Towards a global climate constitution

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1. Climate change and climate policies

The composition of the atmosphere determines the climatic conditions on our planet. In recent years, supported by the results of Working Group III of the Intergovernmental Panel on Climate Change (IPCC 2008), a consensus has emerged that emissions of greenhouse gases pose a major threat to climatic stability and are a source of catastrophic risk. Since the time of the British industrialisation the atmosphere has served as carbon storage for the fossil fuel-fired economies of industrialised and industrialising countries. In the light of the facts of climatic change the need to limit carbon and other greenhouse gas emissions is generally acknowledged. However, there is as yet no global system of property rights that governs greenhouse gas emissions. Concerning these emissions we are in a state of Hobbesian anarchy. The Kyoto Protocol does not implement effective constraints on greenhouse gas emissions and must be considered a failure (cf. Barrett 2009). What is urgently needed is a global constitutional contract to overcome the inefficiencies and threats of a global "climate anarchy". A constitutional contract would determine emission rights and the terms under which these rights can be exchanged or traded.

In this paper my concern is the study of the incentives of individual countries to sign an international climate agreement that sets the terms of a climate constitution, that is, it establishes emission rights and rules for

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trading these rights to combat the climate problem effectively and efficiently. Here I will largely ignore concerns about fairness of the initial distribution of rights. Elsewhere I have discussed fair appropriation of resources in general (Weikard 1998) and with respect to greenhouse gas emission rights in particular (Weikard 2004).

My approach to this problem links up with and extends a recent strand of literature on international environmental agreements (cf. Hoel 1992; Carraro/Siniscalco 1993; Barrett 1994, 2003). This literature starts out from the assumption that sovereign countries with no initial rules and regulations for the control of transboundary emissions will seek to reach agreement. However, no individual country can be forced to adhere to any rules unless it has signed an agreement and no country can be forced to enter an agreement to effectively establish emission rights. Signing an agreement is voluntary and it is assumed that a country will sign if its position as a signatory is better than as a non-signatory. Furthermore, it is assumed that the group of signatories adopts joint climate policies that are optimal given the climate policies of non-signatories. Similarly, every non-signatory adopts an optimal climate policy given the climate policies of all others. Hence, we assume that climate policies constitute a Nash equilibrium of a transboundary pollution game. Further details of the game theoretical approach to this problem are provided in the next section.

Before I turn to the formal analysis I want to introduce and discuss two additional assumptions. First, we assume that sovereign countries, or their governments – these are the players in our game – are myopic in the sense that their concern is fully focused on the current decision whether or not to join an agreement. In particular, they do not consider the option to join the agreement later and they do not envisage that others may join later. This assumption is in line with the idea that often political agendas are short lived, a government's term of office is limited to a few years and re-election is uncertain. The second assumption is the key idea of this paper. We assume that signing an agreement is an irrevocable commitment. Once a country has signed the climate agreement it gives up its sovereignty in the domain of climate policy and it can never opt out after that. This may seem a strong assumption. However, it is not unprecedented in history. For example, countries composed of federal states do usually not allow that individual states break away. Another example is the formation of the European Monetary Union. Its members have signed an irrevocable commitment to fix the exchange rates of their currencies forever and to give up their sovereignty in the domain of monetary policy. The national central banks have transferred their power to the European Central Bank. For climate policies, a World Environmental Organisation (cf. Odendahl in this volume) could play the role of a climate government that enforces the rules of the climate constitution. In particular, it could monitor abatement targets and introduce and administrate appropriate instruments such as, for instance, a market for emission permits. In essence, a climate agreement that relies on an irrevocable commitment is a *climate constitution*, defines initial property rights (emission rights), and sets the rules for trading these rights. Such climate agreement, if signed by all countries, is a *global climate constitution*.

In the following this paper explores how a global climate constitution may emerge as a sequence of accessions given that, in each round of negotiations, sovereign states are free to join or to maintain their independence. The aim is to unveil the determinants of the progress towards a global climate constitution. To that aim we study a sequential game (with myopic players). The game is introduced in the next section. Section 3 discusses how the game is solved. Section 4 provides simulation results that illustrate the findings. Section 5 draws conclusions for climate policies.

