The Club Approach: A Gateway to Effective Climate Cooperation?

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Abstract

Although the Paris agreement arguably made some progress, interest in supplementary approaches to climate change cooperation persist. We study the conditions under which a climate club might emerge and grow. Using agent-based simulations, we show that even with less than a handful of major actors as initial members, a club can eventually reduce global emissions effectively. To succeed, a club must be initiated by the “right” constellation of enthusiastic actors, offer sufficiently large incentives for reluctant countries, and be reasonably unconstrained by conflicts between members over issues beyond climate change. A climate club is particularly likely to persist and grow if initiated by the United States and the European Union. The combination of club-good benefits and conditional commitments can produce broad participation under many conditions.

> "So far, there has been no club that has brought about transformational change."[1]

The global negotiations under the United Nations Framework Convention on Climate Change (UNFCCC) have thus far had only limited success in terms of producing an effective agreement for climate change mitigation. Only 36 countries – responsible for less than 20% of global emissions – completed Kyoto 1 (2008–2012) with binding emissions reduction or limitation commitments. In Kyoto 2 (2013–2020), even fewer countries − responsible for an even smaller share of global emissions − participate with binding commitments. The 2015 Paris agreement is legally binding and commendably includes "contributions" from nearly all states. However, these contributions are specified voluntarily ("nationally determined") and are neither legally binding, nor subject to any sanctions for non-compliance. Even if we assume that Paris will nevertheless achieve full compliance, the current nationally determined contributions (NDCs) will take us only part of the distance towards the very ambitious 2^0C (or even 1.5^0) goal (UNFCCC 2015). Finally, it remains uncertain whether the Paris agreement's dynamic mechanisms – a stringent collective temperature target, a periodic global "stocktake", a peer-review mechanism aimed at fostering compliance through naming and shaming, and gradually increasing NDC ambitions – will work fast enough to "prevent dangerous anthropogenic interference with the climate system."[2]

Scholars, environmentalists, and policymakers alike therefore continue to consider supplementary climate cooperation approaches. One option is the "club" approach, whereby a climate club initiated by "enthusiastic countries" tries to induce "reluctant countries" to follow

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[1] Morgan, Messner, and Schellnhuber 2014.

[2] UNFCCC 1992, Article 2.

suit.[3] For the purposes of this paper, 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 climate change mitigation.

The global impact of a group's mitigation efforts will depend upon its size and on who the members are. Thus, an initially small climate club's effectiveness depends on its ability to encourage deeper cooperation among club members and to attract new members. Because reducing emissions is costly, reluctant countries have an incentive to remain non-members.[4] To become successful, a climate club must be able to offset this incentive.

Using an agent-based model (ABM), we study the conditions under which a group that is initially small can attract more members and thereby become more effective in reducing emissions. Thus, we try to model the evolution of cooperation on a single issue (climate change mitigation) within a particular institutional context (climate clubs). We focus on which countries become club members and measure "success" in terms of these members' aggregate share of global emissions. Finally, we examine the sensitivity of our results to alternative assumptions concerning damage costs and bilateral relationships beyond climate change (trade, affinity, and militarized conflict).

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[3] Victor 2011; Keohane and Petsonk 2015; Nordhaus 2015; Stewart, Oppenheimer and Rudyk 2013a, 2013b.

[4] Abatement costs are often assumed to be lower in poor countries than in richer ones. Providing a new representation of investment risks, Iyer et al. 2015 challenge this assumption.

Prakash and Potoski draw a useful distinction between two types of clubs.[5] In "Buchanan clubs," the production and allocation of club goods are primary goals.[6] Moreover, no incentive for free riding exists – only those paying the club fee enjoy club goods due to the possibility of exclusion.[7]

By contrast, in "voluntary clubs" the main goal is to produce a public good (or some other benefit that generates a positive externality);[8] hence, strong incentives for free riding may exist. It follows that substantial inducements may be required to encourage membership and to cause members to contribute more to the public good than non-members do. Climate clubs may be considered as a subcategory of voluntary clubs.

We simulate how a climate club's membership might evolve, contingent on three factors. The first is which countries are enthusiastic and thus serve as initiators of the club (enthusiasts are assumed to have an exogenous non-economic motivation to start a club). The second is whether enthusiastic countries make conditional pledges for additional emissions reductions. Finally, the third factor is the level of club-good provision.

We consider a club good consisting of a preferential trade agreement exclusively for club members. Linking climate change mitigation to trade in this way could violate the WTO's most-

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[5] Prakash and Potoski 2007.

[6] Buchanan 1965.

[7] Buchanan reserves the term "club good" for excludable goods that exhibit little or no rivalness for low to moderate consumption levels yet significant rivalness for higher consumption levels (because of congestion effects). By contrast, as used in the climate club literature, a "club good" may or may not entail a congestion effect. It may even become gradually more beneficial with increasing participation; indeed, as we will show, a major driving force in our model is that the "club good" scales up with club size.

