The Club Approach:

A Gateway to Effective Climate Cooperation?

Jon Hovi[a,b], Detlef F. Sprinz[c], Håkon Sælen[b], and Arild Underdal[a,b]

[a] Department of Political Science, University of Oslo

[b] Center for International Climate and Environmental Research, Oslo (CICERO)

[c] Potsdam Institute for Climate Impact Research (PIK) and University of Potsdam

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"So far, there has been no club that has brought about transformational change."
(Morgan et al. 2014,
http://www.wri.org/blog/2014/05/renewables-club-change-world)

The global UNFCCC negotiations have thus far failed to produce an effective agreement for mitigation of climate change. When Kyoto 1 (2008–2012) expired, only 36 countries had participated with binding emissions reduction or limitation commitments. Worse, these countries were responsible for less than 20% of global emissions. In Kyoto 2 (2013–2020), even fewer countries – responsible for an even smaller share of global emissions – participate with binding commitments. And prospects remain uncertain (at best) for reaching a more effective agreement that can enter into force after 2020.

Scholars, environmentalists, and policymakers alike have therefore proposed alternative approaches for climate cooperation. One such alternative is the "club" approach, whereby (1) small groups of "enthusiastic" countries would outline what they are willing and able to do, conditional on what other enthusiastic countries offer and implement, and (2) "reluctant" countries would be enticed to join via "exclusive and contingent" measures (Victor 2011).

Small groups of countries that cooperate on climate change already exist; however, these groups' empirical record is not particularly impressive (Andresen 2014; Weischer et al. 2012). To understand *why* these groups have largely failed to reduce emissions and to judge whether future groups may be more successful, we must determine the *conditions* under which a climate club can effectively reduce global emissions. A small group's mitigation efforts will have only a limited impact on global emissions.[1] Thus, a climate club's effectiveness depends on its ability to attract new members while ensuring that new and existing members alike reduce their emissions substantially. Because reducing emissions is

[1] *How* limited the effect will be obviously depends on who the member countries are.

costly, reluctant countries have an incentive to remain non-members. To become successful, a climate club must be able to offset this incentive.

We study the conditions under which a climate club initiated by one or more enthusiastic countries can emerge and grow by inducing reluctant countries to become members. If these conditions prove strict, reasons exist for being pessimistic that the club approach could provide guidance on major climate action. If the conditions prove reasonably slack, greater optimism might be in order.

We first derive theoretical conditions for a climate club to emerge and grow. Next, we use simulations to study how a climate club might evolve over time, contingent on (1) which countries are enthusiastic, (2) the presence and size of club-good benefits, and (3) whether enthusiastic countries make conditional pledges concerning additional emissions reductions. Finally, we provide an illustrative case study of the Renewables Club, established in 2013. This case study aims to assist the reader's intuition by assessing the prospects of a climate club that does *not* satisfy our theoretical conditions for being effective.

Our simulations are based on an agent-based model (ABM). ABMs are ideal for studying dynamic processes in heterogeneous settings. The emergence of a climate club is indeed a dynamic process and one that occurs in a heterogeneous setting. To the best of our knowledge, we present the first ABM of climate clubs.

We find that even a club with fewer than a handful of major actors as *initial* members can grow and eventually become very effective in reducing global emissions, provided that three conditions are met. First, the club must pursue an open membership policy. Second, it must provide sufficiently large incentives for reluctant countries to become members. Third, cooperation must not be constrained by internal conflict over exogenous issues (i.e., over issues beyond climate change).

We proceed as follows. In section 2, we review relevant literature. In section 3, we derive theoretical conditions for a climate club to attract new members (and thereby enhance its ability to reduce global emissions). In section 4, we describe our ABM and report the simulation results. In section 5, we present findings from our illustrative case study. Finally, in section 6 we provide our conclusions.

LITERATURE REVIEW

We first review the general literature on club formation and then the literature that specifically considers clubs' potential for enhancing international climate cooperation.

General Literature on Club Formation

As emphasized by Cornes and Sandler (1986: 161–162), the origins of club theory can be traced at least back to Pigou (1920) and Knight (1924). These early contributions were concerned with identifying optimal tolls for constraining traffic on a congested road, assuming that a less attractive alternative road exists. They thus essentially tried to identify the optimal size of a club (i.e., the club consisting of the drivers on the more attractive road).

Buchanan (1965) remains the most influential work on club theory to date. He defined a club as a member-owned institutional arrangement aiming to provide a "club good," that is, an excludable good characterized by little or no rivalness.[2] Buchanan studied the conditions under which club goods will be provided, what the optimal size of the club is, and how the provision conditions interact with the optimal-size conditions.

Other influential early contributions include Tiebout (1956), Wiseman (1957), and Olson (1965). Tiebout (1956) suggested a "voting-with-the-feet" hypothesis, stating that a population will tend to partition itself among jurisdictions (or clubs) to match individuals' preferences for local public goods and taxation options. In contrast, Wiseman (1957) formulated a club principle for cost sharing among users of a public utility. Finally, Olson (1965) introduced the notion of exclusive groups while analyzing the production of impure public goods.

[2] Club goods are non-rival only for low to moderate consumption levels; at some point, congestion effects set in and the good becomes rival.

It is important to note that including all these contributions under the rubric of club theory requires a rather broad definition of clubs. In particular, whereas Buchanan was concerned with club goods (excludable and non-rival), Tiebout focused on private goods (excludable and rival), and Olson studied what he termed "exclusive" public goods (non-excludable and rival). What these scholars have in common is that they all focused on goods provision in groups of (more or less) limited size.

Following these path-breaking contributions, a substantial body of research on club theory has developed.[3] In particular, scholars have considered whether and how club formation and optimality conditions are influenced by heterogeneous populations (e.g., Fraser and Hollander 1992), transaction and exclusion costs (e.g., Helsley and Strange 1991), and uncertain use due to capacity constraints (e.g., Sandler et al. 1985).

Specific Literature on Climate Clubs

Prakash and Potoski (2007) draw a useful distinction between two types of clubs.[4] In "Buchanan clubs," the production and allocation of club goods are the primary goals; indeed, such production and allocation are goals in themselves. For example, a tennis club's primary goals are to provide required facilities for its tennis-playing members and to allocate playing times. By contrast, in "voluntary clubs" the main goal is to produce a public good or some other benefit that generates a positive externality.

This distinction is crucial. In a Buchanan club, no incentive for free riding exists, because only those who pay the club fee can enjoy the benefits. By contrast, in a voluntary club strong incentives for free riding may exist. Thus, the production and allocation of club goods are here primarily tools for encouraging membership and for inducing members to contribute more to the production of a public good (or some other benefit that entails a positive externality) than non-members do.

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[3] For an excellent early review, see Sandler and Tschirhart (1997).

[4] Other, more nuanced typologies also exist. For example, Cornes and Sandler (1986) distinguish no less than eight types of clubs.

Climate clubs may be considered as a subset of voluntary clubs. We define a climate club as *any international actor group that (1) starts with fewer members than the UNFCCC has and (2) aims to cooperate on one or more climate-change-related activities, notably mitigation, adaptation, climate engineering, or climate compensation*.

Although our definition also includes groups – large as well as small – that cooperate on adaptation, climate engineering, or climate compensation, we here consider only cooperation on *mitigation*. More specifically, we analyze the conditions under which groups that are *initially* small (and thus quite ineffective) can attract more members (and thereby become *more* effective). If a climate club is *very* successful, it might end up with all UNFCCC countries as members.

The purpose of a climate change mitigation club (henceforth simply "climate club") is to induce countries to undertake mitigation (which entails a positive externality) *beyond* what UNFCCC agreements require. Furthermore, a climate club must provide incentives such as club goods that are exclusive to club members to overcome the temptation to free ride.

Scholarly interest in climate clubs has been spurred by the slow progress in the UNFCCC negotiations. A well-known barrier for progress in negotiations is the consensus rule, which provides a veto to the least enthusiastic party.

To bypass this barrier, Victor (2011) suggests that cooperation should begin with small groups (i.e., clubs) consisting of enthusiastic countries and that these groups should aim for agreements with a high degree of flexibility concerning choice of policy strategies. They should also focus on policies that governments actually control, rather than on emission levels (which are only partly under governmental control). The "backbone" of Victor's proposal is a series of contingent offers, whereby governments outline what they are "willing and able to do," depending on what others offer and implement. Finally, reluctant countries should be enticed to join via "exclusive and contingent" measures, such as preferential market access for club members.