2. A model of sequential accession

In recent years a standard model for the study of international environmental agreements has emerged. This model is designed to study the incentives of individual sovereign countries to join an international agreement to combat transboundary pollution. The model is a two-stage game where at stage 1 countries simultaneously sign or ratify an agreement or not and, at stage 2, they determine their abatement efforts where signatory countries act jointly and non-cooperatively vis-à-vis other countries that have not signed the agreement.[1] The second stage game is usually a standard transboundary pollution game as introduced by Mäler (1989) and further analysed by Folmer/von Mouche (2000). In the case of cli-

[1] The first to study this kind of model were Hoel (1992), Carraro/Siniscalco (1993) and Barrett (1994). Finus (2003) provides a more recent survey.

mate change, greenhouse gases are global pollutants. Damages from climate change depend on the stock of greenhouse gases and are independent of the location of emissions. This, in turn, makes the abatement of greenhouse gases a global pure public good. It is well-known that in the absence of regulation and enforcement the private provision of public goods constitutes a social dilemma where the individual contributions fall short of the efficient levels. A social dilemma is characterised by free-rider incentives. Each individual country benefits from the abatement of others while the individually chosen abatement levels disregard of the benefits that accrue to others. The inefficiencies of the private provision of public goods can be overcome by joint action. A global climate constitution, to which all countries subscribe, would set abatements to efficient levels. With appropriate redistributions – via the initial allocation of emission permits – each country will be better off with a global climate constitution compared to the absence of cooperation.

Notwithstanding the efficiency of a global climate constitution, still there exist strong free-rider incentives. From the perspective of an individual country it is usually preferable to *not* sign the climate agreement when others sign. At stage 1 of our game we assume that the agents are sovereign countries. As such they cannot be forced to enter the agreement. Participation is voluntary. The irritating finding in this setting is that an efficient global agreement would emerge if the gains from cooperation are small. If, however, the gains are large then at best an agreement with few participants can be reached (cf. Barrett 1994). This result stems from the fact that when stakes are high, free-rider incentives will be strong.

In the following I will study this two-stage game, but I will assume that it is played for several rounds by myopic countries that make irrevocable commitments. If an agreement is formed in one round, then all signatories form a single player in the subsequent round. Hence, the game has (potentially) a different set of players in every round and is, therefore, not simply a repeated game. Our setting is a coalition formation game with sequential accession – but note that the decision to sign or not is taken simultaneously in any given round. Formally the game has infinitely many rounds, but in practice it stops when all countries have signed the climate constitution. The results obtained below show that if at some stage an equilibrium agreement with few countries emerges, others will indeed have an incentive to join at the next stage. As no member country is allowed to resign, the signatories become a single "large player". It is attractive, then, for others to join this large player as well.

Now I introduce the game more formally.

Consider a set of n countries, denoted by N. At stage 1 of the game each country $i \in N$ decides whether to sign a climate agreement or not. Those countries that sign, the group of signatories $S \subseteq N$, adopt a joint best climate policy. Sometimes I will refer to S as the coalition. As every country is free to join, this type of game is an open-membership coalition formation game. Because there is a unique agreement – i.e. I do not consider multiple agreements –, it is a cartel formation game.

At stage 2 of the game the signatories S, acting jointly, and all other countries, acting individually, play a transboundary pollution game. More specifically non-signatories set abatement levels q_i to maximise their own payoff. The signatories adopt a joint climate policy and maximise their joint payoff, i.e. the sum of the payoffs of all coalition members

For a non-signatory country the objective function is given by

(1) $$V_i = B_i(q) - C_i(q_i),$$

where $C_i(q_i)$ is the cost of own abatement and $B_i(q)$ with $q \equiv \sum_{j \in N} q_j$ is the benefit from global abatement. In our specific context the benefit of abatement is the avoided damage from climate change. In practice, of course, it will be very difficult to assess avoided damages (from storms, droughts or floods, for instance) because they are counterfactual, uncertain, and subject to discounting as the largest damages will occur in the far future, decades or centuries ahead.

For the group of signatories we write the objective function as

(2) $$V_S = B_S(q) - C_S(q_S).$$

To obtain simulation results and to illustrate the findings I adopt a particular specification. First, I assume that benefits are linear in abatement but they may differ across countries. Linear benefits are consistent with estimates used in the DICE model (Nordhaus 1997) and the estimates provided by the FUND model (Tol 2002). Second, I assume that abatement costs are quadratic. This reflects increasing marginal abatement cost. However, we assume, for simplicity, that all countries have the same cost function. Abatement costs can be interpreted to include costs of monitoring and enforcement of emission rights. The following specifications are used.