[8] One referee argued that "public good club" might be better than "voluntary club". We agree. However, in this paper we stick to the latter, which is the more established term.

favored-nation (MFN) principle.[9] We see at least three possible options for overcoming this constraint. The first is through the GATT's Article XX(g), which opens for exceptions to the MFN principle in relation to natural resource conservation.[10] The second is by adding the preferential trade agreement to existing WTO provisions, in accordance with Article XXIV. The third is by WTO members creating a new MFN exception that explicitly permits discriminatory climate club trade benefits.[11]

The emergence of a climate club is envisioned as a complex and dynamic bottom-up process that occurs in a heterogeneous setting.[12] ABMs are ideal for studying processes with these characteristics.[13] Unlike game-theoretical models, which present only equilibrium outcomes, they describe the *emergence* of cooperation explicitly. They also facilitate grounding heterogeneous model agents' traits on empirical data. To the best of our knowledge, we have developed the first ABM of climate clubs.[14]

Our results suggest 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, assuming that the club pursues an open-membership policy and provided that two conditions are met.

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[9] The IPCC's 5th Assessment Report provides an account of the relationship between climate policy, international cooperation, and WTO regulations. See Stavins et al. 2014, 1030–1035.

[10] Helm, Hepburn, and Ruta 2012.

[11] Gardoqui and Ramírez 2015 offer a detailed discussion of the third option, which in our view may be hard to accomplish. Considering that the need to work in small groups concerning climate arises precisely because countries disagree, it seems unlikely that all WTO members would consent to creating such a new MFN exception.

[12] Victor 2011.

[13] See, e.g., Miller and Page 2007.

[14] Sælen (2016) presents a variation of this model focusing on side-payments.

First, the “right” actors must be enthusiastic. In particular, the actors initiating the club must control a sufficiently large share of global emissions and income. The United States or the European Union (but not China) can under some conditions single-handedly initiate a club that can persist and attract other members. If both were enthusiastic, the prospects for at least moderate club success would appear bright, because in our model the United States and the European Union can in many cases entice China to join by appealing to its self-interest.

Second, the club must provide sufficiently large incentives for reluctant actors to become members. A combination of club-good benefits and conditional commitments produces broad participation under a range of conditions. Conditional commitments effectively enhance climate cooperation in the presence of club-good benefits and vice versa.

In the next section, we briefly review relevant research literature. In the third section, we describe our model and report our simulation results. The final section offers our conclusions.

Literature Review

Reviewing recent climate-club literature, Falkner argues that starting small might be advantageous in at least three ways – by facilitating dialogue and bargaining, by creating incentives for membership, and by offering great powers a privileged position (thereby enhancing the legitimacy of international climate governance in their eyes).[15] Focusing on incentives and therefore being grounded in the second way, this paper considers the potential for enthusiastic

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[15] Falkner 2016. Gampfer 2016 finds that climate clubs need careful institutional design to be perceived as legitimate and hence to be politically feasible.

actors to use club goods and conditional commitments to attract members. This section identifies and discusses three main determinants of climate club success, thereby providing a basis for our simulations. First, however, we briefly review the general climate club literature.[16]

Climate clubs

A well-known barrier for progress in the UNFCCC negotiations is the consensus rule, which enables determined countries to block collective decisions that are not in their interest, either single-handedly or by forming small, vocal coalitions.

To bypass this barrier, Victor suggests that cooperation should begin with small groups (or "clubs") of enthusiastic countries and be based on a high degree of flexibility concerning the choice of policies.[17] The "backbone" of his 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. We refer to such contingent offers as "conditional commitments." Finally, reluctant countries should be enticed to join via "exclusive and contingent" measures, that is, club goods (what Olson terms "selective incentives").[18]

The club approach leaves it to each country whether to participate in the *initiation* of a climate club ("enthusiastic" country), to join later, or to stay out, based on different calculi of optimality.

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[16] For recent reviews of the related literatures on repeated games and coalition games, see Hovi, Ward and Grundig 2015; Hovi et al. 2016.

[17] Victor 2011.

[18] Olson 1965.

Rather than relying on decision rules that may obstruct groups of countries from jointly engaging in climate change mitigation, the club approach envisions the development of a coalition of the willing. It thus allows for coalition sizes substantially smaller than required for UNFCCC consensus. Put differently, rather than potentially obstructing attempts to form a mitigation coalition, the club approach allows for bottom-up formation of coalitions based on optimality for club members.

Stewart et al. present climate clubs as one of three building blocks in their proposed new strategy for global climate change mitigation.[19] Unlike us, they conceive of climate clubs as Buchanan clubs (where non-climate, excludable benefits provide the primary or even the sole incentive for participation). They also propose that membership should be broadened to include not only states but also transnational groups of firms in key industry sectors.

A few scholars have assessed the empirical record of actor 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 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.[20] He concludes that these alternatives have largely served as "discussion clubs" that have achieved very little in terms

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[19] Stewart, Oppenheimer, and Rudyk 2013a; Stewart, Oppenheimer, and Rudyk 2013b.

[20] Andresen 2014.

of actual emissions reductions. Similarly, after considering no fewer than 17 climate clubs, Weischer et al. conclude that these clubs are little more than forums for political dialogue.[21]

Which actors are enthusiastic?

