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Negotiating Environmental Agreements under Ratification Uncertainty

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Abstract

In this paper we analyze the impact of ratification uncertainty on the optimal terms of international environmental agreements (IEAs). We combine the literature on IEAs with the one on two-level games of ratification by incorporating uncertain preferences of the pivotal voter in the ratification stage. We find that ratification uncertainty which has an non-monotonic impact on the strength of the commitment and – depending on the model specification – on the participation threshold as well. Specifically, for increasing variance in the ratification the commitment level that is specified in the agreement first decreases, while for sufficiently large variance it again increases and returns to the level that is preferred by the negotiators.

Keywords: international environmental agreement, coalition formation, ratification, two-level games, uncertainty, minimum participation threshold.

JEL codes: Q54, C72, H41, P17

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1 Introduction

Achieving meaningful cooperation on global public good provision like greenhouse gas emission reductions remains an important challenge. The Kyoto protocol and its potential successor is a prominent showcase of both the tedious negotiation process as well as the difficulties or failure in several countries to ratify an already signed agreement. Such problems in formulating successful international agreements hardly come as a surprise for economists.

A large strand of literature (e.g., Carraro and Siniscalco 1993; Barrett 1994; Hoel and Schneider 1997; Kolstad and Ulph 2008) deals with self-enforcing environmental agreements. It relies on a multi-stage model where countries first decide whether or not to join a climate coalition, and, second, coalition members maximize their collective payoff by choosing their emission reductions. These models derive rather pessimistic results on the prospects of cooperation.[1] These studies focus on the commitment level only. Several international agreements do, however, include minimum participation rule. The Kyoto protocol, for example required a double trigger before entering into force: it had to be ratified by at least 55 parties to the UNFCCC, incorporating Annex I parties which accounted for at least 55% of total Annex I carbon emissions in 1990. A few studies analyze the impact of such minimum participation rules on the success of international agreements.[2]

In this paper, we consider the choice of both commitment levels and minimum participation rules in international agreements, but add With this, we relax the frequent assumption made in this literature that countries act as unitary actors.

This literature models countries as unitary actors and assumes that the negotiated agreement automatically enters into force. In reality, the temporal structure is more complex: most negotiated agreements must also be ratified by the legislatures of the respective countries. For example, it took 8 years for the Kyoto protocol to enter into force after it had

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[1]Baker (2005); Kolstad (2003); Ulph and Maddison (1997) and Ulph and Ulph (1996) incorporate uncertainty and learning about the cost and benefits of climate change in such model framework which does not qualitatively change the pessimistic insights.

[2]Black et al. (1993), Carraro et al. (2003), Carraro et al. (2009), Rutz (2001), and Weikard et al. (2009) analyze exogenous and endogenous minimum participation rules and show that those may even generate full participation, i.e. a grand coalition if countries are not too heterogeneous.

been signed in 1997. Most prominently, the U.S. did not ratify this protocol. While certainly strategic aspects may play a role here,[3] a country's ratification may also be subject to political economy considerations *after the agreement is signed*. For example, ratification uncertainty may be caused by potential changes of governments or preferences of the pivotal voters.

In this paper, we reconsider the choice of commitment levels and minimum participation rules in international agreements under ratification uncertainty. That is, we employ a model that allows for ratification failure after an agreement has been signed. Such risk arises from the fact that countries do not consist of single decision makers but rather of a plurality of players involved in the negotiation and ratification processes and that those players may have heterogeneous preferences that are not necessarily common knowledge.

Such interaction between different players involved in the negotiation and ratification processes has been described by Putnam (1988). He formulates a metaphor of two tables at which the negotiator of a country sits: the national and the international one. The negotiator's task is to reconcile the interests at both tables, that is, to find the overlap in the win sets (set of all negotiation outcomes that are preferred to the status quo and could therefore be agreed upon) of all participating countries. If there is no overlap, the agreement fails. Putnam suggests a two-level game consisting of a negotiation level (international table) and a ratification level (national table) and describes different aspects that influence the relation between those two levels. Most approaches of formalizing this metaphor have concentrated on a game with two negotiators and one ratifier (e.g., Kıbrıs 2012; Iida 1996; Iida 1993; Kroll and Shogren 2008; Humphreys 2007). Negotiators first decide on the content of the agreement which is then presented to the ratifier in the ratification stage. Ratifiers either accept or reject according to their own preferences. Naturally, negotiators need to take those ratification constraints into account. They can be certain (Humphreys 2007; Hug 2009; Kroll and Shogren 2008) or, due to asymmetric information, uncertain (Iida 1993; Iida 1996; Kıbrıs 2012; Milner and Rosendorff 1997) to the negotiators.