(1′) $V_i = b_i q - \frac{1}{2} c q_i^2$,

(2′) $V_S = \sum_{i \in S} (b_i q - \frac{1}{2} c q_i^2)$,

where $b_i > 0$ is country i's marginal benefits from abatement and $c > 0$ is a cost parameter.

As indicated before, the two-stage game of coalition formation and abatement is played sequentially for several rounds. Each round the game consists of the two stages just described. Hence, the first round starts with the formation of an initial agreement followed by the transboundary pollution game. In the second and all subsequent rounds signatories remain signatories as we assume an irrevocable commitment. The remaining non-signatories, however, can announce their willingness to join at the first stage of each round. The second-stage game is then played by the coalition and the remaining non-signatories. We assume that countries are myopic and do not condition their choice of strategy on coalition formation at a later stage.[2] Now we can turn to the analysis of the game.

3. Solving the model

To solve the model we first turn to the analysis of the two-stage game. This analysis is general and applies to every round of the game. This is due to the assumption of myopic players. The analysis employs backward induction and I start with the second stage of a given round. At that stage a certain coalition S has formed. Hence, there are $|N| - |S|$ non-signatories. The coalition and the non-signatories adopt abatement strategies that are mutually best responses. Hence, we determine a Partial Agreement Nash Equilibrium (Chander/Tulkens 1995). Given our specification with linear benefits of abatement, countries have a dominant strategy, i.e. their optimal abatement level is independent of others' choices.

[2] The case of forward looking countries that keep the option to renegotiate is analysed by Weikard and Dellink (2011).

For a non-signatory country $j \notin S$ the optimal provision of abatement – maximising eq. (1′) – is

$$(3) \qquad q_j = \frac{b_j}{c}.$$

The coalition partners $i \in S$ maximise their joint payoffs. Maximising eq. (2′) we obtain Samuelson's rule for the optimal provision of a public good: the sum of the marginal benefit must equal the individual marginal abatement costs cq_i. Solving for q_i gives

$$(4) \qquad q_i = \frac{1}{c}\sum_{i \in S} b_i .$$

Equations (3) and (4) determine equilibrium abatement levels for all countries for any given coalition *S*. The corresponding payoffs can be obtained from eqs. (1′) and (2′). The equilibrium abatement levels and the corresponding payoffs are unique. This implies that for any given coalition *S* the coalition payoffs and the payoffs of all non-signatories are uniquely determined (Folmer/von Mouche 2000). We can say that payoffs just depend on the coalition that forms and we re-interpret the payoff function and write it as $V(S)$ instead of $V(q_1,...,q_n)$. The function $V(S)$ is called a partition function.

To summarise, at stage 2 the transboundary pollution game determines a partition function that gives the coalition payoffs and the payoffs of all non-signatories for all possible coalitions $S \subseteq N$.

Before we can turn to the analysis of stage 1, where countries decide on coalition membership, we need to discuss how the coalition shares its payoff among its members. Of course, what an individual country gets within a coalition, i.e. when signing the agreement, is important for its incentives to sign. Hence, coalition formation will depend on the sharing rule that is employed by the coalition. Weikard et al. (2006) have examined how different sharing rules affect coalition stability. They find that sharing the gains from cooperation proportional to emissions gives rise to more effective climate coalitions than rules motivated by fairness, for instance when gains are distributed to favour poor countries. In the subsequent literature it has been noted by Carraro et al. (2006), McGinty (2007), Weikard (2009) and Fuentes-Albero/Rubio (2010) that carefully designed sharing rules can improve coalition stability. In what follows we assume that the coalition employs a sharing rule that satisfies a *Claim Rights Condition* which says that the coalition payoff should be shared such that each country's claim should be satisfied whenever this is possible, i.e. whenever the coalition payoff exceeds the sum of the members' claims (cf. Weikard 2009). A country's claim is the payoff it would receive if it remains outside the coalition. Formally this can be stated as follows:

> *Claim Rights Condition:* For all $i \in S$ and all $S \subseteq N$, $V_i(S) \geq V_i(S - \{i\})$ if and only if