A first crucial factor influencing a climate club's chances of eventually becoming successful in reducing global emissions is which actors serve as enthusiasts (club founders). What characterizes actors likely to play this role?

The most plausible and effective candidates will likely be major emitters with relatively low GHG abatement costs, relatively high damage costs, or – ideally – both. This presumption informs our simulations. We do realize, though, that even countries meeting all of these requirements need not become frontrunners. Very long time lags, measured in decades and even centuries, between mitigation measures (~costs) and environmental effects (~benefits) generate profound asymmetries in cost-benefit considerations.[22] Potential club founders may therefore be looking also for short-term and private benefits. Collaboration with attractive club partners may well be the most effective way to produce such benefits (see below). Mitigation measures can also have positive domestic side effects (co-benefits) such as improved public health through reduced local pollution. Some governments rely on support from influential environmental NGOs or broader "Baptists and Bootleggers" coalitions.[23] Finally, climate change policies and practices are in some cases guided also by norms of appropriateness, in particular by distributive-fairness principles

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[21] Weischer, Morgan, and Patel 2012. Note that their definition of a "climate club" differs from ours; hence, their conclusions will not necessarily apply to "clubs" as defined here.

[22] Underdal 2010.

[23] DeSombre 1995.

concerning responsibility (“guilt”), capacity, and need.[24] A comprehensive analysis of global climate change negotiations should consider also such domestic sources of “enthusiasm”. In the simulations presented in this paper, however, we limit the analysis to climate club benefits originating from the international level.

Conditional commitments

A second factor concerns climate club members’ use of conditional commitments. Several scholars have considered how followers are likely to respond to a leader’s taking unilateral environmental action – conditionally or unconditionally. A main finding is that unconditional unilateral action typically has zero or even adverse effect on followers’ emissions reductions.[25] In contrast, conditional unilateral action can contribute positively under some circumstances.[26] In our model, conditional unilateral club action constitutes a core element.

The 2015 Paris Agreement lets each party set its own mitigation target by submitting a so-called Nationally Determined Contribution (NDC). NDCs may contain conditional components (UNFCCC 2015, paragraph 26.1), which could be expressed in two main ways. One type (“intrinsic” conditionality in Lipson’s terminology)[27] would link a country’s own commitments to other countries’ mitigation efforts. Another type (“extrinsic” conditionality) would make a country’s

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[24] See, for example, Mattoo and Subramanian 2012.

[25] See, for example, Hoel 1991; Buchholz, Haslbeck, and Sandler 1998.

[26] Holtsmark 2013; Underdal et al. 2012.

[27] Lipson 1981.

own commitments conditional on other countries' efforts in other yet related policy domains, such as financial and technological support.

While extrinsic conditions are left for future research due to space constraints, our simulations consider the effect of intrinsic conditions. Some countries used intrinsic conditions also under the 2009 Copenhagen Accord.[28]

Club goods

Finally, a third factor that might influence a climate club's success is whether and to what extent it provides club goods. Making countries' access to a club good conditional on their mitigation efforts constitutes a form of issue linkage.[29] Club initiation and growth requires that actors expect the club to provide net benefits for them. One form of such benefits is club goods, such as preferential terms of trade or investment, joint R&D programs in renewable energy technology, access to emissions trading programs, or extension of pipelines or electricity grids to facilitate efficient use of total energy production capacity.

Some scholars find that club goods in the form of technology R&D can advance climate cooperation.[30] However, Barrett questions their findings, arguing that several international agreements (including the Montreal Protocol) require the parties to cooperate on technology R&D, yet do not encourage members to withhold the fruits of such R&D from non-members. A likely

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[28] The Copenhagen Accord pledges are available from: http://www.c2es.org/docUploads/targets-and-actions-copenhagen-accord-05-24-2010.pdf

[29] See Finus 2003 for an overview.

[30] Carraro and Siniscalco 1997; Buchner et al. 2005.

reason, he argues, is that doing so would be detrimental to members' self-interest.[31] Similarly, club goods in the form of linkage to trade have been proposed,[32] although such linkage, too, may be detrimental to members' self-interest. In practice, however, countries sometimes do seem to accept losses from imposing trade sanctions when they believe sanctions might serve a sufficiently important purpose.[33] Moreover, it seems fully consistent with Victor's basic idea of enthusiasm to assume that enthusiastic actors might be prepared to forgo potential benefits from trade with reluctant actors that decline to join the club.

Our work is related to that of Nordhaus,[34] who finds that small trade penalties on non-participating countries can induce an agreement with broad participation and deep emissions reductions. However, his analysis differs from ours in two important respects. First, he adopts a top-down approach in which the regime's design is already optimized to achieve high levels of participation and abatement, while we consider how cooperation might evolve from a small initial coalition. Second, whereas he assumes that cooperation centers on "an international target carbon price," we assume that it centers on undertaking emissions reductions equivalent to a fixed percentage of GDP.[35] While a common carbon price is economically more efficient, we deem it politically less realistic.

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[31] Barrett 2003, 309–10.

[32] See, for example, Stiglitz 2006 and Nordhaus 2015.

[33] Current U.S. and EU trade sanctions against Russia provide an example.

[34] Nordhaus 2015.