In our paper, we extend this literature to include more than two negotiation parties. This allows us to study the role of ratification uncertainty on two design elements: (i) the

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[3]Ratification constraints may be exploited to achieve advantageous bargaining positions (Schelling 1960).

commitment level and (ii) a minimum participation requirement. Importantly, we find that ratification uncertainty has a non-monotonic impact on the commitment level: for an increasing variance of the preferences of the pivotal voters in the ratification stage, the commitment level first decreases, before increasing again. While this result may appear counter-intuitive at a first glance, the intuition is rather straightforward. Relative to a situation without uncertainty, the negotiators may try to reduce the commitment level of the agreement in order to increase the chances of the agreement to be ratified and to enter into force. For very large uncertainty, however, the marginal impact of such a compromise in the commitment level on the probability of ratification is rather small such that the commitment level returns to the one that is preferred by the negotiators. We derive similar insights for the optimal minimum participation level.

Two caveats need to be given. First, we focus on ex ante symmetric countries such that the commitment level which is specified in the agreement is identical for all countries.[4] Second, we concentrate on the formulated terms of the agreement once the parties sit on the negotiation table. That is, we do not study the decision of countries to enter the negotiations.[5]

The remainder of the paper is structured as follows. We formulate to basic model in section 2. We then turn to the non-cooperative case in section 2.1 before discussing the probability of ratification in section 2.2 and the optimal design in section 2.3. Section 3 illustrates some results based on numerical simulations before we conclude in section 4.

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[4]An extension would involve a multi-dimensional negotiation space as commitment levels for all respective parties need to be specified. For this an extension of the literature on two-level games is necessary. Kıbrıs (2012), Iida (1993) and Iida (1996) consider a single dimension, while Hug (2009) considers two-dimensional negotiation space. Humphreys (2007) claims to provide a model which can account for public goods by introducing a multi-dimensional policy-variable. However, he does not introduce the specific preference structure of public goods. Kroll and Shogren (2008) study a bilateral public good setting where own and foreign contributions are negotiated.

[5]Such an entry decision corresponds to the decision of countries to join a coalition in the case without ratification uncertainty.

2 Basic setup of the theoretical model

Let the number of countries be denoted by n. Each country must choose its abatement level of a global pollutant q_i $(i = 1, \ldots, n)$ which induces some abatement costs $C(q_i)$ that are assumed to be strictly increasing and convex in the abatement level, $C'(\cdot) > 0$, $C''(\cdot) \geq 0$ and identical across countries. Abatement creates benefits $B_i(Q) = b_i Q$, where $Q = \sum_i q_i$ denotes the aggregate abatement level and $b_i > 0$ is a country specific benefit parameter. In line with a large part of the coalition formation literature, we thereby assume benefits to be linear in abatement. The payoff of a country i from abatement related activities is therefore given by $\Pi_i(q_i, Q) = b_i Q - C(q_i)$.

We use the benefit parameter b_i to incorporate uncertainty regarding ratification. While b_i^R denotes the (known) benefit preference of the representative of country i, i.e. the negotiator, the preference b_i^P of the pivotal agent in the ratification process (e.g., median voter) in country i is unknown to the negotiator at the time the agreement is negotiated. We assume that it is given by

$$b_i^P = b_i^R + \epsilon_i + \theta \tag{1}$$

Here, ϵ_i reflects a country-specific shock of the preference parameter and θ refers to a shock that is common to all countries. We assume that countries are ex ante symmetric, i.e. $b_i^R = b^R$ and that ϵ_i are independently identically distributed with a cumulative distribution function $G(\cdot)$ (density $g(\dot{)}$) with mean zero. Any differences in expected value between voters and negotiators preferences are thus captured by the distribution of the global shock θ whose cumulative distribution function is denoted by $H(\cdot)$ with density $h(\dot{)}$. We denote the mean of θ by d. For simplicity, we assume that both distributions are uniform:[6]

$$\epsilon_i \sim U[-\Delta_\epsilon, \Delta_\epsilon]$$

and

$$\theta \sim U[d - \Delta_\theta, d + \Delta_\theta].$$

Importantly, we assume that domestic and foreign representatives have identical beliefs

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[6]The qualitative insights of our paper do not depend on this assumption.

about country i's voters.[7] We interpret the uncertainty as originating from the temporal features of ratification processes: once an international agreement is signed, or for the purpose of the argument, a domestic legislation is proposed, time may passes that generates new information to the voters and thereby may change their final decision. Examples reach from nuclear accidents as Chernobyl or Fukushima which subsequently changed the attitudes of median voters towards nuclear power to elections taking place in the country and exchanging the decision makers in the ratification process and thereby possibly changing the ratifiers preferences. Alternatively, the uncertainty may stem from potential changes in the government.

In the following, we study the impact of uncertainty on the terms of international agreements. Importantly, we start with the assumption of all n countries sitting at the negotiation table. That is, we do not consider an initial decision to enter negotiations.[8] We assume that the agreement has the following structure: First, it specifies a minimum number $\hat{r}$ of countries that have to ratify the agreement before it enters into force. Second, it specifies a commitment level $\hat{q}$ for ratifying countries have to deliver in case that the agreement becomes active.[9]

We assume that all uncertainty with respect to all b_i^P is resolved *before* the ratification processes in the countries start. Further, we assume that ratification takes places sequentially. The order is randomly determined *after* the agreement is formulated. This assumption makes countries ex ante symmetric, i.e. all countries are identical at the time of the negotiations. We denote the set of ratifying countries by R.