A few scholars have assessed the empirical record of groups that have tried to address climate change outside the UNFCCC. The evidence suggests that such groups have (thus far) been no more effective in advancing climate cooperation than the UNFCCC has been. For example, Andresen (2014) evaluates select "exclusive alternatives" to the UNFCCC, such as the Asia–Pacific Partnership on Clean Development and Climate Change (APP), the Major Economies Forum on Energy and Climate (MEF), the G20, and the Climate and Clean Air Coalition. He concludes that these alternatives have largely served as "discussion clubs" that have achieved very little in terms of actual emissions reductions.[5] Similarly, after considering no fewer than 17 climate clubs,[6] Weischer et al. (2012) conclude that these clubs are little more than forums for political dialogue.

The general conditions for club formation and optimal club size are well understood. Moreover, previous research has convincingly documented that existing climate clubs' achievements are extremely limited. However, scholars have only just begun explaining *why* existing clubs have largely failed in reducing emissions. Even more importantly, they have only just begun identifying what it would take for a climate club to eventually become more effective in reducing greenhouse gas (GHG) emissions than UNFCCC agreements are. In particular, they have not yet pinpointed the conditions under which climate clubs can *emerge and grow over time*. This paper contributes to filling this void. We do so by using a combination of theorizing, ABM simulations, and an illustrative case study.

CONDITIONS FOR THE EMERGENCE AND GROWTH OF CLIMATE CLUBS

Under what conditions can climate clubs emerge and grow? To answer this question, we proceed in four steps. First, we characterize countries likely to play the crucial initiator role. Second, we explore forms of benefits that the initiator(s) may use to induce other countries to join the club. Third, we consider the conditions under which reluctant countries can be

[5] Andresen (2014) invokes the term "exclusive group" rather than "climate club"; however, his use of the term seems to indicate that his notion of an exclusive group bears strong similarity to our notion of a climate club.

[6] Note that Weischer et al.'s (2012) definition of climate clubs differs from ours.

expected to respond favorably to the incentives offered by the club. Finally, we emphasize that a club's prospects may also depend on its capacity to integrate or aggregate divergent preferences and to overcome conflict over exogenous issues.

Throughout this analysis we make the seemingly safe assumption that no "single-best-effort" solution (Barrett 2007) is available: not even China, currently the largest GHG emitter would, acting alone, be *able* to keep GHG concentrations below the levels required to "prevent dangerous anthropogenic interference with the climate system" (UNFCCC, Article 2).

Establishing Clubs

Cooperation, even within a fairly small group, can significantly improve the cost-benefit balance for all participating countries. For cooperation to emerge, however, some countries must serve as initiators or founders. What characterizes countries likely to play these roles?

Assuming rational behavior motivated by self-interest, the most plausible candidates will be major emitter countries with relatively low GHG abatement costs, relatively high damage costs, or both.[7] Because the human impact on the global climate system can be traced to a very wide range of human activities, climate change policies are inextricably linked to multiple other policy domains. An overall assessment of a party's costs and benefits must therefore also include significant side effects of mitigation, such as improved public health via reduced local pollution levels or competitive disadvantages in international markets. Conversely, measures undertaken entirely or partly for other purposes (such as enhancing energy efficiency or reducing local pollution) may also cut GHG emissions. As a rule-of-thumb, however, we may expect to find cooperation initiators among (large-emitter) countries with a relatively positive balance between marginal climate-change damage costs

[7] As some uncertainty pertains to both of these components, particularly to future damage costs, subjective *beliefs* may deserve more attention than in most other environmental policy domains.

and marginal GHG abatement costs.[8] Moreover, once a serious initiative is taken, we would expect the outsiders most likely to join to be found among countries with equally or slightly less positive ratios between marginal damage costs and marginal abatement costs.

Empirical research indicates that climate change policies and practices are often guided also by values and norms of appropriateness (see e.g., March and Olsen 2006; Lange et al. 2007; Dannenberg et al. 2010). For example, in the UNFCCC negotiations, certain norms of distributive fairness – notably those of responsibility ("guilt"), capacity, and need – are frequently invoked and rarely disputed (Ringius et al. 2002; Lange et al. 2007). All these norms converge in differentiating obligations so that the rich shall contribute more to mitigation – also in relative terms – than the poor, and this differentiation is non-linear; the poorest shall be exempt from costly obligations for which they are not adequately compensated. Rich countries internalizing these norms will be willing to contribute more than their own balance of damage costs and abatement costs would indicate. We are thus left with two principal sources of climate policy "enthusiasm": a relatively favorable cost-benefit balance and internalized norms of distributive fairness (or of ethical behavior more broadly defined).[9]

Forms of Club Benefits

A necessary condition for club initiation and growth is that countries expect membership to provide net benefits. In general, we may expect prospective members' interest in joining a club to be highest when club benefits can be internalized (i.e., confined to members only) and costs externalized (i.e., paid by outsiders). Few if any climate change mitigation measures seem to score high on both of these dimensions. In fact, as long as we consider

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[8] Other things being equal, countries responsible for large GHG emissions have stronger incentives to mitigate climate change than do countries responsible for smaller emissions because large emitters cause more damage, also to *themselves*.

[9] Kant's (1785/1993) ethical imperative – act only according to that maxim whereby you can, simultaneously, will that it should become a universal law – may be the most widely acknowledged general norm of ethical behavior. Applied to climate change mitigation, one plausible interpretation would be to act so as to maximize sustainable global welfare.

mitigation measures *only*, the reverse configuration will occur more frequently. Yet, by joining a climate club, a prospective member may obtain at least one of four types of benefits.

First, benefits may come in the form of climate damage avoided through enhanced mitigation measures (i.e., through provision of the *global public good* itself). Compared to unilateral mitigation efforts, cooperation can substantially improve a country's cost-benefit balance. Specifically, cooperation might curtail a country's aggregate mitigation costs (because of fewer competition disadvantages), while also enhancing global emissions reductions (because of its partners' reciprocation). The size of this improvement will depend on (1) partners' control over global GHG emissions, and (2) the marginal impact of its own commitment on the depth and scope of its partners' mitigation commitments. For an actor motivated only by self-interest, an ideal partner would be one that controls a high proportion of GHG emissions and responds positively and strongly to an increase in the actor's own contribution. An actor guided (also) by norms of distributive fairness would consider how well its own contribution complies with these norms and would also consider the marginal impact of its own contribution on its partners' compliance with the same norms.

Second, benefits may come in the form of *club goods*. Exclusive privileges may include, for example, mutually advantageous terms of trade and investment, joint R&D programs in renewable energy technology, and expansion or extension of pipelines or electricity grids to mutually enhance energy security. Existing international regimes limit the range of trade and investment arrangements that can be reserved for club members only. Yet, as more countries explore new measures for mitigating GHG emissions (for example, national emissions trading systems), new opportunities arise for generating exclusive benefits in ways that escape current restrictions. Recent examples include the California–Quebec (2013) agreement to harmonize and integrate their emissions trading systems and the Asia–Pacific Economic Cooperation (2012) agreement to reduce applied tariff rates to five per cent or less on a number of "environmental goods". Neither of these agreements amounts to transformative change but they nonetheless indicate that exclusive privileges can be provided also for members of climate clubs. And for the least reluctant non-members, even participation in fairly modest cooperative schemes may be sufficiently attractive to tip the scales in favor of membership.

Third, benefits may come in the form of *side payments* (transfers). Multiple side-payment arrangements already exist, ranging from global schemes under the UNFCCC framework (e.g., the Clean Development Mechanism) to bilateral agreements whereby developed countries help fund climate-friendly measures in developing countries. Although many of these arrangements do not fully meet the defining characteristics of a "club," they show the wide spectrum of side payments and functional equivalents available to induce cooperation. Club members can cooperate also in linking the upgrading of their own mitigation policies and practices with (threats of) sanctions on non-members who do not contribute their "fair share." (Threats of) sanctions in the form of (say) trade and investment restrictions can make non-cooperation more costly; however, existing global and regional regimes limit the legal scope of such restrictions. Moreover, if the *threat* of sanctions were to fail, the actual implementation of sanctions would likely incur costs also for club members. Indeed, so would *lack* of such implementation. For these and other reasons, club members will – unless the power balance tilts decisively in their favor – likely be reluctant to adopt a coercive strategy.

Finally, benefits may come in the form of (predictable) *side effects*.[10] Increasing club members' mitigation efforts will likely reduce the *indirect* abatement costs of at least some non-members. The most important type of indirect abatement costs may well stem from the weakening of a country's international competitive edge as a result of implementing costly mitigation measures. Reducing such indirect costs will rarely if ever suffice to induce countries to fully match efforts made by club members; however, even more marginal contributions will, in principle, improve the latters' cost-benefit balance.

[10] Here, we use the term side *payments* for deliberately designed incentives and the term side *effects* for unintended consequences of mitigation measures.