[35] Sælen (2016, pp. 918–919) discusses the assumption in more detail.

Preferential market access – the club good we focus on in our simulations – will be more attractive the more members the club already has and the larger the economies these members have.[36] In a club with many and large members, market access could make a significant difference, because few alternative suppliers and buyers would remain outside. Our ABM therefore models club-good benefits as an increasing function of club size. These increasing returns combined with cross-actor differences in cost-benefit calculus may trigger a snowball effect, whereby reluctant actors requiring the smallest non-climatic compensation join first and contribute to shifting the cost-benefit balance for actors requiring slightly higher compensation, and so on.

To create such an effect, the club must pursue an open-membership policy, so that reluctant actors wishing to join are free to do so, provided they satisfy membership requirements.[37] This condition, which is satisfied in our simulations, excludes the possibility that a group such as the European Union could succeed as a climate club by increasing membership, simply because the European Union would unlikely accept new members on the basis of applicants' climate policies. The same is true for most of the "exclusive groups" considered by Andresen, such as the G20, the G8, and the MEF.[38]

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[36] In this respect, preferential market access differs significantly from most other club goods. For example, preferential access to a new technology would likely become less beneficial the larger the number of other countries having such access (because the competitive edge provided by the technology would shrink).

[37] A similar open-membership policy is pursued by WTO plurilateral agreements. For example, see the WTO Agreement on Government Procurements, Article XXIV.2.

[38] Andresen 2014.

Under what conditions should we expect reluctant actors to respond positively to a climate club offering a club good? According to Weischer et al.,[39] the club good must be significant enough to outweigh the temptation to free ride by remaining a non-member. Thus, the club must control sufficient resources so that it can make membership worthwhile for reluctant actors. A second condition is that it must be credible that an actor will enjoy the club good if and only if it becomes a club member. [40]

The latter condition implies that compliance enforcement will be essential for a climate club to become effective. We nonetheless follow the extensive game-theoretic literature on stable coalitions, drawing on d'Aspremont's two-stage model,[41] in focusing on participation. Some scholars argue that participation is the binding constraint.[42] Club goods' excludability significantly simplifies the policing of free riding in a climate club.[43]

The list of major GHG emitters indicates that at least some potentially powerful clubs might include members with strongly divergent preferences regarding the distribution of mitigation commitments.[44] Some potential members' relationships – such as that between China and the United States – are also strained by geopolitical or economic conflicts. The joint statements issued by China and the United States nevertheless suggest that conflict over other issues need not

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[39] Weischer, Morgan, and Patel 2012.

[40] The same applies for conditional commitments (if any).

[41] d'Aspremont et al. 1983.

[42] See, for example, Barrett 2003.

[43] Stewart, Oppenheimer, and Rudyk 2013a.

[44] See, for example, Shum 2014. To illustrate, a club including the four largest GHG emitters would consist of China, the United States, the European Union, and India.

prevent all forms of climate club cooperation. We conduct sensitivity tests to check the influence on our main simulation results by including exogenous stakes in our ABM simulations.

Although conditional commitments and club goods constitute the major focus of this paper, we emphasize that a climate club might also generate other types of benefits. First, a club might reduce climate damage through enhanced mitigation measures (i.e., through provision of the global public good itself). Second, benefits may come in the form of side-payment arrangements similar to existing global schemes under the UNFCCC framework (e.g., the Clean Development Mechanism) whereby developed countries help fund climate-friendly measures in developing countries. Finally, benefits may come in the form of (predictable) *side effects*,[45] such as a reduced loss of competitive edge in international markets.

Agent-based Simulations of Climate Club Emergence and Growth

The theoretical discussion above has provided some general expectations concerning the conditions under which a climate club might persist and grow. However, deriving predictions that are more exact requires detailed analysis of every actor's cost- benefit calculations in a wide range of scenarios. The good news is that much of the data underlying such calculations are available, and although the costs and benefits of climate change mitigation are uncertain, information asymmetries do not appear particularly stark. However, because each actor's costs and benefits differ from others' and depend on every other actor's choices, the interaction becomes complex

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

even when based on quite simple input assumptions. Analytical models would hardly be able to incorporate all relevant data, so numerical simulations can add to our understanding of the emergence and growth of climate clubs.

Our ABM aims to capture select essential climate club features, while leaving out many complicating real-world factors. The basic decision is binary: Each actor must decide whether to join a climate club. We assume that any actor that wishes to join is free to do so, provided it satisfies the membership criterion – that each member must implement mitigation measures worth at least 1% of its GDP. Thus, the model considers one specific form of a climate club.

We initially also make the simplifying assumption that decisions concerning climate cooperation are based on the merits of that issue area only. However, we relax this assumption in the sensitivity analysis.