If $r \geq \hat{r}$ countries ratify the agreement, it enters into force. In this case, ratifying countries $i \in R$ are bound to abate $q_i \geq \hat{q}$, while other countries ($i \notin R$ do not face any obligation. In case that less than $\hat{r}$ countries ratify, no country faces any obligation as the agreement does not enter into force.

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[7]For a theoretical treatment of strategic use of uncertainty in case of asymmetric information between domestic and foreign representatives, see Iida (1996).

[8]We hope to be able to address this in further research.

[9]Alternatively, the commitment level could be a more complicated function of the number of ratifying countries. Our assumptions reflects the style in which the Kyoto protocol was set up.

2.1 The non-cooperative case

We first consider the case in which no agreement exists. Here, the representative can implement his personally desired policy:

$$\max_{q_i} b_i^R(q_i + Q_{-i}) - C(q_i) \qquad \Leftrightarrow \qquad C'(q_i) = b^R \tag{2}$$

where $Q_{-i} = Q - q_i$. The linear benefits imply a dominant strategy. The solution is denoted by q^N.

We assume that the representatives can implement their unilaterally optimal level and that voters' preferences only affect the acceptance of a potential international agreement.

2.2 The ratification decisions

In order to investigate the optimal design of an agreement, we need to solve the game backward, i.e first derive the conditions under which countries ratify the agreement. Remember that we assumed a sequential ratification process which happens under full information about all countries' realizations of preferences of pivotal voters b_i^P.

It is obvious that countries that do not ratify the agreement will choose q^N as derived in (2). Taking this into account, a country may only ratify the agreement if its ratification is needed to achieve the minimum participation threshold $\hat{r}$. If at least $\hat{r}$ other countries ratify, a country will not do so since its ratification does not affect the contributions of any other country. As a consequence, no more than $\hat{r}$ countries will ever ratify the agreement.

Assume that a country is decisive for reaching the minimum participation threshold. It then may consider ratifying only if this (weakly) increases its payoff relative to the case when it does not ratify, i.e. when the agreement does not enter into force and all countries fall back to their non-cooperative level q^N:

$$b_i^P \left[\hat{r}\hat{q} + (n - \hat{r})q^N\right] - C(\hat{q}) \geq b_i^P n q^N - C(q^N)$$

$$\Leftrightarrow \quad b_i^P \geq \beta := \frac{C(\hat{q}) - C(q^N)}{\hat{r}(\hat{q} - q^N)} \tag{3}$$

where $\beta = \beta(\hat{q}, \hat{r})$ denotes the minimum benefit parameter that makes ratification of a given agreement $(\hat{r}, \hat{q})$ worthwhile to a country. That is, the country may only ratify if its benefits from the additional abatement by all $\hat{r}$ ratifying countries exceed its additional abatement costs.

Under the assumed sequential ratification process, it thus follows that the last $\hat{r}$ countries for which $b_i^P \geq \beta$ will ratify the agreement. The agreement thus enters into force if $b_i^P \geq \beta$ holds for at least $\hat{r}$ countries. With (1), this requires $\epsilon_i \geq \beta - b^R - \theta$ such that the probability of this participation threshold $\hat{r}$ being reached is given by

$$\pi = \pi(\hat{q}, \hat{r}) = \int \left[\sum_{r=\hat{r}}^{n} \binom{n}{r} (1 - G(\beta - b^R - \theta))^r G(\beta - b^R - \theta)^{n-r} \right] dH(\theta) \qquad (4)$$

We will later illustrate our model based on two special cases. Case (1) assumes no country-specific shocks ($\Delta_\epsilon = 0$) such that all uncertainty is captured by $H(\cdot)$. Here, (4) reduces to:

$$\pi^1 = \pi^1(\hat{q}, \hat{r}) = 1 - H(\beta - b^R) \qquad (5)$$

Case (2) assumes no global shocks ($\Delta_\theta = 0$) such that the realizations of b_i^P are independent across countries:

$$\pi^2 = \pi^2(\hat{q}, \hat{r}) = \sum_{r=\hat{r}}^{n} \binom{n}{r} (1 - G(\beta - b^R - d))^r G(\beta - b^R - d)^{n-r} \qquad (6)$$

where d was defined as the mean of θ, i.e. the expected difference between representatives and pivotal voters preferences.

It will be important how the probability π of the agreement entering into force (or, in the special cases, π^1 and π^2) depends on the design of the agreement, i.e. the choice of the commitment level $\hat{q}$ and the minimum participation $\hat{r}$. We obtain the following Lemma.