(5) $$V_S(S) \geq \sum_{i \in S} V_i(S - \{i\}) .$$

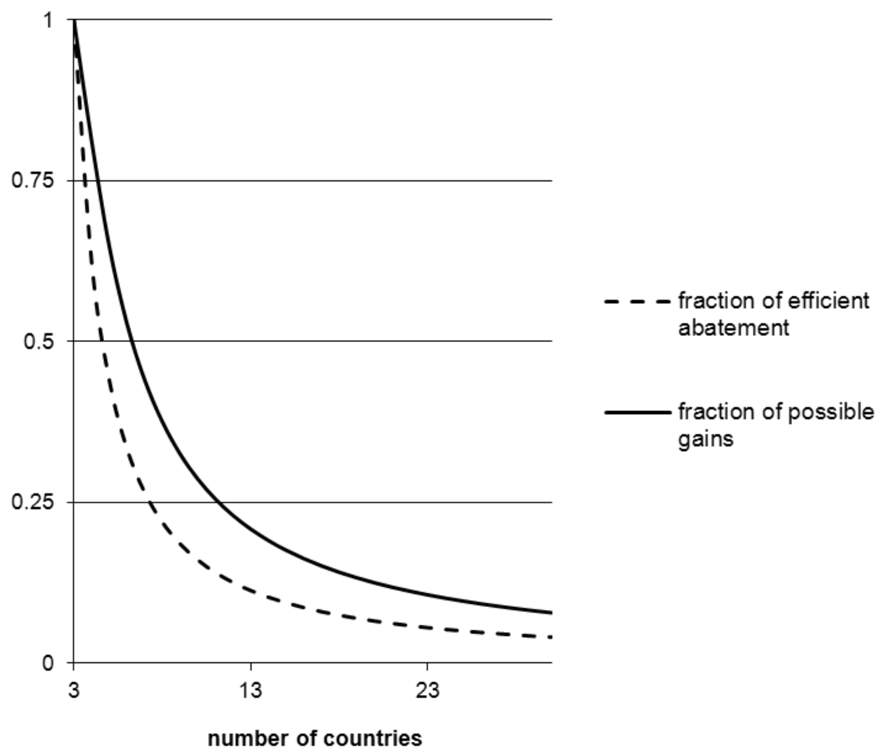
We can now turn to the analysis of the first stage of the game. Here we examine the incentives of countries to join a coalition. We are interested to identify stable coalitions. A coalition is stable if no member has an incentive to leave (internal stability) and no non-signatory has an incentive to join (external stability). Formally we can define stability as follows:

> *Cartel stability* (d'Aspremont et al. 1983): A coalition $S \subseteq N$ is internally stable if and only if $V_i(S) \geq V_i(S - \{i\})$ for all $i \in S$. It is externally stable if and only if $V_j(S) \geq V_j(S \cup \{j\})$ for all $j \notin S$. A coalition is stable if and only if it is externally and internally stable.

Consider now a particular coalition *S*. If the coalition payoff is sufficient to meet all claims and if the coalition payoff is shared such that the Claim Rights Condition is met, then no member of *S* will prefer to leave the coalition. Hence, *S* is internally stable. It is easy to see that every coalition that is possibly internally stable under some sharing rule is also internally stable under any rule that satisfies the Claim Rights Condition. Hence, if we assume that the Claim Rights Condition is applied, internal stability of a given coalition can be checked by checking condition (5). Whether or not (5) holds depends only on the partition function.

Equipped with these insights we can move to the stability analysis of our game. First, as a benchmark, consider a set of identical countries. Then, $b_i = b_j$ in equations (3) and (4). In this case any coalition with 3 countries is stable (Barrett 1994; Weikard 2009). Every larger coalition is internally unstable. This holds regardless of the size of marginal benefits and the number of countries. Consequently if we have few countries, or few larger regions that represent a number of individual countries, then we would find efficient (if there are just three regions) or almost efficient abatement levels. If we have many countries, the largest part of the potential gains from cooperation remains unexploited. This just illustrates the well-known result that free-rider incentives increase with group size (Olson 1965). In fact, it illustrates that this result extends to coalition formation games. Figure 1 shows the global abatement level and the global net gains from abatement as a percentage of the efficient level for different numbers of countries under a stable 3-player coalition ($b_i = 1; c = 1$).[3]

Figure 1: Relative efficiency of a three-player stable agreement



[3] This and the following figures are plots of simulation results from the model described above.