Expanding Club Membership

Consider a climate club that offers some incentive (such as a conditional commitment, a club good, or both) to entice reluctant countries to become members. Under what conditions should we expect reluctant countries to respond positively?

Weischer et al. (2012) provide a partial answer consisting of two main conditions. First, the incentive must accrue to club members and to club members only. On one hand, it must be credible that a country can enjoy the incentive only by becoming a club member. On the other hand, it must also be credible that the incentive accrues to every club member.

Second, the incentive must be significant enough to outweigh the temptation to free ride. If not, each reluctant country will prefer to remain a non-member. Thus, the club must control sufficient resources so that it can make it worthwhile for reluctant countries to join.

We propose that Weischer et al.'s (2012) conditions should be modified in two ways. First, a third condition should be added: The club must pursue an open-membership policy, so that reluctant countries wishing to join are free to do so, provided they satisfy membership requirements. This condition excludes the possibility that a group such as the European Union could succeed as a climate club, simply because the European Union would unlikely accept new members only (or even mainly) on the basis of applicants' climate policies. The same is true for most of the "exclusive groups" considered by Andresen (2014), such as the G20, the G8, and the MEF. This is not to say that intergovernmental organizations established for other purposes cannot be effective also in mobilizing their members for climate change mitigation; for example, the European Union clearly has far greater institutional capacity than the aforementioned "exclusive groups" to do so. Yet, a club that does *not* pursue an open-membership policy will (at best) have only a very limited potential for club growth.

Second, incentives might work even if they are not offered to all members indiscriminately. In fact, offering differentiated incentives may well be *necessary*. For example, offering undifferentiated side payments to all members might well prove prohibitively expensive.

Weischer et al. (2012) mention preferential market access as an example of a club good that could entice non-members to join a climate club. Preferential market access will be more attractive the more members the climate club already has and the larger the economies these members have. If a club has few and only minor members, the prospects of preferential market access will unlikely outweigh a reluctant country's costs of reducing emissions enough to qualify as a member. The reason is that a reluctant country can then easily find alternative trading partners in other non-member countries. In contrast, with many and large members, access could make a significant difference, because few alternative suppliers and buyers would remain outside the club.

If reluctant countries differ in terms of their abatement costs, offering preferential market access as an incentive might trigger a "snowball effect," whereby reluctant countries with small abatement costs would enter the club first. As these countries become members, countries with somewhat higher abatement costs might also find membership worthwhile, and so on.

Collective Action Potentials and Divergent Preferences

If two or more (potential) clubs can provide members with net benefits beyond what they can achieve through unilateral action, each prospective member may be expected to prefer the club that maximizes its net benefits. Prospective members may well rank alternatives differently; hence, yet another condition for a club to be established is that a critical minimum of parties *agree* on a particular design, including an exchange of mitigation commitments, criteria for membership, and procedural arrangements for decision-making. A quick look at the list of major GHG emitters indicates that at least some potentially powerful clubs will include members with strongly divergent preferences regarding the distribution of mitigation commitments (see e.g., Shum 2014).[11] Some potential members' relationships are also strained by exogenous conflict generated by, for example, geopolitical

[11] To illustrate, a club including the four largest GHG emitters would consists of China, the United States, the European Union, and India.

rivalry or competition in global markets. Consequently, some potentially effective climate clubs may prove politically infeasible, at least as *formalized* arrangements. Such exogenous stakes are not included in our ABM simulations.

AGENT-BASED SIMULATIONS OF CLIMATE CLUBS

Under which conditions, and based on which constellations of initial members, can a climate club emerge and grow? We now try to answer this question using an ABM. While simple and stylized, our ABM explicitly models dynamic interaction between actors. It also incorporates several types of heterogeneity; in particular, actors differ in terms of emissions, gross domestic product (GDP), vulnerability to climate impacts, and motivation for climate action.

The model aims to capture select essential features of climate clubs, while leaving out many real-world complicating factors. The basic decision is binary: Each actor must decide whether to be a member of a climate club or not.[12] The model focuses on one specific form of climate club, requiring each member to implement mitigation measures worth 1% of its GDP. This focus circumvents the question of equitable burden sharing between countries, a central issue in real-world negotiations. Moreover, it sidesteps differences in relative abatement costs as a possible source of variation in actors' motivation to join a climate club. The model is a one-shot sequential game with indefinite number of stages, where all costs are undiscounted, and all actions that are not repealed are instantaneously implemented. While we cannot capture all real-life challenges to international cooperation on mitigating climate change, our model provides a useful tool for systematically exploring the *potential* contributions of clubs to enhancing climate change mitigation.

We consider two mechanisms for club growth. First, in addition to undertaking mitigation – a public good benefitting members and non-members alike – the club may produce a club

[12] Because we model the members of the European Union as a single unit, we use the term "actors" rather than "countries."

good that benefits *members only*. Second, members may offer to deepen their mitigation efforts conditional on new members joining and thus agreeing to spend 1% of GDP on mitigation. We assume throughout that such conditional commitments are credible: The promised additional mitigation effort will be undertaken if and only if the actor concerned actually joins the club. Hence, the additional conditional mitigation effort is by assumption rational.

Model Description

The Technical Appendix provides the model's formulae and describes the model in pseudo-code, thereby complementing the verbal description we offer here. The model's actors are of two types, depending on their motivation for mitigation. *Reluctant* actors are rational and self-interested, and will join the club if and only if doing so leads to private benefits that exceed the abatement costs (i.e., 1% of GDP). *Enthusiastic* actors have an exogenous motivation to start a club, irrespective of the (initial) costs. They are, in other words, willing to incur mitigation costs of 1% of GDP even without any commitment by reluctant parties to follow suit. Furthermore, enthusiastic actors will not necessarily abandon the club even if they would benefit by withdrawing unilaterally. Indeed, they will abandon the club only if – after negotiating with all reluctant actors – the club generates negative net private benefits for that actor, *relative to the no-club scenario*. This rule implies that the club may be larger than the stable coalition as defined in game theory, in which no member faces a unilateral incentive for exit (see e.g., Barrett 1994). Reluctant parties, in contrast, will choose non-membership as long as their payoff outside the club (where they can free-ride on members' mitigation) is greater than their payoff inside it.

Actors have three further attributes with empirically grounded values: emissions (Global Carbon Project 2014 (2013 figures) / World Resources Institute 2014 (2011 figures)), GDP (World Bank 2014 (2013 figures)), and climate-change vulnerability scores (Notre Dame Global Adaptation Index 2014 (2012 figures)). Complete data is available for 168 countries, accounting for 98% of both global emissions and Gross Global Product (GGP). The European Union is modelled as a single actor; hence, the model includes 141 actors (or agents).

Damage Costs. The model considers only climate damage costs that can be avoided through club action. Thus, the *global* damage costs equal the difference between the business-as-usual (no-club) scenario and the scenario where *all* actors spend 1% of their GDP to mitigate climate change (the scenario with universal club participation). The size of this difference is a model input, which we refer to as *Global Damage.* Because huge uncertainties exist in the global cost-benefit analysis of mitigation, we run the model for various values to check for robustness. However, we take it for granted that global benefits outweigh global costs. When only a subset of the actors participates, the total benefit generated by the club is assumed to be a linear function of the emissions covered. In particular, a club covering 50% of global emissions is assumed to produce 50% of the climate benefits produced by a global club. In reality, there may be both decreasing and increasing returns to participation, for example, due to increasing marginal damage costs and carbon leakage, respectively. Lacking empirically grounded functions, we simply assume a linear relationship. Finally, we assume that damage costs are distributed in proportion to actors' GDP and vulnerability.

Because vulnerability[13] affects damage costs, which in turn affect the incentive for club membership, vulnerability heterogeneity leads to heterogeneous incentives for membership. The model incorporates empirical data on vulnerability from the Notre Dame Global Adaptation Index (2014), which allocates scores based on actors' exposure, sensitivity, and adaptive capacity in eight sectors. The scores range from 0.15 (Switzerland) to 0.59 (Burundi). Empirical grounds for operationalizing index scores into damage functions are lacking, therefore we rerun the model for different degrees of differentiation between the highly vulnerable and the less vulnerable by varying an input variable called *Vulnerability Weight.* The actor-specific vulnerability in the model is given by

$$Vulnerability_i = \frac{NDGAIN_i + (Vulnerability\ Weight - 1) \times (NDGAIN_i - \overline{NDGAIN})}{\overline{NDGAIN}} \quad (1)$$

[13] Strictly speaking, actors' incentives depend on their own *perceived* vulnerability. However, the model assumes perfect information about vulnerability.