Lemma 1 *The probability that the agreement enters into force is decreasing in the chosen commitment level $\hat{q}$. For a sufficiently small variance of the country-specific shocks ϵ_i (e.g., case 1 where these do not exists), the probability increases in the minimum participation threshold $\hat{r}$. In general, the probability π may be decreasing of increasing in $\hat{r}$.*

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Proof of Lemma 1: Equation (4) immediately shows that the probability π is decreasing in β as this increases the probability of individual countries ratifying the agreement. Since β is increasing in $\hat{q}$:

$$\frac{\partial \beta}{\partial \hat{q}} = \frac{\partial \beta(\hat{q}, \hat{r})}{\partial \hat{q}} = \frac{C'(\hat{q})(\hat{q} - q^N) - (C(\hat{q}) - C(q^N))}{\hat{r}(\hat{q} - q^N)^2} > 0 \tag{7}$$

where we used the convexity of the cost function $C(\cdot)$. Similarly β is decreasing in $\hat{r}$:

$$\frac{\partial \beta}{\partial \hat{r}} = \frac{\partial \beta(\hat{q}, \hat{r})}{\partial \hat{r}} = -\frac{\beta}{\hat{r}} < 0 \tag{8}$$

which already proves the claim regarding the impact of $\hat{q}$ and – by continuity – regarding the impact of $\hat{r}$ on π for small variance (see (5). Increases in $\hat{r}$ have, however, a directly declining effect on π even when β is kept fixed as more countries are required to ratify before the agreement enters into force (see (4). The potentially decreasing effect of $\hat{r}$ on π can be easily seen by comparing the extreme cases of $\hat{r} = 1$ and $\hat{r} = n$ for the case 2 in which no global shock exists:

$$\pi^2(\hat{q}, 1) = 1 - G(\beta_1 - b^R - d)^n$$
$$\pi^2(\hat{q}, n) = (1 - G(\beta_n - b^R - d))^n$$

where $\beta_r = \beta(\hat{q}, 1)/r$. Here $\pi^2(\hat{q}, 1) > \pi^2(\hat{q}, n)$ would be obtained if $1 > G(\beta_1 - b^R - d)^n + (1 - G(\beta_n - b^R - d))^n$ for which examples can easily be created. $\square$

Intuitively, a larger commitment level increases benefits linearly while costs are convex such that a larger benefit parameter is needed to make ratification worthwhile. A larger participation threshold has two separate effects: (i) it increases the gains from the agreement for an individual country and thereby increases the willingness to ratify, but (ii) requires more countries to succeed in their ratification process which may lower the probability of reaching this threshold if country-specific shocks are significant. This latter effect is absent if no such country-specific shocks exist since then either all countries or no country would be able to ratify.

Figure 1 illustrate the probability π as a function of the design parameter $\hat{q}$ and $\hat{r}$ of the
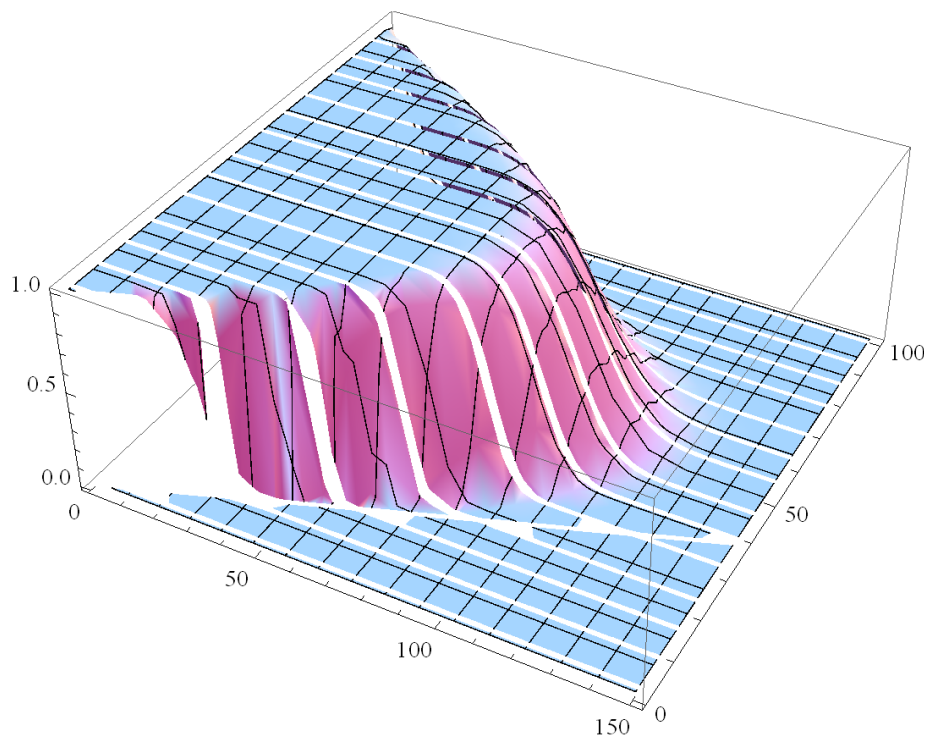
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agreement.