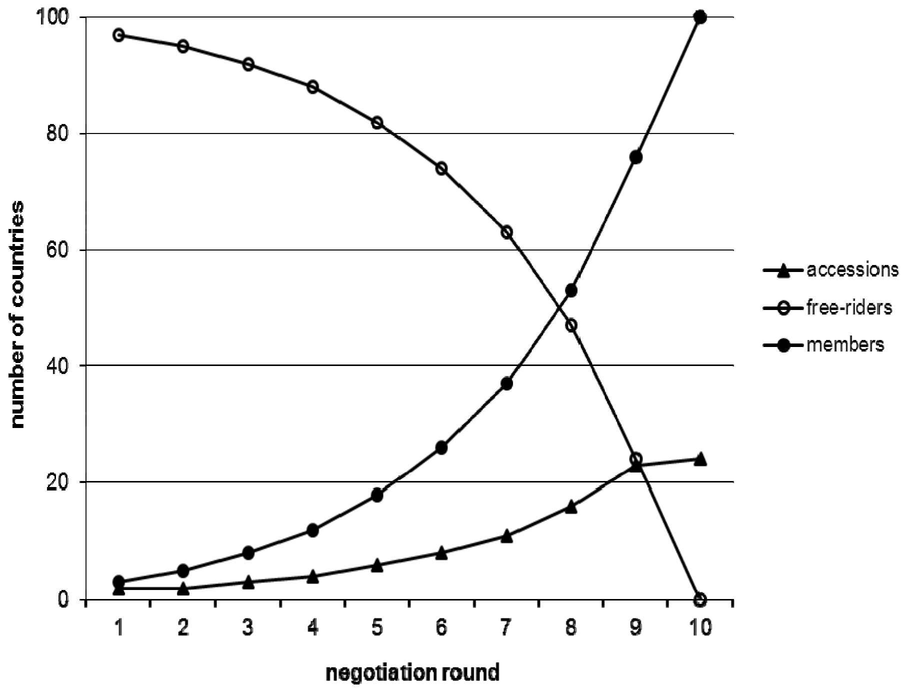
Now we turn to the sequential play of several rounds of the two-stage game. Starting with identical players, the first round will generate a 3-player coalition. This coalition acts as a single player in the next round. Hence, the total number of players is reduced to $n-2$ after the first round. Because the coalition is a "large player", it is an attractive coalition partner in the second round of the game. It has been shown elsewhere that increasing heterogeneity of players supports larger equilibrium coalitions (cf. Weikard 2009). Eventually then, in further rounds, more than three players will sign up. Hence, with irrevocable commitment we expect that the number of countries that join the agreement is always higher in later rounds. In the next section we study this effect resorting to numerical simulation results.

4. Simulation results

Models of coalition formation are haunted by complexity. Even in a cartel game, where we rule out the coexistence of several agreements, we need to consider $2^n - n$ possibilities; an impossible task for a large number of countries. Hence, theoretical analysis has often adopted the assumption of identical countries (cf. Finus 2003) and empirical analysis has worked with a small number of regions (e.g. Nagashima et al. 2009). Here I pursue a third possibility. Starting out from the idea that sovereign countries, not regions, are the signatories of a climate agreement, we want to have a model with many countries. Also we want to relax the assumption that countries are identical. However, differences between countries are captured in a stylised way. We construct a model where countries differ in size of marginal benefits of abatement. A country with high marginal benefits is a country that is vulnerable to climate change. I assume that countries' marginal benefits are uniformly distributed in the interval $[0, 2]$ such that the average marginal benefit is 1. Also, as indicated before, we assume identical abatement costs across countries ($c = 1$). The results are obtained from numerical simulations.

The coalition formation and abatement game is played for several rounds until a grand coalition, the global climate constitution, has evolved.