It is expressed as the percentage loss in GDP_i arising when the global loss is 1% of GGP. $\overline{NDGAIN}$ is the GDP-weighted average NDGAIN score across all actors. Higher *Vulnerability Weight* means higher variance in vulnerability across actors. We will run the model for the values 0, 1, and 2. When *Vulnerability Weight* equals zero, every actor's *Vulnerability* equals 1. In contrast, when *Vulnerability Weight* equals 1 (2), Switzerland's *Vulnerability* equals 0.6 (0.2) and Burundi's *Vulnerability* equals 2.3 (3.7). To obtain actor-specific damage, we multiply $Vulnerability_i$ by *Global Damage*. The specification shown in equation (1) ensures that the global damage is held constant even as its distribution across actors changes. The ranking of actors is also unchanged.

Damage costs, as well as all other costs and benefits, are measured in percentage of GDP. Given the above definitions and assumptions, an actor's incentive to mitigate climate change depends on its vulnerability and emissions. Emissions matter because (other things being equal) a large actor emits more GHGs than a smaller actor does and therefore causes more climate damage, including to itself.

Instruments for Club Growth. We study two instruments for club growth – club-good benefits and conditional commitments (increased mitigation pledges in exchange for increasing membership). The model permits us to study these two instruments separately and in combination.

Club-good benefits. The model assumes that only club members benefit from the club good (e.g., preferential market access). This benefit is assumed to be an increasing function of the sum of other club members' GDP. In other words, the larger the market to which a member gains preferential access, the more that member benefits. However, the model also assumes that the club-good benefit increases at a decreasing rate. For simplicity, a logarithmic function is assumed:

$$Club\ Benefit_i = CBscale \times \ln \left(\sum_{j \neq i}^{M} GDP\right) \qquad (2)$$

An actor's *Club-good Benefit* is measured as a percentage of its own GDP, while the *M* other members' *GDP* is measured as a percentage of GGP. *CBscale* is an input used to set the magnitude of the club good. Generally, the club-good benefit is assumed to be less than 1%

of GDP. Importantly, club membership entails no costs other than the abatement costs. Hence, the incentive to form the club would exist even absent climate change.

Conditional mitigation pledges. Victor (2011) argues that climate club pledges should not just be declarations of what a country *will* do, but promises of effort *conditional* on what others pledge or do. Our model includes one specific form of such conditional commitments; in particular, a model option allows members to pledge a deepening of their mitigation effort if a new entrant joins the club. Because additional mitigation benefits all actors, this instrument is less targeted than a club good is. On the other hand (and unlike the offer of a club-good benefit), a conditional commitment does not require linkage of climate change mitigation to some *other* good or benefit.

In our model, a new member's entry produces benefits for existing members through reduced climate damage and (depending on other inputs chosen) an increase in the club good. Members therefore have an interest in undertaking additional mitigation to induce an otherwise reluctant actor to join. If the additional mitigation they are willing to offer would benefit the reluctant actor more than its net cost of joining (i.e., taking into account its other benefits from membership), a mutually advantageous expansion is possible. In such cases, the model assumes that existing members increase their mitigation expenditure above 1% of GDP, by an amount just enough to reduce the reluctant actor's damage costs to the level where its net cost of joining is zero, thereby inducing it to join. Members share the additional effort in proportion to their benefit from expansion – measured in absolute terms. A member's benefits from expansion are the climate damages averted (a function of *GDP* and *Vulnerability*) (vis-à-vis the situation without the reluctant actor's joining) and its additional *Club-good Benefit* (a function of *GDP*) produced by the reluctant member's joining. The cost-sharing rule we use is a generalization of the Chander–Tulkens rule in which actors pay according to their marginal damage costs relative to the sum of all actors' marginal damage costs (Chander and Tulkens 1995). This arrangement ensures that no existing member is made worse off by expansion; however, its other distributional characteristics point to "victim pays" rather than "polluter pays."

Model Steps

The model includes (up to) three steps.

Initialization: The modeler chooses the inputs listed in Table 1.

Step 1: Enthusiastic actors join the club *automatically*. A reluctant actor joins if and only if the sum of its club-good benefit and its gross private benefit from reducing its own emissions exceeds the "club fee" (1% of GDP). First, every reluctant actor makes a preliminary decision (in random order). Additional decision rounds take place until no additional actor wants to join. Thus, an actor that chose not to join in the first round can reverse its decision in a later round, when the club – and hence the club-good benefit – has grown.

Step 2 (included only if conditional commitments are allowed): The model calculates the benefit to each member from each non-member's entry. If the total benefit to the club of a specific reluctant actor's entry enables the club to increase mitigation commitments enough to induce the non-member to join, a deal based on conditional commitments is struck. This step is repeated until no more mutually advantageous deals can be made, following the same logic as in Step 1. If there is a club good, its size increases as the club expands, so that a non-member who initially declined might later find it in its best interest to join even *absent* additional mitigation from existing members. If so, the non-member will simply join as in Step 1.

Step 3: Enthusiastic actors assess whether they are better off than they would be in the absence of the club. If this is the case, they remain members. If not, they leave the club. If at least one actor leaves the club, reluctant actors will reassess whether membership pays off.

[Tables 1 and 2 about here]

Model Results

Our analysis focuses on the potential for club growth under (1) different (hypothetical) constellations of enthusiastic actors, (2) different scales of the members-only club good, (3) different assumptions about whether conditional commitments are used to induce reluctant actors to join, and (4) different combinations of the previous factors. For enthusiastic actors, we consider the world's three biggest emitters individually, every combination of these three, and the BASIC[14] and BRICS[15] groups.

No Conditional Commitments. Table 3 shows the clubs emerging from different constellations of enthusiastic actors and under different magnitudes of the club good, given no conditional commitments. *Global Damage* cost is set to 3% of GGP, and the *Vulnerability Weight* is set to unity, resulting in the damage-cost distribution across actors shown in Figure 1. While global damages total 3% of GGP, most actors have damages of a higher percentage, because GDP and NDGAIN index scores are negatively correlated (i.e., small economies are generally more vulnerable). Alternative values for *Global Damage* and the *Vulnerability Weight* are explored further below.

[Figure 1 about here]

With zero club-good provision and no conditional commitments, enthusiastic actors have no means for inducing others to join. Three constellations nevertheless persist, because members are better off than they would be without a club. Note that these constellations are not stable coalitions according to game theory's standard definition. In particular, they are not internally stable because a member would benefit by exiting unilaterally. Thus, club persistence rests on the assumption that enthusiastic actors are not motivated exclusively by material self-interest.

Setting the *Club-Good Scale* to 0.1 implies, for example, that membership in a club where the other members account for 10% of GGP yields a benefit of .23% of GDP, and that a global

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[14] Brazil, South Africa, India, and China.

[15] BASIC countries plus Russia.

club increases members' GDP by approximately .45%. Now all initiating coalitions except one (China alone) are able to persist. Furthermore, China will join whenever the European Union or the United States is an enthusiastic actor, or whenever both are.

Table 1. Model inputs set at initialization

Input	Explanation	Baseline model values	Sensitivity test values
Vulnerability Weight	Degree of differentiation between more and less vulnerable countries	1	0; 2
Global Damage	The difference in global climate damage costs between the business-as-usual (no-club) scenario and the scenario where *all* actors spend 1% of their GDP to mitigate climate change	3% of GGP	1.5% of GGP; 4.5% of GGP
Enthusiasts	Which actors are "enthusiastic"?	See Table 3	
CBscale	Scaling factor for exclusive club good	0; 0.1; 0.2; 0.25	
Conditional commitments	Conditional commitments allowed?	Yes/No	

Note: The first two inputs are empirical parameters with uncertain values, included for the purpose of sensitivity analyses. The last three are characteristics of the negotiation process – and are the analysis's main foci.

Table 2. Emissions (including land-use change and forestry), GDP, and vulnerability index scores of the twenty largest emitters.

Actor	GHG share	GGP share	Vulnerability index
China	27.3	12.3	0.30
United States	13.6	22.4	0.20
European Union	9.0	23.2	0.20
India	6.4	2.5	0.43
Indonesia	4.8	1.2	0.34
Russian Federation	4.7	2.8	0.29
Japan	3.1	6.5	0.29
Brazil	2.2	3.0	0.30
Canada	1.8	2.4	0.23
Iran, Islamic Rep.	1.7	0.5	0.29
Korea, Rep.	1.6	1.7	0.35
Saudi Arabia	1.5	1.0	0.34
Mexico	1.4	1.7	0.29
South Africa	1.3	0.5	0.37
Malaysia	1.1	0.4	0.31
Australia	1.0	2.1	0.24
Venezuela, RB	0.9	0.6	0.29
Thailand	0.9	0.5	0.31
Kazakhstan	0.9	0.3	0.28
Turkey	0.8	1.1	0.28

Sources: Global Carbon Project (2014)(fossil fuel and cement emissions in 2013), World Resources Institute (2014) (land-use change and forestry emissions in 2011), World Bank (2014) (GDP in 2013 at market exchange rates), and Notre Dame Global Adaptation Index (2014) (vulnerability scores for 2012). EU vulnerability is the average of its members' vulnerabilities.