Figure 1: *Probability of the agreement entering into force for case 2 of fully independent country shocks, i.e. with no global shock, for $\hat{q} \in [1, 150]$ and $\hat{r} \in [2, 100]$. Cost functions are chosen as $C(q) = 50q^2/2$, the parameter set at $n = 100$, $b^R = 50$, $d = 0$, $\Delta_\epsilon = 50$, $\Delta_\theta = 0$.*

2.3   The optimal design of the agreement

We will now use the insights from the previous section to study the optimal design of the agreement, i.e. the optimal choice of $\hat{1}$ and $\hat{r}$.

We assume that countries maximize the sum of expected utility of negotiating country representatives. Given our symmetric setting and, in particular, the assumption that the sequence in which countries' ratification processes occur is randomly determined *after* the agreement is signed, this optimization is equivalent to each country maximizing its expected

utility. The sum of expected utility is given by:

$$
\begin{aligned}
W(\hat{r}, \hat{q}) &= (1 - \pi(\hat{r}, \hat{q})) \left[nb^R(nq^N) - nC(q^N) \right] \\
&\quad \pi(\hat{r}, \hat{q}) \left[nb^R(\hat{r}\hat{q} + (n - \hat{r})q^N) - ((n - \hat{r})C(q^N) + \hat{r}C(\hat{q})) \right] \\
&= n \left[b^R(nq^N) - C(q^N) \right] + \pi(\hat{r}, \hat{q})\hat{r} \left[nb^R(\hat{q} - q^N) - (C(\hat{q}) - C(q^N)) \right] \quad (9)
\end{aligned}
$$

The first part states the welfare of the welfare of all countries without any agreement. The second part adds the gains from the agreement which enters into force with probability π and makes $\hat{r}$ countries change their abatement level. This change leads to a cost difference, but also creates a additional benefits to all n countries.

The welfare function (9) immediately implies that the optimal $\hat{r}$ maximizes the expected number of ratifying countries for a given $\hat{q}$, i.e.

$$
\max_{\hat{r}} \pi(\hat{r}, \hat{q})\hat{r} \quad (10)
$$

From Lemma 1 we know that the probability is always increasing in $\hat{r}$ if country-specific shocks are of minor importance, e.g. in case 1 where only global shocks may occur. In this case, it is therefore optimal to choose $\hat{r} = n$. In general, however, a larger number of ratifying countries may lead to a decline in the probability such that an interior solution may result. We therefore immediately obtain the following proposition.

Proposition 1 *If uncertainty regarding the ratification originates from global shocks only, the agreement should require full participation ($\hat{r} = n$). If country-specific shocks are dominant, it can be optimal to require only partial participation ($\hat{r} < n$).*

Proposition 1 shows that uncertainty may only impact the optimal participation threshold $\hat{r}$ if country-specific shocks exists (i.e. if $\Delta_\epsilon > 0$. It is instructive, however, to see to which level the optimal participation threshold converges when the variance in the distribution of country-specific shocks goes to infinity. Here, we obtain the following result:

Proposition 2 *For $\Delta_\epsilon \to \infty$, the optimal participation threshold converges to a level $\bar{r}$*

given by

$$\bar{r} = \arg\max_{\hat{r}} \hat{r} \sum_{r=\hat{r}}^{n} \binom{n}{r}$$

Proof of Proposition 2: This follows immediately from (10) and (4) when noting that for any given Δ_θ, $G(\beta - b^R - \theta)$ converges to 0.5 when $\Delta_\epsilon \to \infty$. $\square$

We illustrate the dependence between this limit of the participation threshold $\bar{r}$ and n in Figure 2. The relationship is surprisingly linear, the best linear fit is given by $\bar{r} = -1.08777 + 0.440294n$ and describes the data well for $n > 20$ (derivation using Wolfram Mathematica 8).[10]
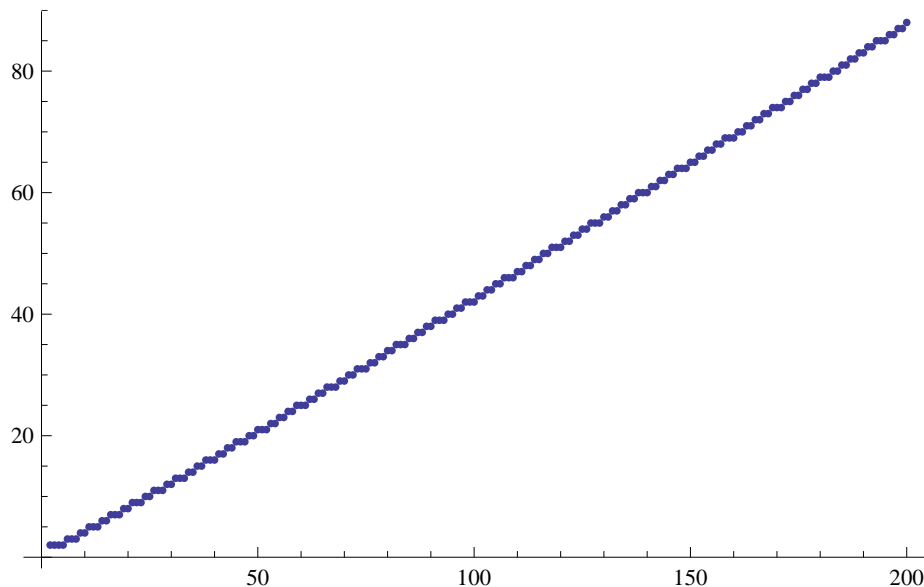