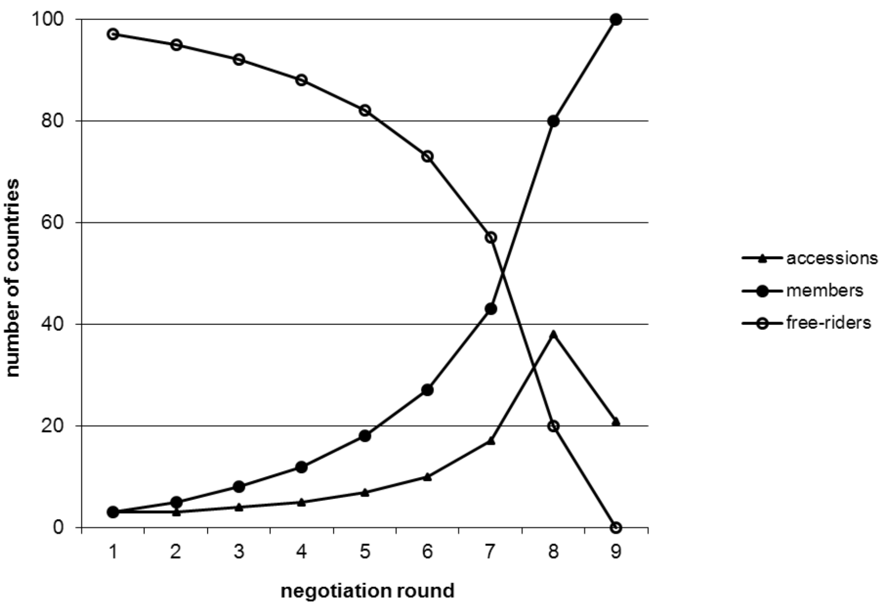
Figure 2: Scenario 1 – countries with identical costs and benefits



Three different scenarios with 100 countries have been computed. The first scenario starts with our benchmark case of identical countries ($b_i = 1; c = 1$). Figure 2 shows how the coalition size evolves with the number rounds. Indeed, as stipulated before, the number of accessions is higher in later rounds. In the first two rounds the equilibrium coalition size is 3, i.e. the number of accessions is 2 in each round. In each of rounds 9 and 10, however, more than 20 countries join. After 10 rounds all countries have joined the global climate constitution and the game ends.

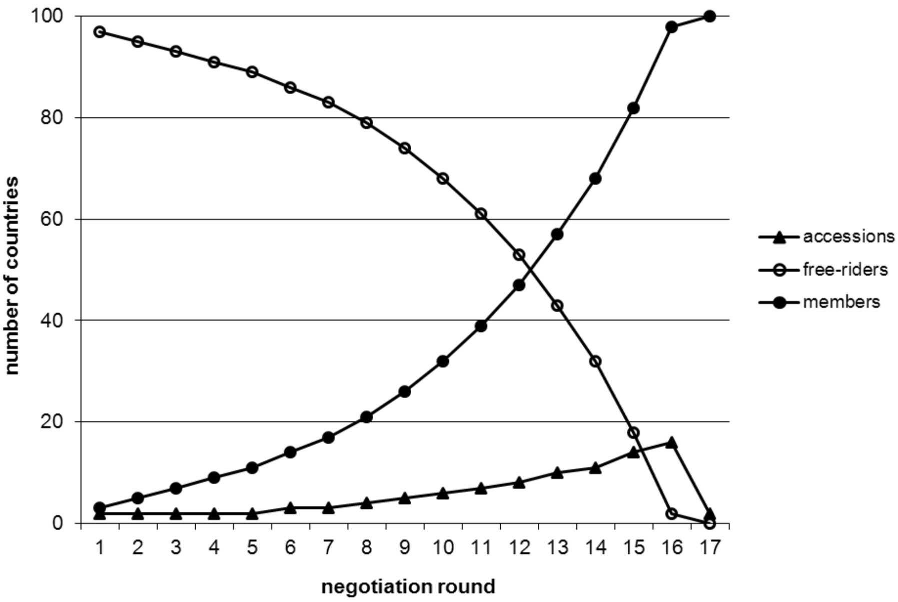
The remaining two scenarios deal with the case of heterogeneous players, where players differ in marginal benefits of abatement. Typically, with many countries, we find multiple equilibria. In the first round every country could be in a coalition with few others. If countries are identical, it can be any three countries that form a coalition. While with identical countries the resulting global abatement is independent of the identity of the members – only the number matters –, this is different for heterogeneous countries. A coalition of vulnerable countries with high marginal benefits will abate more than a coalition with the same number of countries but low marginal benefits. In principle, then, we have many equilibrium coalitions in each round and, therefore, many equilibrium paths of sequential accession. The scenarios computed describe two extreme paths of accession.

