}$ exist and are also strictly and monotonically decreasing.

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