Figure 2: *Relationship between participation threshold and number of players for $\Delta_\epsilon \to \infty$.*

For determining the optimal choice of the commitment level $\hat{q}$, we need to consider its marginal impact on welfare:

$$\frac{\partial W(\hat{r}, \hat{q})}{\partial \hat{q}} = \pi \hat{r} \left[n b^R - C'(\hat{q}) \right] + \frac{\partial \pi}{\partial \hat{q}} \hat{r} \left[n b^R (\hat{q} - q^N) - (C(\hat{q}) - C(q^N)) \right] \tag{11}$$

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[10]Precisely, $\hat{r} \sum_{r=\hat{r}}^{n} \binom{n}{r}$ is increasing in r as long as $\hat{r} \binom{n}{\hat{r}} < \sum_{r=\hat{r}+1}^{n} \binom{n}{r}$.

The first part reflects the optimal commitment level q^{*R} from the perspective of the representatives, given by $C'(\hat{q}^{*R}) = nb^R$, who would like to internalize all mutual benefits. However, they also need to consider the impact of $\hat{q}$ on the probability that the agreement enters into force. This is given by the second part of (11). Note that the term in the brackets is positive as representative would formulate only an agreement that makes them better off than would could be achieved unilaterally (q^N).

For the case of an interior solution, (11) leads to the following first order condition:

$$\pi \left[sb^R - C'(\hat{q}) \right] = -\frac{\partial \pi}{\partial \hat{q}} \left[nb^R(\hat{q} - q^N) - (C(\hat{q}) - C(q^N)) \right] \tag{12}$$

Lemma 1 stated that π is decreasing in $\hat{q}$. Therefore the right-hand side is positive which implies $sb^R > C'(\hat{q})$ and $\hat{q} < q^{*R}$. In general, representatives therefore need to reduce the commitment level below their personally preferred q^{*R}.

Proposition 3 *Under ratification uncertainty, the commitment level in international agreements is generally chosen below the level preferred by the representatives.*

Proposition 3 states the the benefits from abatement across countries will only be partially internalized from the perspective of representatives who negotiate the agreement. Intuitively, this is driven by a simple consideration: reducing the abatement requirement increases the chances of the agreement to take effect.

Note that a similar compromise may already be necessary without uncertainty if the voters' preferences differ sufficiently from those of representatives. They would agree only if $\beta \leq b^R + d$. Here, the representative may need to reduce the commitment in order to generate acceptance of voters if d is sufficiently negative. However, uncertainty adds an important insight: The extent to which representatives lower the commitment below their preferred level depends crucially on the quantitative impact on the probability of ratification in the respective countries. If the variance of voters' preference (i.e. if Δ_θ or Δ_ϵ) is very large, $\partial \pi / \partial \hat{q}$ is close to zero such that condition (12) leads to a commitment level close to q^{*R}.

We obtain an interesting non-monotonic impact of uncertainty:

Proposition 4 *The variance of voters' preferences has a non-monotonic impact on the optimal commitment level $\hat{q}$ if*

$$d \leq \beta(q^{*R}, n) = \frac{C(q^{R*}) - C(q^N)}{n(q^{*R} - q^N)}$$

Increases in Δ_θ or Δ_ϵ, first lead to reduced optimal commitment levels before increasing them again.

If

$$d > \beta(q^{*R}, n) = \frac{C(q^{R*}) - C(q^N)}{n(q^{*R} - q^N)}$$

the optimal commitment level under ratification uncertainty with sufficiently large variance is larger than under certainty ($\Delta_\theta = \Delta_\epsilon = 0$.

For $\Delta_\theta + \Delta_\epsilon \to \infty$, the optimal commitment level converges to q^{*R}.

At a first glance, the non-monotonic impact of uncertainty may appear surprising. However, the intuition for proposition 4 is straightforward. Representatives may choose a smaller commitment level in order to increase the chances for the agreement to be ratified and to enter into force. As long as the variance is relatively small, a reduction in commitment effort can increase ratification probability substantially and is traded-off against the negative impact on welfare under the agreement. If, however, the variance of voters' preferences is too large, the marginal impact of such a reduction on the probability of ratification is very small. As a consequence, the representatives return to their preferred commitment level. We give an analytical proof in the Appendix.

So far, we based our discussion of the impact of ratification uncertainty on limiting cases of large variance of the distributions. In general, the optimal design $(\hat{q}, \hat{r})$ of an international agreement is jointly determined by (12) and (10). In order to gain insights into the intermediate cases we turn to numerical simulations in the next section.