Figure 3: Scenario 2 – countries with heterogeneous abatement benefits, optimistic path of accession



Scenario 2 is the optimistic scenario. It starts with a coalition of the countries with highest marginal benefits. For ease of reference I will call them "large countries". These are subsequently joined by the remaining non-signatories, again the largest of these join first. Scenario 3 is the pessimistic scenario. Here it is assumed that countries with the lowest marginal benefits ("small countries") sign the agreement first. The results for scenarios 2 and 3 are presented in Figures 3 and 4, respectively. As expected, in the pessimistic scenario many more rounds of accession are needed to reach a global climate constitution. In the optimistic scenario almost 40 countries enter in round 8 and the global climate constitution is fully established after 9 rounds. In the pessimistic scenario, while the general pattern of accession is the same, it takes 17 rounds to establish the global climate constitution.

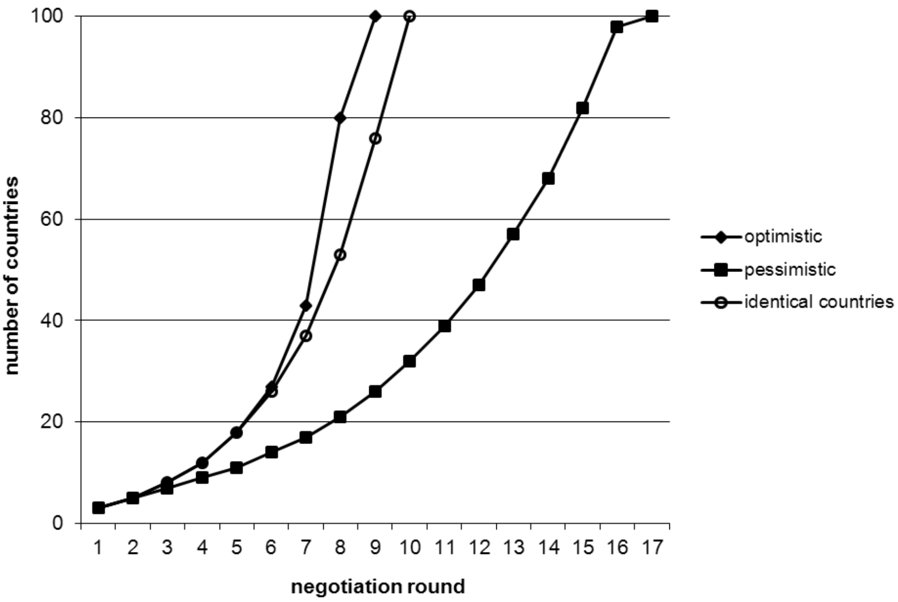
Figure 4: Scenario 3 – countries with heterogeneous abatement benefits, pessimistic path of accession



The mechanism that drives these results is as follows. Large players, when joined by others, induce larger abatements and higher coalition benefits that can be redistributed according to the Claim Rights Condition to stabilise a coalition. If large countries make a start, an even larger player emerges in the next round. This speeds up the accession in all later rounds. By contrast, if small countries make a start, the resulting coalition is not much larger, if at all, than other countries. A coalition of small countries will induce fewer accessions than a coalition of the same number of large countries.

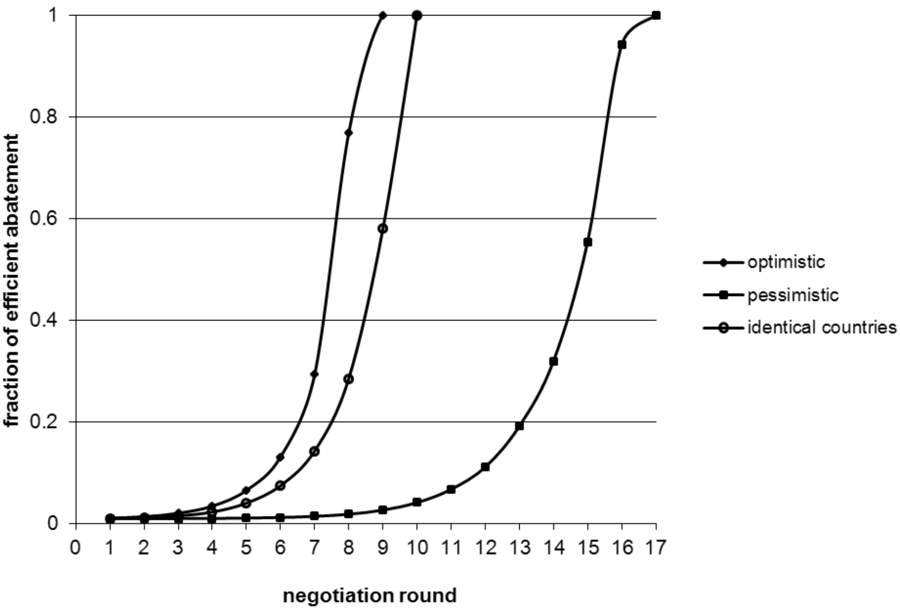
Figure 5 shows a comparison of the paths of accession. Figure 6 shows the corresponding global abatement levels. While the optimistic scenario gives the same number of coalition members as the benchmark scenario up to round 5, note that abatement is higher because large countries abate more. By contrast, in the pessimistic scenario we have a smaller number of accessions compared to the benchmark from round 3 onwards. Abatement levels are well below both other scenarios. This is due to two effects. First, a coalition of large countries abates more than coalition of the same number of small countries. Second, a coalition of large countries forms a particularly large player that increases heterogeneity of players in subsequent rounds. This speeds up accessions.