The model is a one-shot sequential game with an indefinite number of stages. All costs and benefits are measured in present value and all decisions (unless revoked) are implemented instantaneously. We assume complete information. 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, besides undertaking mitigation – a global public good benefitting members and non-members alike – the club may produce a club good for *members only*. Second, members may offer to deepen their mitigation efforts conditional on new members joining (and thereby agreeing to spend at least 1% of their GDP on mitigation). We will refer to such offers as “conditional commitments.”[46]

Model Description

The Technical Appendix provides our model’s formulae and describes the model in pseudocode, 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; hence, they will join the club if and only if joining leads to private benefits that exceed abatement costs (1% of GDP). As defined by Victor, e*nthusiastic* actors are willing to spend their own resources on mitigation.[47] We assume they have an intrinsic motivation to start a club, despite that doing so entails (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. However, even an enthusiastic actor will exit if the club – after negotiations with all reluctant actors – proves to generate lower net private benefits for the enthusiastic actor concerned than the *no-club scenario* does. Thus, enthusiastic actors compare the payoff they get as a member of the club with the payoff they would get if they left and the club collapsed. In this respect, enthusiastic actors behave akin to the *conditional cooperators* modeled

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[46] A potential challenge for a sub-global club is carbon leakage, which may arise through different mechanisms (Hoel 2012). Like most game-theoretic climate-coalition models, our model does not explicitly address this challenge. We expect that carbon leakage would at least initially reduce clubs’ effectiveness. However, limited data make this reduction’s magnitude difficult to estimate. Most estimates rely on computable equilibrium models and find leakage rates in the range between 5% and 20–30% (Hoel 2012; Sterner, Carbone, and Fischer 2015). Leakage decreases with club size but depends also on other factors such as economies' openness (Böhringer, Fischer, and Rosendahl 2010).

[47] Victor 2011.

by Richter and Grasman and to the *strong reciprocators* modeled by Sælen:[48] prefering to participate conditional on a certain amount of reciprocity. If all actors were enthusiastic, mitigation would become an assurance game. Reluctant actors, by contrast, will free ride on members' mitigation as long as their payoff outside the club is greater than their payoff inside. They therefore compare their payoffs inside and outside the club holding other actors' membership constant.

Actors have three further attributes with empirically grounded values: emissions,[49] GDP,[50] and climate change vulnerability scores (see table 2).[51] Complete data are available for 168 countries, accounting for 98% of both global emissions and Gross Global Product (GGP). Because we model the European Union as a single actor, the model includes 141 actors.

Estimating the global costs and benefits of climate change mitigation is beyond this study's scope. Rather, we run the model for different assumptions concerning the club's impact in terms of damage costs avoided. The input variable *Global Damage* expresses the assumed damage cost difference between the business-as-usual (BAU; no-club) scenario and the scenario where *all* actors spend 1% of their GDP to mitigate climate change (the scenario with universal club participation). In the Stern Review,[52] 1% of GGP emerges as the central estimate for stabilizing atmospheric concentrations at 500–550 parts per million CO_2 equivalents (ppm CO_2e). That

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[48] Richter and Grasman 2013; Sælen 2012.

[49] Sources: Global Carbon Project 2014 (2013 figures) / World Resources Institute 2014 (2011 figures).

[50] Source: World Bank 2014 (2013 figures).

[51] Source: Notre Dame Global Adaptation Index 2014 (2012 figures).

[52] Stern 2007.

would avoid the worst climate change impacts, which in the business-as-usual (BAU) scenario would "equate to an average reduction in global per-capita consumption of 5%, at a minimum, now and forever," the report finds. Translating those findings to our model is non-trivial for reasons including that the report measures costs and benefits in different units, assumes cost-efficient mitigation, and has caused substantial academic controversy. The most recent IPCC report suggests mitigation is somewhat more expensive, with annual GGP losses from stabilizing at 530–550 ppm CO_2e starting at .5% in 2020, rising via 1% in 2030 and 2% in 2050 to 4% in 2100 (median estimates).[53] That scenario will entail a slightly less than 40% probability that warming will not exceed 2°C above preindustrial levels.[54] The report does not monetize benefits of stabilization, but the consequences of doing nothing seem no less grave than they did when the Stern Review was conducted. It seems safe to assume that collectively spending 1% of GGP on mitigation would provide substantial benefits but that it would not suffice to achieve the 2°C target. In the baseline model, we set *Global Damage* to 3% of GGP, implying that the present value of climate benefits of a global club outweighs costs by a factor of three, which is conservative compared with the Stern Review. For sensitivity checks, we also present results for values of 1.5% and 4.5% of GGP.

When only a subset of the 141 actors participates, the climatic benefit is assumed to be a linear function of 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. Carbon leakage (footnote 46)

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[53] Clarke et al. 2014, 450.

[54] Clarke et al. 2014, 440.

would suggest concavity, while increasing marginal damage costs would suggest convexity. We ignore both.

Our approach assumes governments attach some weight to future costs incurred by their citizens. In contrast, a purely myopic government would care little about future climate-change impacts. Specifying costs in their present value sidesteps the difficult question about the rate at which future climate-change impact costs should be discounted.

Finally, we assume that damage costs are distributed in proportion to actors' GDP and vulnerability. Because vulnerability 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,[55] 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) and are denoted $NDGAIN_i$. Translating index scores of vulnerability into damage functions is certainly not trivial, because only limited empirical guidance is available. We use a model input variable called *Vulnerability weight,* which determines the variance of the damage cost distribution across actors, while keeping constant global costs and actors' rank concerning damage costs as a percentage of GDP. Specifically, we use the following formula:

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

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[55] Notre Dame Global Adaptation Index 2014.