3 Comparative statics: impact of uncertainty

We employ a quadratic specification of the cost function, $C(q) = q^2$. We use this to illustrate the impact of the average difference between voters' and representative's preferences d as well as the variance of the global shock (Δ_θ) and the country-specific shock (Δ_ϵ). For illustration purposes, we concentrate on the Cases 1 and 2, i.e. only consider a non-zero variance for one distribution.

We base the illustrations on the following functional forms:

$$C(q) = q^2/2 \qquad b^R = 50 \qquad n = 100$$

fig/fig_case1.pdf

Figure 3: *Relationship between optimal commitment level $\hat{q}$ and difference between voters and representatives' preferences (d) for different levels of Δ_θ (Case 1, $\Delta_\epsilon = 0$)*

Figure 4: *Relationship between optimal commitment level $\hat{q}$ and difference between voters and representatives' preferences (d) for different levels of Δ_ϵ (Case 2, $\Delta_\theta = 0$)*

4 Conclusion

In this paper we analyzed the impact of the ratification process on the optimal design of an international environmental agreement (IEA). We relaxed the frequent assumption of countries being unitary actors and introduced a ratifying agent (e.g. the pivotal voter) who has veto power in the decision of his country to ratify the agreement. The preference of the voter is subject to uncertainty at the time when the agreement is formulated. With our paper, we took a first step in combining the literature on IEAs with the one on two-level games of ratification and created a link between individual preferences and the negotiation outcomes in IEAs.

For IEAs with an endogenous minimum participation threshold, we demonstrated how uncertainty of the ratifiers preferences and the relative position of his preference distribution to the negotiators preferences influence both the chosen level of commitment as well as the chosen minimum participation threshold. Doing so, gives interesting insights into the optimal structure of international agreements. Larger uncertainty in terms of larger variance

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Figure 5: *Relationship between optimal participation threshold $\hat{r}$ and difference between voters and representatives' preferences (d) for different levels of Δ_ϵ (Case 2, $\Delta_\theta = 0$)*

in the distribution of preferences does not necessarily lead to weaker agreements. Instead, increases in the variance of voters' preferences generally have an non-monotonic impact on the optimal commitment level: for small variances, negotiating representatives may compromise upon their own desired commitment level in order to increase the chances of the agreement being ratified in individual countries and therefore entering into force. For larger variance, however, such compromise does not substantially impact the probability of ratification such that negotiators return to implementing their own preferred commitment level in the IEA.

The optimal minimum participation threshold crucially has to take potential country-specific shocks into account. If such exists, less than full participation is generally optimal. Intuitively, it would be very unlikely for all countries to succeed in their ratification processes. Based on simulations, we found that the optimal participation threshold can also depend on the variance of the distribution in a non-monotonic way.

We believe that this paper makes important contributions: (i) it contributes to a more realistic modeling of the temporal structure of international agreements by including a

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ratification stage, (ii) it identifies reason for requiring only partial participation for an agreement to enter into force, (iii) it shows a surprising, yet intuitive non-monotonic relationship between the optimal commitment level and the variance of ratification decisions.

Naturally, our results only provide a first step in understanding the formulation of international agreements in presence of ratification uncertainty. We concentrated on the case of symmetric countries and simple agreements that only specify the level of commitment and the participation threshold. It appears worthwhile to extend the analysis to account for heterogeneities by allowing country-specific commitments that may also vary with the set of countries that end up ratifying the agreement. Similarly, the number of countries that initially engage in negotiations can be made endogenous in order to embed our model in a coalition formation framework. We leave these extensions for future research.

References

Baker, E., 2005. Uncertainty and learning in a strategic environment: Global climate change. Resource and Energy Economics, 27(1), pp.19-40.

Barrett, S., 1998. On the theory and diplomacy of environmental treaty-making. Environmental and Resource Economics, 11(3-4), pp.317-333.

Barrett, S., 1994. Self-enforcing international environmental agreements. Oxford Economic Papers, 46(Special Issue on Environmental Economics), pp.878-894.

Barrett, S., 1997. The strategy of trade sanctions in international environmental agreements. Resource and Energy Economics, 19(4), pp.345-361.

Black, J., Levi, M.D. and De Meza, D., 1993. Creating a good atmosphere: minimum participation for tackling the'greenhouse effect'. Economica, 60(239), pp.281-293.

Bosetti, V. and Cian, E. De, 2012. A good opening: the key to make the most of unilateral climate action. Discussion Paper 2012-49, Cambridge, Mass.: Harvard Project on International Climate Agreements.

Brandt, U.S., 2004. Unilateral actions, the case of international environmental problems. Resource and energy economics, 26(4), pp.373-391.

Cao, J., 2010. Beyond Copenhagen: Reconciling International Fairness, Economic Development, and Climate Protection. Discussion Paper 2010-44, Cambridge, Mass.: Harvard Project on International Climate Agreements.