Figure 5: Comparison of accession paths of identical countries and heterogeneous countries with optimistic and pessimistic accession



In the next section I briefly discuss some policy implications of these results, some limitations of my analysis and directions for further research.

Figure 6: Comparison of global abatement levels of identical countries and heterogeneous countries with optimistic and pessimistic accession



5. Implications for climate policies

The results obtained from the simulations clearly show that the way towards a global climate constitution can be shorter or longer. It will be shorter if countries with high marginal benefits sign the climate agreement early. On the one hand, one may think that this is not only efficient but also a politically reasonable scenario. Those who benefit most from abatement should make a start. Gains from cooperation are larger if accession proceeds from the "larger" to the "smaller" countries. On the other hand, however, there may also be a political obstacle. High marginal benefits of abatement correspond – by construction of the model – to high marginal damages from climate change. Hence, this interpretation of our model suggests that the victims of climate change should move first towards higher abatement levels. Although emissions (and historical emissions) of greenhouse gases are not explicitly modelled, we may still conclude that an accession from "larger" to "smaller" countries will usually not be compatible with the polluters-pay principle.

In models of sequential accession it remains an open problem who enters the agreement first. My modelling approach does not address this question. I just assume that in each round an equilibrium coalition is formed but I do not offer a criterion for equilibrium selection. Still the conclusion remains that if immediate action is required – as, for example, suggested by Stern (2008) –, then it is important that countries with large marginal benefits move first. This will bring significant abatement levels earlier.

Another issue of practical political relevance is how efficient abatement can be achieved. One of the possible tools is an emissions permit market (cf. Meyer in this volume). There are two important issues: efficiency and coalitional stability. Clearly, the growth of the coalition over time implies that more and more externalities are internalised and abatement targets increase. Therefore, the number permits in the market of the incumbent coalition members must decrease. If an optimal number of permits are initially allocated to the private sector in few countries of a small coalition, then, as the coalition grows, permits must be either expropriated (perhaps gradually devaluated) or the government must buy them out and suspend them. The latter option seems to be more appropriate if permits are sold or auctioned to firms upon their initial introduction. The former is more appropriate when firms receive permits free of charge under a "grandfathering" scheme. Concerning stability, the initial allocation of emission permits must be in line with the Claim Rights Condition. In practice this can be achieved if every country is fully compensated for its abatement cost by redistributing the (value of) the benefits of abatement.

Finally, let me emphasise once again that the main driver of the evolution of a global climate agreement is the irrevocability of an initial commitment. It precludes that any country that finds it beneficial to join the agreement at some stage will take a free-rider position at a later stage. While for the theorist this seems to be a strong assumption, it is not at all implausible in the political arena. While joining an agreement may indeed be voluntary, leaving an agreement will spoil the reputation and threaten cooperation in other domains. Hence, there is an extra cost that helps to stabilise agreements such that a global climate constitution can evolve. The important challenge is to make it evolve quickly. The recent climate summits of Copenhagen in December 2009 and Cancún in December 2010 have achieved little. Coalition formation models of the type we have been discussing in this paper explain why an attempt to construct a global climate constitution in one go must fail. The incentives to join are insufficient. My analysis suggests that an alternative political strategy to set up a small coalition of "the willing few" with full commitment may be more successful.

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