Increasing the *Club-Good Scale* from 0.1 to 0.2 doubles the club-good benefit for given club size. Being the largest potential trading partner, the European Union is now successful in inducing China, India, and Indonesia to join, while the United States is able to induce India to join.

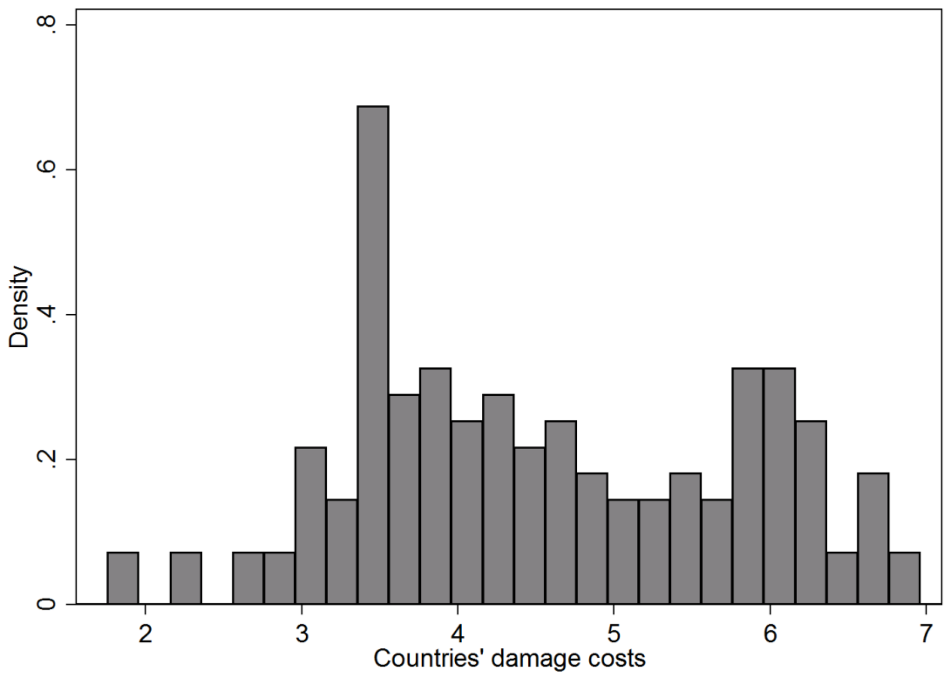
Increasing the *Club-Good Scale* further to 0.25 results in universal membership for all hypothetical enthusiastic-actor coalitions except China alone. Notice that a *Club-Good Scale* value of 0.25 constitutes a rather optimistic assumption; in fact, the club-good benefit will then outweigh the abatement costs of 1% of GDP whenever other members' aggregate GDP exceeds 55% of GGP. Under these assumptions, the interaction between reluctant actors constitutes a coordination game with multiple equilibria even absent any enthusiastic actors.

[Table 3 about here]

Table 3. Simulated membership and emission coverage (% of global emissions) resulting from different constellations of enthusiasts under different club-good magnitudes. Vulnerability weight = 1. Without conditional commitments.

	No club good		**Club-good scale = 0.1**	
Enthusiasts	Emissions covered	Members	Emissions covered	Members
China	0	None	0	None
US	0	None	41	US, China
EU	0	None	36	EU, China
China, US	0	None	41	China, US
China, EU	0	None	36	China, EU
US, EU	0	None	50	China, US, EU
China, US, EU	50	China, US, EU	50	China, US, EU
BASIC	37	BASIC	37	BASIC
BRICS	42	BRICS	42	BRICS
	Club-good scale = 0.2		**Club-good scale = 0.25**	
China	0	None	0	None
US	47	China, US, India	100	All actors
EU	61	China, US, EU, India, Indonesia	100	All actors
China, US	47	China, US, India	100	All actors
China, EU	61	China, US, EU, India, Indonesia	100	All actors
US, EU	61	China, US, EU, India, Indonesia	100	All actors
China, US, EU	61	China, US, EU, India, Indonesia	100	All actors
BASIC	37	BASIC	100	All actors
BRICS	42	BRICS	100	All actors

Figure 1. Distribution of damage costs (% of GDP) across actors under baseline assumptions.



The Effect of Conditional Commitments. Table 4 shows the simulation results when conditional commitments are introduced. With no club good, conditional commitments prove to be ineffectual with one important exception: China will join an EU–US coalition. Combined with a small (0.1) or intermediate club good (0.2), conditional commitments broaden participation for all the hypothetical enthusiastic-actor constellations we consider. With the small club good, conditional commitments induce India to join any coalition, the United States to join any coalition including China, the European Union to join BASIC and BRICS, and Indonesia to join BRICS. With the intermediate club good, conditional commitments enlarge all coalitions to 23 actors responsible for 88% of global emissions. Thus, depending on the initial constellation of enthusiastic actors, 18–22 actors join because of conditional commitments. The 23 members are the world's 20 largest emitters plus Nigeria, Pakistan, and the Democratic Republic of the Congo. When combined with the largest club good (0.25), conditional commitments change the outcome from zero to full participation even when China is the only enthusiastic actor. Generally, the total conditional expenditure is in the range of .3–.7% of GGP.

[Table 4 about here]

Sensitivity Analysis. Tables 5 and 6 test the sensitivity of our results with respect to the magnitude and distribution of damage costs. *Global Damage Costs* is varied by +/- 50% and *Vulnerability Weight* is set to zero (i.e., damages are proportional to GDP as Vulnerability_i equals 1) and 2 (i.e., damages are distributed with larger variance, as shown in Figure 2).

[Tables 5 and 6 about here]

[Figure 2 about here]

If the club's effect on climate damage is reduced, so that spending 1% of GGP yields benefits of 1.5% rather than 3% of GGP, no coalition persists for zero or small club-good benefits (see the first top-left and top-right quadrants of Tables 5 and 6). With an intermediate club-good benefit (0.2), three coalitions persist absent conditional commitments. Conditional commitments make a substantial difference for this club-good size, facilitating five additional coalitions and enlarging two of the existing ones (see the lower-left quadrant in Tables 5 and 6). For the largest club-good size (0.25), the reduction in *Global Damage Costs* has less effect, although it reduces participation in two cases without conditional commitments and eliminates one coalition with conditional commitments. Hence, a large club-good benefit is often a necessary condition for cooperation when the environmental benefits are small.

Conversely, *increasing* the club's potential climatic benefits from 3% to 4.5% of GGP entails three distinct effects. First, participation increases; indeed, one actor (China) now even has an incentive for acting *unilaterally*. Second, the leverage of conditional commitments increases; hence, conditional commitments now make a difference in most cases – including all cases with zero club-good benefits. An exception concerns the most optimistic club-good-benefit assumption (0.25), which mostly generates universal participation even *without* conditional commitments. Finally, the impact of the club-good benefits declines somewhat. The reason is that participation is now considerable even with small (or even zero) club-good benefits.

Varying the value of *Vulnerability Weight* indicates that the damage-cost distribution is less influential than the damage-cost magnitude. The degree of heterogeneity has a non-linear effect on participation and the sign of this effect depends on who the enthusiasts are. If damage costs are assumed to be proportional to GDP (Vulnerability Weight = 0), EU and US incentives for mitigation increase (relative to our baseline scenario), while emerging economies' incentives for mitigation decrease. Stronger incentives for mitigation increase reluctant actors' likelihood of joining the club. Assuming a more unequal distribution of vulnerability than in the baseline scenario has the opposite effect, giving China (once again) an incentive for unilateral action. In three cases where the club-good benefit is small (0.1), conditional commitments are particularly effective at inducing emerging economies to join.

In general, the distribution of vulnerability has systematic effects on the distribution of abatement costs, but not on the aggregate mitigation level. The distribution of vulnerability shows no systematic interaction with the effectiveness of club-good benefits or of conditional commitments.

Table 4. Simulated membership and emission coverage (% of global emissions) resulting from different constellations of enthusiasts under different club-good magnitudes. Vulnerability weight = 1. With conditional commitments.