It expresses actor-specific vulnerability 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. The value of *Vulnerability weight* determines how skewed damage costs are in disfavor of the most vulnerable. Because this skewness is highly uncertain, we analyze a wide range of possibilities. As one extreme case, we set *Vulnerability weight* to 0, implying that Burundi and Switzerland suffer the same percentage reduction in GDP as a result of climate change. As the other extreme, we set *Vulnerability weight* to 2, implying that Burundi suffers a reduction 19 times greater than Switzerland does. In the baseline case, *Vulnerability weight* is set to 1, implying that Burundi suffers a reduction four times greater than Switzerland does.

Damage costs, as well as all other costs and benefits, are measured in their present value, as a percentage of current 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 (in the form of preferential market access for members) and conditional commitments (increased mitigation pledges in exchange for increasing membership). The model permits us to study these two instruments separately and in combination.

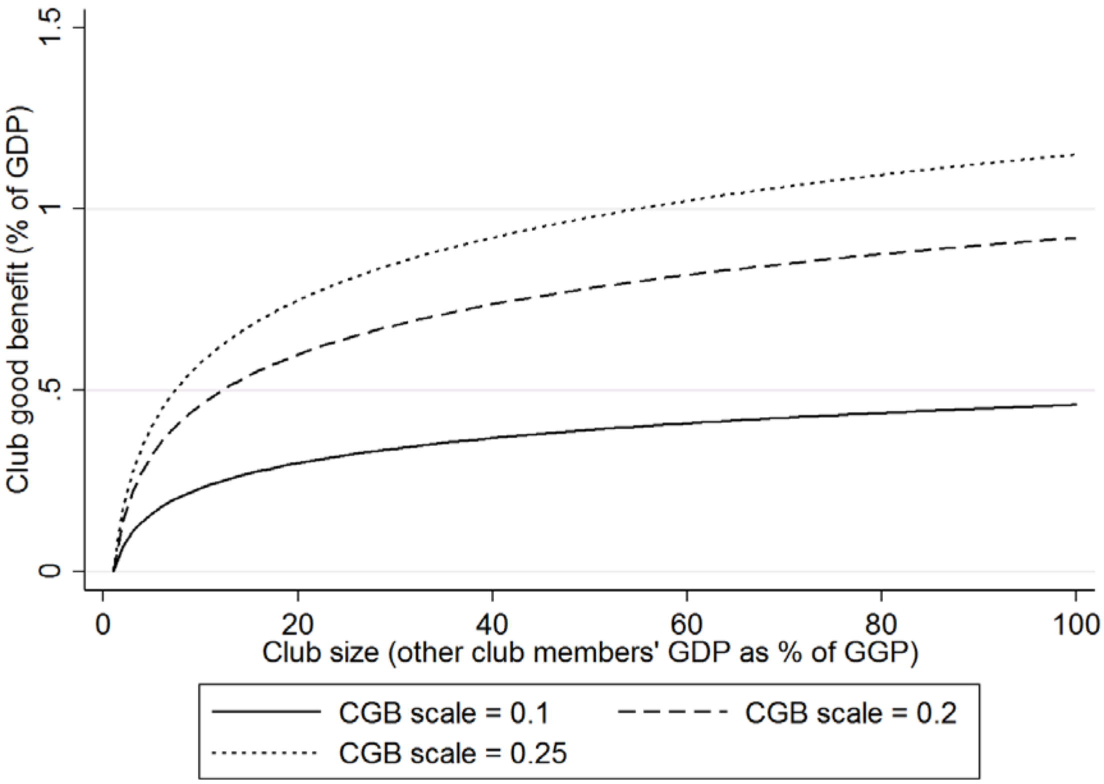
Concerning club-good benefits, the model assumes that only club members benefit from the club good. Available data does not allow a precise empirical calibration of the size of such goods, but the following characteristics seem plausible: i) benefits increase with the sum of other members' GDP, but at a decreasing rate; ii) benefits are generally less than 1% of GDP, otherwise the club-good benefit would suffice to motivate membership even disregarding the public good produced from mitigation; iii) benefits are comparable with estimated benefits from possible new trade deals. Such estimates do not abound, but Francois et al. estimate that a transatlantic trade and investment agreement would increase the European Union's GDP by 0.3–0.5% and the United States' GDP by 0.2–0.4%.

Taking the natural logarithm of other members' GDP achieves i). Point ii) suggests multiplying that logarithm by a scaling factor of about 0.2 or less and point iii) suggest multiplying by around 0.1. We run the model for values between 0 and 0.25, focusing particularly on the points 0.1, 0.2, and 0.25. Denoting this multiplier *CGB scale*, we get the following equation:

$$Club\ benefit_i = CGB\ scale\ \times \ln\ \left(\sum_{m \neq i}^{members} GDP_m\right) \tag{2}$$

The corresponding *club-good benefit* functions are illustrated in Figure 1. For comparison with Francois et al.'s estimates, a club consisting of the European Union and the United States would increase each member's GDP by around 0.3%, 0.6%, and 0.75% for the respective CGB scale values. A *CGB scale* of 0.25 hence represents very optimistic assumptions.