Carraro, C., 1998. Beyond Kyoto: A Game-Theoretic Perspective. draft, (October 1998), pp.17-18.

Carraro, C., Eyckmans, J. and Finus, M., 2006. Optimal transfers and participation decisions in international environmental agreements. The Review of International Organization, 1(4), pp.379-396.

Carraro, C., Marchiori, C. and Oreffice, S., 2009. Endogenous Minimum Participation in International Environmental Treaties. Environmental and Resource Economics, 42(3), pp.411-425.

Carraro, C. and Siniscalco, D., 1993. Strategies for the international protection of the environment. Journal of Public Economics, 52(3), pp.309-328.

Currarini, S. and Tulkens, H., 1998. Core-theoretic and political stability of international agreements on transfrontier pollution. CORE Discussion Paper 9793, Louvain-la-Neuve: CORE, Universit Catholique de Louvain.

D'Aspremont, C. et al., 1983. On the stability of collusive price leadership. Canadian Journal of , 16(1), pp.16-25.

Engel, K.H. and Saleska, S.R., 2005. Subglobal regulation of the global commons: The case of climate change. Ecology Law Quarterly, 32, pp.183-234.

Finus, M., Ierland, E. and Dellink, R., 2006. Stability of climate coalitions in a cartel formation game. Economics of Governance, 7(3), pp.271-291.

Hoel, M., 1991. Global environmental problems: The effects of unilateral actions taken by one country. Journal of Environmental Economics and Management, 20(1), pp.55-70.

Hoel, M. and Schneider, K., 1997. Incentives to participate in an international environmental agreement. Environmental and Resource Economics, 9(2), pp.153-170.

Hug, S., 2009. Models of multilateral negotiations and ratification, Working Paper.

Humphreys, M., 2007. Strategic ratification. Public Choice, 132(1-2), pp.191-208.

Iida, K., 1996. Involuntary defection in two-level games. Public Choice, 89(3-4), pp.283-303.

Iida, K., 1993. When and How Do Domestic Constraints Matter?: Two-Level Games with Uncertainty. Journal of Conflict Resolution, 37(3), pp.403-426.

Kolstad, C. and Ulph, A., 2008. Learning and international environmental agreements. Climatic Change, 89(1-2), pp.125-141.

Kolstad, C.D., 2011. Public Goods Agreements with Other-Regarding Preferences. Draft.

Kolstad, C.D., 2003. Uncertainty in self-enforcing international environmental agreements. Draft.

Konrad, K.A. and Thum, M., 2011. Unilateral action and negotiations about climate policy. Working Paper.

Kroll, S. and Shogren, J.F., 2008. Domestic politics and climate change: international public goods in two-level games. Cambridge Review of International Affairs, 21(4), pp.563-583.

Kıbrıs, A., 2012. Uncertainty and ratification failure. Public Choice, 150(3-4), pp.439-467.

Lange, Andreas, 2006. The Impact of Equity-Preferences on the Stability of International Environmental Agreements, Environmental and Resource Economics, 34, pp. 247-267.

Lange, Andreas and Carsten Vogt, 2003. Cooperation in International Environmental Negotiations due to a Preference for Equity, Journal of Public Economics 87, pp. 2049-2067.

Milner, H. V. and Rosendorff, B.P., 1997. Democratic Politics and International Trade

Negotiations: Elections and Divided Government As Constraints on Trade Liberalization. Journal of Conflict Resolution, 41(1), pp.117-146.

Missfeldt, F., 1999. Game-Theoretic Modelling of Transboundary Pollution. Journal of Economic Surveys, 13(3), pp. 287-321

Pavlova, Y. and Zeeuw, A. de, 2011. Asymmetries in international environmental agreements. Environment and Development Economics, 18(1), pp. 51-68.

Putnam, R.D., 1988. Diplomacy and domestic politics: the logic of two-level games. International Organization, 42(3), pp.427-460.

Rutz, S., 2001. Minimum participation rules and the effectiveness of multilateral environmental agreements. Working Paper ETH Zurich,

Schelling, T.C., 1960. The strategy of conflict, Cambridge, MA: Harvard University Press.

Tarar, A., 2001. International Bargaining with Two-Sided Domestic Constraints. Journal of Conflict Resolution, 45(3), pp.320-340.

Ulph, A. and Maddison, D., 1997. Uncertainty, learning and international environmental policy coordination. Environmental and Resource Economics, 9(4), pp.451-466.

Ulph, A. and Ulph, D., 1996. Who Gains from Learning about Global Warming? In E. V. Ierland and K. Gorka, eds. Economics of atmospheric pollution. Heidelberg: Springer Verlag, pp. 31-67.

Wagner, U.J., 2001. The design of stable international environmental agreements: Economic theory and political economy. Journal of economic surveys, 15(3), pp.377-411.

Weikard, H.-P., Wangler, L. and Freytag, A., 2009. Minimum participation rules with heterogeneous countries. Jena Economic Working Paper.