	No club good		**Club-good scale = 0.1**	
Enthusiasts	Emissions covered	Members	Emissions covered	Members
China	0	None	47	China, US, India
US	0	None	47	US, China, India
EU	0	None	56	China, US, EU, India
China, US	0	None	47	China, US, India
China, EU	0	None	56	China, US, EU, India
US, EU	50	China, US, EU	56	China, US, EU, India
China, US, EU	50	China, US, EU	56	China, US, EU, India
BASIC	37	BASIC	60	BASIC, US, EU
BRICS	42	BRICS	69	BRICS, US, EU, Indonesia
	Club-good scale = 0.2		**Club-good scale = 0.25**	
China	88	23 actors	100	All actors
US	88	23 actors	100	All actors
EU	88	23 actors	100	All actors
China, US	88	23 actors	100	All actors
China, EU	88	23 actors	100	All actors
US, EU	88	23 actors	100	All actors
China, US, EU	88	23 actors	100	All actors
BASIC	88	23 actors	100	All actors
BRICS	88	23 actors	100	All actors

Figure 2. Distribution of damage costs across actors (% of GDP) when Vulnerability Weight equals 2 and Global Damage Cost equals 3% of GGP.

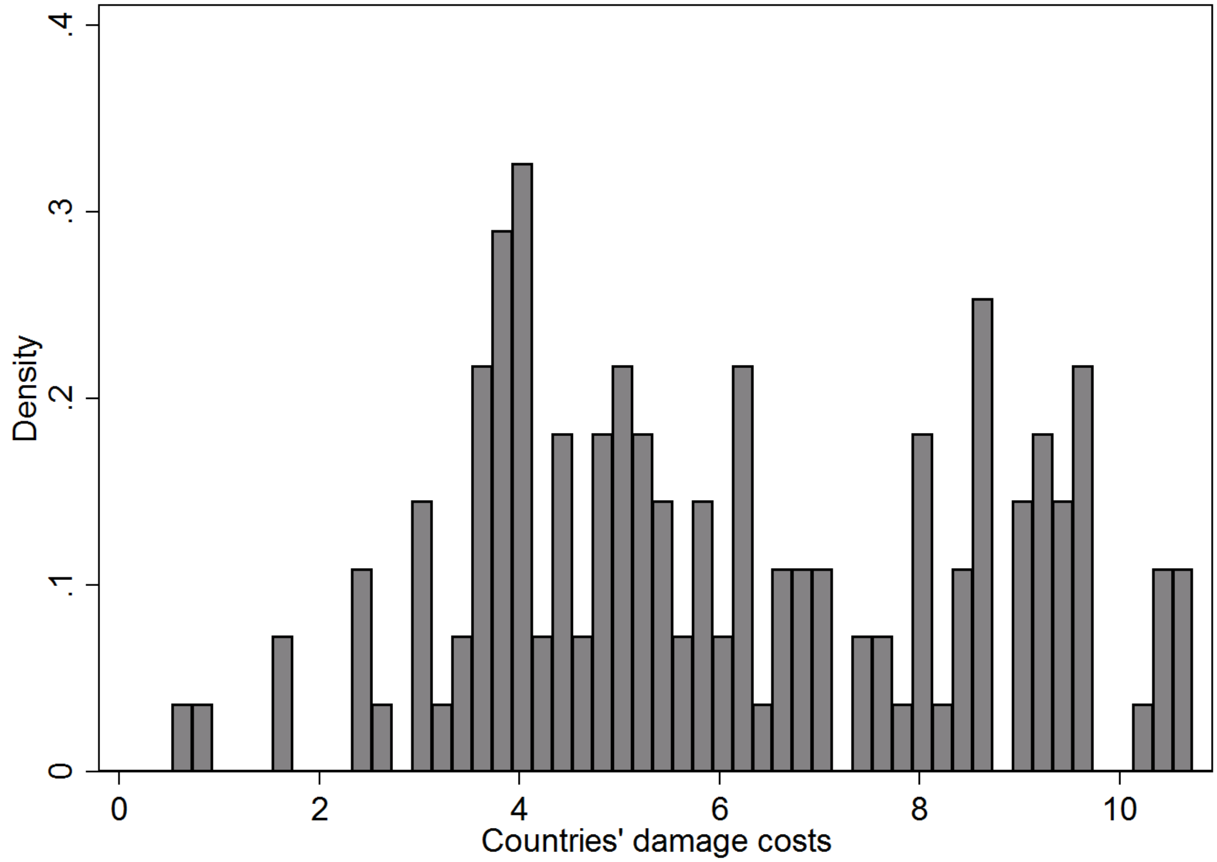


Table 5. Sensitivity of simulated participation (% of global emissions) to *Global Damage Costs* and *Vulnerability Weights.*

	Baseline	Damages -50%	Damages +50%	Vulnerability weight = 0	Vulnerability weight = 2	Baseline	Damages -50%	Damages +50%	Vulnerability weight = 0	Vulnerability weight = 2
Enthusiastic actors	**No club good**					**Club-good scale = 0.1**				
China	0	n.c.	27	n.c.	27	0	n.c.	27	n.c.	27
US	0	n.c.	41	n.c.	27	41	0	n.c.	n.c.	27
EU	0	n.c.	36	n.c.	27	36	0	n.c.	n.c.	27
China, US	0	n.c.	41	41	27	41	0	n.c.	n.c.	27
China, EU	0	n.c.	36	36	27	36	0	n.c.	n.c.	27
US, EU	0	n.c.	50	n.c.	27	50	0	n.c.	n.c.	50
China, US, EU	50	0	n.c.	n.c.	27	50	0	n.c.	n.c.	50
BASIC	37	0	n.c.	n.c.	n.c.	37	0	n.c.	n.c.	n.c.
BRICS	42	0	n.c.	n.c.	n.c.	42	0	n.c.	n.c.	n.c.
	Club-good scale = 0.2					**Club-good scale = 0.25**				
China	0	n.c.	27	n.c.	27	0	n.c.	100	100	n.c.
US	47	0	66	41	n.c.	100	n.c.	n.c.	n.c.	n.c.
EU	61	0	66	56	43	100	n.c.	n.c.	n.c.	n.c.
China, US	47	0	66	41	n.c.	100	n.c.	n.c.	n.c.	n.c.
China, EU	61	0	66	56	43	100	n.c.	n.c.	n.c.	n.c.
US, EU	61	50	66	56	66	100	n.c.	n.c.	n.c.	n.c.
China, US, EU	61	50	66	56	66	100	n.c.	n.c.	n.c.	n.c.
BASIC	37	0	72	n.c.	n.c.	100	37	n.c.	n.c.	37
BRICS	42	n.c.	72	64	n.c.	100	42	n.c.	n.c.	42

Notes: N.c. stands for no change from the baseline scenario. No conditional commitments are offered.

Table 6. Sensitivity of simulated participation (% of global emissions) to *Global Damage Costs* and *Vulnerability Weights.*

	Baseline	Damages -50%	Damages +50%	Vulnerability weight = 0	Vulnerability weight = 2	Baseline	Damages -50%	Damages +50%	Vulnerability weight = 0	Vulnerability weight = 2
Enthusiastic actors	**No club good**					**Club-good scale = 0.1**				
China	0	n.c.	61	n.c.	27	47	0	69	50	34
US	0	n.c.	61	n.c.	27	47	0	69	50	52
EU	0	n.c.	61	n.c.	27	56	0	69	50	61
China, US	0	n.c.	61	41	27	47	0	69	50	52
China, EU	0	n.c.	61	36	27	56	0	69	50	61
US, EU	50	0	61	n.c.	27	56	0	69	50	61
China, US, EU	50	0	61	n.c.	27	56	0	69	50	61
BASIC	37	0	64	n.c.	n.c.	60	0	72	60	37
BRICS	42	0	69	n.c.	n.c.	69	0	72	64	60
	Club-good scale = 0.2					**Club-good scale = 0.25**				
China	88	0	95	82	92	100	0	n.c.	n.c.	n.c.
US	88	47	95	82	92	100	n.c.	n.c.	n.c.	n.c.
EU	88	61	95	82	92	100	n.c.	n.c.	n.c.	n.c.
China, US	88	47	95	82	92	100	n.c.	n.c.	n.c.	n.c.
China, EU	88	61	95	82	92	100	n.c.	n.c.	n.c.	n.c.
US, EU	88	61	95	82	92	100	n.c.	n.c.	n.c.	n.c.
China, US, EU	88	61	95	82	92	100	n.c.	n.c.	n.c.	n.c.
BASIC	88	37	95	82	92	100	n.c.	n.c.	n.c.	n.c.
BRICS	88	42	95	82	92	100	n.c.	n.c.	n.c.	n.c.

Notes: N.c. stands for no change from the baseline scenario. Conditional commitments are offered**.**

Summary of Results

Our main results may be summarized in seven points. First, even modest club-good benefits (substantially smaller than the abatement costs) enable some constellations of enthusiastic actors to persist and to induce reluctant large actors to join. Hence, if club goods can be provided, the prospects for international cooperation on climate change mitigation increase substantially.