Figure 1. Club-good benefit functions under various assumptions tested



Turning to conditional commitments, Victor argues that pledges should not just be declarations of what an actor *will* do, but promises of effort *conditional* on what others pledge or do.[56] Our model includes one specific form of such conditional commitments: It 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 benefit 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.

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[56] Victor 2011.

In the 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 benefit. Each non-member *i's* entry therefore benefits each member *m* enough to compensate it for the costs of a certain extra mitigation effort, Δ_{im}. We incorporate increasing marginal cost per unit of emissions reductions, assuming a quadratic cost function. Hence, benefits are a concave function of *m*'s expenditure (see Table A.1 in the Technical Appendix). If the sum of Δ_{im} across members would benefit *i* enough to outweigh *i*'s net cost of joining (taking into account its other benefits from membership), a mutually advantageous expansion is possible in which existing members increase mitigation expenditure incrementally above 1% of GDP in return for the potential member *i* committing to spend 1% of its GDP, resulting in damage cost reductions that outweigh (additional) mitigation expenditure for every actor involved. This situation amounts to an assurance game for the members. In one equilibrium, all make zero extra effort. In other equilibria, the members collectively make just enough effort to induce the potential entrant to join. This collective effort can be divided in many ways, which may give rise to internal bargaining. Because prospects for international cooperation in the face of assurance games are reasonably good,[57] and because the number of club members is, at least initially, small, we assume that agreement among members will be reached, enabling the club to induce the potential entrant to join. Following a standard effort-sharing rule in the game-theoretical literature on international environmental agreements,[58] we assume that each actor's extra effort is proportional to its benefit

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[57] Barrett 2013.

[58] See, for example, Finus 2003.

from expansion, Δ_{im}. This rule ensures the expansion makes no member worse off. In principle, members also benefit from every other member's increased expenditure, and these benefits should increase their willingness to contribute. The effect will, however, likely be weak in most cases, so we have not included it in the analysis reported here.

Conditional commitments are assumed fully credible, a simplification that future work should seek to drop.

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. Additional decision rounds occur 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.

Step 2 (included only if conditional commitments are allowed): The model calculates the benefit to each member for each non-member's potential 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.[59] If at least one actor leaves, every actor will reassess whether membership pays off.

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 actors	1	0; 2
Global damage	The difference in global climate damage costs between the business-as-usual (BAU; 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	
CGB scale	Scaling factor for exclusive club good	0; 0.1; 0.2; 0.25	0, 0.01, …, 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 constitute the main foci of the analysis.

Model Results

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[59] Unlike the model analysed by Weikard (2011), our model permits a club member to withdraw (as Canada did from Kyoto).

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, and (3) different assumptions about whether conditional commitments are used to induce reluctant actors to join. The dependent variable is club participation measured in terms of members' share of global emissions. The results are presented in Tables 3 (without conditional commitments) and 4 (with conditional commitments), and in Figure 3.

Table 2. Emissions (including land-use change and forestry), GDP, and vulnerability index scores of the 10 largest emitters and the group of 30 most vulnerable countries.

Actor	% GHG share	% GGP share	Vulnerability index
China	27.3	12.3	0.30
United States	13.6	22.4	0.20
EU	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
Vulnerable 30	3.1	1.5	0.54

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). The vulnerabilities of the EU and "Vulnerable 30" represent the average of their members' vulnerabilities.

For enthusiastic actors, we consider the world's three biggest emitters individually, every combination of these three, plus the BASIC[60] and BRICS[61] groups. These countries with large emissions and economies have the greatest ability to affect global emissions. On the other hand, the most vulnerable countries have the greatest interest in reducing global emissions. We therefore also consider what a coalition of the 30 most vulnerable countries (denoted "Vulnerable 30") might achieve. The Technical Appendix lists this coalition's members. These members have small incomes and low emissions, as shown in Table 2. The results for this coalition will therefore illustrate the potential for small countries to initiate effective cooperation. The model is not well suited for assessing clubs accounting for less than 1% of GGP (the logarithmic club-good benefit function would give negative values). Assuming 30 countries act unitedly is an optimistic assumption and results in an upper boundary for small countries' potential.

In the baseline runs, *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 2. While global damages total 3% of GGP, most actors suffer damages greater than 3% of GDP, 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 below.