Second, larger club-good benefits can – assuming increasing returns from the club good – induce universal participation. However, very large club-good benefits may well be unrealistic.

Third, with no club-good benefits, conditional commitments are effective only under a limited set of conditions. Hence, Weischer et al.'s (2012) condition that the club must provide benefits exclusively to members holds (with a few but important exceptions).

Fourth, the combination of club-good benefits and conditional commitments produces broad or even universal participation under a variety of conditions. In other words, conditional commitments are highly effective in the presence of club-good benefits.

Fifth, higher returns from cooperation tend to increase participation. While both intuitive and consistent with observations of how individuals act in cooperation-game experiments (Ambrus and Pathak 2011), this result contradicts certain game-theoretic predictions concerning treaty participation (see e.g., Barrett 2003: chap. 7).

Sixth, higher climate damage costs increase the effectiveness of conditional commitments, while reducing the need for club-good benefits somewhat. The reasons are that conditional commitments' leverage then becomes greater and that participation is then considerable even with small (or even zero) club-good benefits.

Finally, increasing or decreasing the variance of actors' vulnerability does not alter the aforementioned six results. However, it does sometimes change *which* actors become club members. Moreover, it affects the distribution of abatement costs.

The conditions for climate clubs to emerge and grow posited by our ABM are arguably not currently fulfilled in the real world; however, our results present a fairly optimistic view of the prospects for effective climate change mitigation under counterfactual conditions. In particular, they suggest that if one or more major economies were willing to lead and significant club-good benefits were offered, conditional commitments would have a substantial potential for inducing reluctant actors to join a climate club and to undertake significant mitigation.

THE RENEWABLES CLUB: AN ILLUSTRATIVE CASE STUDY

Providing information on existing climate clubs, Weischer et al. (2012) suggest that no such club has thus far generated additional mitigation efforts beyond what countries would do without the club. We now consider the practical challenges facing one particular club – the Renewables Club – concerning membership, club-good benefits, potential expansion, and situation structure. The aim is to map in what ways the Renewables Club falls short of fulfilling the conditions for eventually becoming effective in reducing global emissions.

The Renewables Club was announced by then German Federal Minister of the Environment, Peter Altmaier, in Berlin on 1 June (World Environment Day) 2013. Its founding members were China, Denmark, France, Germany, India, Morocco, South Africa, Tonga, the United Arab Emirates, the United Kingdom, and the International Renewable Energy Agency (IRENA). According to the German Federal Ministry for the Environment (2013), these members account for 40% of present worldwide investment in renewable energy.

The Renewables Club aims to "advance the case of renewable energy, in particular the objectives and programmes of IRENA," and to galvanize support for an energy transition at the "forefront of the development and deployment of renewable energy technologies" (ibid.). In particular, the club pursues the following goals (ibid.):

> • Supporting, including at the highest levels, the implementation of robust policies and setting conducive enabling environments for a greater use of renewable energy, thereby shaping investments and unleashing new business opportunities[;]

- Sending a strong political message of support for renewable energy's business case;
- Raising awareness on renewable energy as a major means to help reduce greenhouse gas emissions, in an effort to stabilize the climate system;
- Promoting renewable energy as one of the important elements of energy security, economic prosperity and sustainable development; and
- Lending additional political support to the work of IRENA, as well as the efforts of other entities active in the field of renewable energy.

While these goals clearly relate to climate change mitigation, they remain unspecific. According to the press release of the German Federal Environment Ministry (2013), the members "are united by an important goal: a worldwide transformation of the energy system"; however, this goal is not explicitly mentioned in the international communique issued by the founding members.

Membership

Which criteria served the inclusion of members into the Renewables Club? While the question of membership criteria figured in the press at the time of the club's launching, no official documentation is available. Based on the communique that led to the founding of the club, it seems that members must share a political ambition to promote worldwide renewable energy diffusion in cooperation with IRENA. Climate change is barely mentioned yet constitutes part of the original domestic context of the former German Federal Environment Minister's founding of the club.

A parliamentary inquiry by Hermann Ott and the Green Parliamentary Group in the German Bundestag aimed to elucidate the membership criteria more formally. The response to this inquiry suggests that considerable heterogeneity exists concerning club members' national goals for the renewable-energy sector. Although no explicit club targets exist concerning emissions reductions or energy efficiency, interviews corroborate that one criterion used for member selection was domestic policies aiming for an energy transition based on renewables. Other criteria for selecting members included country representatives' personal capacities and countries' potential for acting as a "game changer" (Interviewee 1).

The response to the inquiry by Ott and his parliamentary group also mentions the possibility of accepting additional members (Deutscher Bundestag 2013, 2–4). However, conditional commitments intended to induce reluctant countries to join have apparently not been made.

In essence, it appears that a mix of developed and developing countries (including some with expected severe climate-related impacts) was selected. The club includes some major emitters whose combined emissions currently constitute approximately one third of global GHG emissions. Thus, based on the simulation results reported in the previous main section, it seems likely that the club has the membership base required for eventually becoming effective in mitigating global emissions. However, eventual success will almost certainly require provision of club-good benefits able to spur cooperation and attract new members.

Club-good Benefits

As already noted, climate clubs without member-specific benefits will unlikely succeed or even persist. So far, the Renewables Club has not specified any benefits exclusively for members. None of the five bullet points mentioned above refer directly to such benefits (German Federal Ministry for the Environment 2013). And despite the club's focus on technologies for renewable energy (Deutscher Bundestag 2013, 2), it provides no specification of whether, and if so how, such technologies will be advanced by the club.

A plausible explanation for the lack of material club goods is the fact that the club focuses on political dialogue (Interviewee 1). Thus, the most visible club-good benefits so far might be political attention, "mutual access," and trust building (Interviewee 1). Other (future) club-good benefits could derive from adapting the idea of the trade clause employed by the Montreal Protocol (Article 4) and from exchange of patents, resources, or funding (Interviewee 2).

Expanding Membership

The Renewables Club foresees expansion, yet does not advance any criteria under which countries should be approached as potential club members (German Federal Ministry for the Environment 2013). Decisions on new members were first scheduled to be made in

January 2014 and then postponed until an international meeting in May 2014 (Morgan et al. 2014); however, no information on membership expansion appears to be available so far.

Assessment

Deemed by currently available information, members of the Renewables Club undertake additional (although unspecified) efforts that benefit the rest of the world in terms of avoided climate-change damages. The club appears to reflect high-level political ambitions to help decision-makers galvanize support in their domestic political settings. Thus, the Renewables Club might serve a legitimating function at the national and transnational levels, much as other international organizations often do.

Overall, the Renewables Club has attracted some attention (mostly during 2013), pursues climate-related goals without material club goods or a mechanism for conditional commitments, opens for expansion (yet does not espouse clear rules for accession of new members), and might create some positive political externalities for IRENA and positive climate externalities for members and non-members alike. The fact that members already include some major GHG emitters provides a basis for club persistence and growth. However, the lack of material club goods points in the opposite direction. It is questionable whether the Renewables Club currently produces significant benefits beyond what would be generated by IRENA, in any case. To become effective in mitigating climate change, the club must likely generate club-good benefits well beyond what we have seen thus far.

CONCLUSIONS

In this paper, we have studied the conditions under which a (small) climate club can grow and eventually become capable of reducing global GHG emissions effectively. We began by reviewing theory-building research, looking for *mechanisms* that can drive such a development, and deriving the *conditions* under which we may expect such mechanisms to be triggered and generate momentum. Although diverse in other respects, this research literature converges in pointing to *exclusive benefits* for club members as essential for club formation and growth.

Our second step was to use agent-based modeling to explore numerically the performance of alternative hypothetical clubs and the effectiveness of two design features – club goods and conditional mitigation commitments – in inducing "outsiders" to join. Supporting Victor's (2011) argument, we found that even a club with only a few major actors as initial (enthusiastic) members *can* grow and eventually become very effective in reducing global emissions, provided that it (1) pursues an open-membership policy, (2) offers sufficiently large incentives for members, and (3) is unconstrained by conflict over exogenous issues. Both instruments – club goods and conditional mitigation commitments – can contribute to club growth. Used separately, each instrument is effective only under a restricted set of favorable conditions but the *combination* of conditional commitments and club-good benefits can be effective in a much broader set of circumstances.

The potential role of conditional commitments in reducing GHG emissions is a particularly interesting finding. Climate change mitigation is a quintessential collective action problem, focusing on what Olson (1965) labelled "inclusive collective goods." For these types of goods, benefits produced through one country's mitigation efforts cannot feasibly be withheld from any other country. A credible conditional commitment by "enthusiasts" – particularly targeted commitments by partners with large emissions – can change potential members' cost-benefit balance by reducing their indirect costs (in the form of, for example, weaker market positions for important industries) and/or increasing the benefits indirectly produced through their mitigation efforts (by triggering additional mitigation efforts by others). Since the overarching purpose of a climate club is to provide an *inclusive* collective good, club members will benefit from expanding membership. Moreover, since the actors most likely to respond positively to targeted conditional commitments by current club members probably will share the founding members' general concerns about the impact of climate change, agreement on "exchange rates" for mitigation efforts should be easier to reach in a club setting than in the setting of UNFCCC global conference diplomacy.

Our final step was to assess one recent initiative, the Renewables Club, in light of our findings. At this early stage, exclusive benefits for club members have not been clearly specified, let alone provided. In this regard, the Renewables Club seems to resemble many other international forums for dialogue and consultation on climate change. These forums can serve useful functions, such as coordinating diplomatic initiatives or creating a conducive setting for raising political awareness and enhancing political legitimacy across conventional political divides. In a world torn by huge asymmetries between rich and poor and by strong competition in global markets and international politics, these would be non-trivial achievements. Yet, such contributions are a far cry from the kind of powerful climate-club *action* that we have considered in this paper.

The agent-based model presented in this paper provides an innovative and empirically grounded formalization of climate club dynamics. Yet, it leaves out several real-world aspects likely to affect climate clubs' prospects. First, countries – and the European Union – are modeled as unitary actors. Some of the greatest impediments to international cooperation are created by the interaction between domestic and international political processes (Mayer 1992). Further refinements could explicitly include aspects of domestic politics, for example the roles of veto players and winning coalitions. Second, most policymakers and stakeholders care about distributive (and procedural) fairness (Dannenberg et al. 2010). Widely accepted principles of fairness could be modeled, for example, as "filters" excluding policy options that clearly fail to meet one or more of these principles (Kallbekken et al. 2014). Third, the model assumes that all conditional commitments are fully credible. This is an overly bold assumption, and since credibility is vital for conditional commitments to work, plausible modifications could enhance the real-world relevance of findings derived from the model. Fourth, game-theoretic models suggest that side payments can drastically increase mitigation when countries are strongly asymmetric (Barrett 2003). In contrast to conditional commitments, side payments work through offering benefits *exclusively* to potential entrants. An extension of the model will include side payments.

Finally, the kind of analysis reported in this paper may provide inputs to further refinement of general club *theory*. In particular, this type of analysis may serve as a basis for further clarifying the relationship between the type(s) of goods (to be) provided by a club and the instruments available for recruiting club members. As indicated above, the role of conditional commitments in enhancing the supply of collective goods will to some extent depend on whether these goods are, in Olson's (1965) terminology, inclusive or exclusive. This line of reasoning could be extended to, for example, further analysis of the interplay between club goods, conditional commitments, and side payments in alternative club settings.

Technical Appendix

The following provides a technical and complete description of the model expressed through equations and pseudo-code. For further explanation, please see the verbal description in the main manuscript. The model code is available from the authors.

Table A.1. Model parameters and variables.

Variable or parameter	Explanation	Measurement units
	Global input parameters	
CBscale	Scaling factor for exclusive club good. See Table 1 for numerical values.	-
Vulnerability Weight	Degree of differentiation between more and less vulnerable countries. See Table 1 for numerical values.	-
Global Damage	The difference in global climate damage costs between the no-club scenario and the scenario where *all* actors spend 1% of their GDP to mitigate climate change. See Table 1 for numerical values.	% of Gross Global Product (GGP)
Club fee	The mitigation expenditure required by club members. Set to 1% of entrant's GDP.	% of entrant's GDP
Conditional commitments	Conditional commitments allowed?	Yes/No
	Agent-specific input parameters	
GDP_i	GDP at market exchange rates, 2013 (World Bank 2014).	Share of GGP
$Emissions_i$	Emissions from fossil fuels and cement, 2013 (Global Carbon Project 2014) + Net emissions from land use change and forestry, 2011 (World Resources Institute 2014).	Share of global emissions
$NDGAIN_i$	Vulnerability Scores, 2012 (Notre Dame Global Adaptation Index 2014). ∈[0,1]	-
$Enthusiast_i$	Is *i* "enthusiastic"?	Yes/No
	Agent-specific variables derived in the model	
$Vulnerability_i$	The percentage loss in GDP_i arising when the global loss is 1% of GGP. $\frac{NDGAIN_i + (Vulnerability\ Weight - 1) \times (NDGAIN_i - \overline{NDGAIN})}{\overline{NDGAIN}}$ $\overline{NDGAIN}$ is GDP-weighted mean *NDGAIN.*	$\frac{\text{\% of GDP}_i}{\text{\% of GGP}}$
$Damage\ cost_i$	The difference in *i's* damage costs between the no-club scenario and the scenario where *all* actors spend 1% of their GDP to mitigate climate change. $Vulnerability_i \times Global\ damage$	% of GDP_i
$Club\ Benefit_i$	The exclusive club good benefit earned by member *i.* $CBscale \times \ln\left(\sum_{m \neq i}^{members} GDP_m\right)$	% of GDP_i
Benefit of $membership_i$	The gross private benefit of membership equals club benefits plus the private benefit from reducing one's own emissions (in terms of damage costs avoided).	% of GDP_i

	$Club\ Benefit_i + Damage\ cost_i \times Emissions_i$	
WTA$_i$	Global mitigation effort that would compensate non-member *i*'s net cost of joining. $(Club\ fee - Benefit\ of\ membership_i)/Damage\ cost_i$	share of global emissions covered by additional effort × increased depth of expenditure commitments
WTP$_{im}$	Expenditure member *m* is willing to undertake to induce non-member *i* to join. Equals *Benefit of membership*$_m$ in a club including *i* minus *Benefit of memberhip*$_m$ in the current club without *i*.	% of GDP$_m$
Ratio$_i$	The ratio between the additional mitigation effort members offer non-member *i* and the mitigation effort that would compensate *i*'s net cost of joining. $\sum_{m\neq i}^{Members}(WTP_{im} \times Emissions_m)/WTA_i$	-
Topup$_{kl}$	Additional expenditure actually incurred by *l* to induce *k to* join[16]. $WTP_{kl}/Ratio_k$	% of GDP$_l$
Payoff$_i$	*Payoff* for members incorporates (i) *Club benefit,* (ii) *Club fee,* (iii) the total additional expenditure incurred by *i* to induce others to join, and (iii) the difference in *i's* damage costs between the realized scenario and the scenario where *all* actors spend 1% of their GDP to mitigate climate change. $Club\ benefit_i - Club\ fee - \sum_{m\neq i}^{members} Topup_{mi} - Damage\ cost_i \times (\sum_{n}^{non-members} Emissions_n - \sum_{m}^{members}\sum_{j\neq m}^{members}(Topup_{jm} \times Emissions_m))$	% of GDP$_i$

Initialization

Each agent *i* (in random order):

Calculate *Vulnerability*$_i$

Calculate *Damage cost*$_i$

[16] The additional mitigation by the club is distributed proportional to *WTP*$_{im}$. Dividing by the potential entrant's benefit-cost ratio implies that the members undertake the minimum additional effort necessary to compensate the potential entrants cost of membership.

Execution

Step 1

Each enthusiast (in random order):
    Become member
Loop until no more agents want to join:
    Each non-member *i* (in random order):
        Calculate *Benefit of membership*$_i$
        Agent with greatest *Benefit of membership:*
            If *Benefit of membership*$_i$ > *Club fee*
                Become member
End loop

Step 2 (If conditional commitments are allowed)

Loop until no more agents want to join:
    Each non-member *i* (in random order):
        Calculate *Benefit of membership*$_i$
        Calculate WTA_i
        Ask each member *m* (in random order):
            Calculate WTP_{im}
        Calculate $Ratio_i$
        If $Ratio_i > 1$:
            Become member
            Ask other members *m* (in random order):
                Set $Top\text{-}up_{im} = WTP_{im}/Ratio_i$[a]
    The model checks whether any non-member would join voluntarily as in Step 1
End loop

Step 3

Loop until no more enthusiasts want to leave the club
    Each enthusiast *i* (in random order):
        Calculate $Payoff_i$:
        If $Payoff_i$ < - *Damage Costs*[17]$_i$:
            Become non-member
    If any enthusiasts left the club:
        Each reluctant member *i* (in random order):
            Calculate *Benefit of membership*$_i$
            If *Benefit of membership*$_i$ < *Club fee:*
                Become non-member
        Repeat Step 2
End loop

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[17] The right-hand side of the inequality is payoff in the no-club scenario.

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