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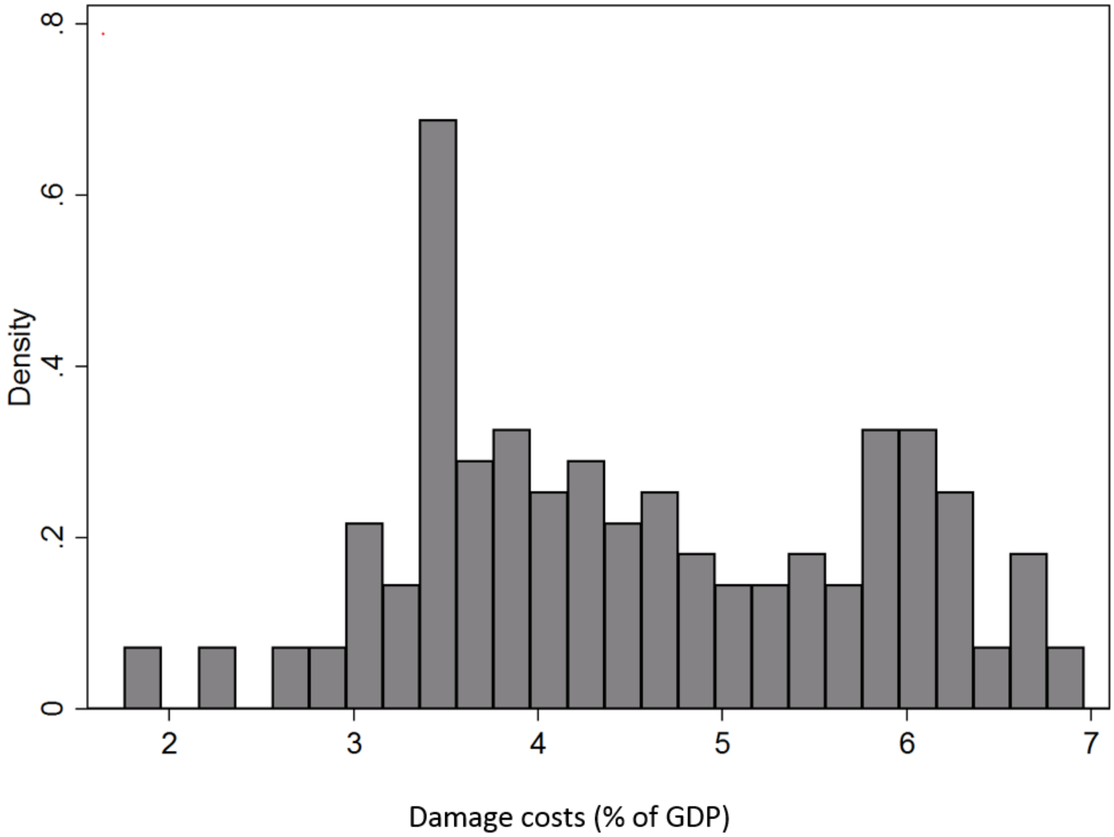
[60] Brazil, South Africa, India, and China.

[61] BASIC countries plus Russia.

Figure 2. Histogram of actors' damage costs (% of GDP) under baseline assumptions



The first quadrant of Table 3 explores the scenario with zero club-good provision and no conditional commitments, that is, where enthusiastic actors have no means for inducing others to join. Three instances of clubs nevertheless persist, because members are better off than they would be without a club. When the *CGB scale* is set to 0.1, all initiating coalitions except one (China alone) persist. Furthermore, China will join all other coalitions of initiators. Because of large emissions and relatively high vulnerability,[62] it takes relatively little in our model to tip China's benefit-cost calculus in favor of mitigation.

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[62] These two characteristics may be expected to spur China's willingness to engage in climate cooperation generally. Indeed, at COP21 in Paris other countries' negotiators did not consider China as a country that might potentially block an agreement

Increasing the *CGB 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 successfully induces India and China to join. The BASIC and BRICS coalitions still fail to recruit any reluctant actors.

Increasing the *CGB scale* further to 0.25 results in universal membership for all hypothetical enthusiastic-actor coalitions except China alone and the Vulnerable 30. We emphasize that this scenario is rather optimistic; indeed, the club-good benefit will then outweigh the abatement costs of 1% of GDP whenever other members' aggregated GDP exceeds 55% of GGP (see Figure 1). Under these assumptions, the interaction between reluctant actors constitutes an assurance game with multiple equilibria even absent any enthusiastic actors. Note that even under the most optimistic scenario, the Vulnerable 30 manages to recruit only China.

Figure 3 shows participation (measured as the share of global emissions) as a function of CGB scale, with a resolution of 0.01 for the latter. Without conditional commitments, the function is a mix of flat sections and spikes. The spikes may partly be explained by the simple fact that certain individual actors account for a large share of global emissions. However, a more complex dynamic is also at work, namely cascade effects. When one actor joins, the club-good benefit increases, thereby making it more attractive for other actors to join, too. Many curves display two spikes. The first is caused by a few large reluctant actors joining the club and the second by a cascade including virtually all the others. Because the second spike occurs for *CGB scale* values that may be

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(personal communications), although its submissions and statements in the negotiation process attempted to set out a hardline position.

difficult to bring about empirically, the analysis suggests that participation in a club based solely on club-good benefits will be limited to at most a handful large (and enthusiastic) emitters.

Table 3. Simulated equilibrium membership and emission coverage (% of global emissions) by enthusiastic-actor constellation and club-good benefit size. Vulnerability weight = 1. Without conditional commitments.

	No club good		***CGB 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
Vulnerable 30	0	None	30	Vulnerable 30, China
	***CGB scale* = 0.2**		***CGB 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
Vulnerable 30	30	Vulnerable 30, China	30	Vulnerable 30, China

The Effect of Conditional Commitments

Table 4 shows the simulation results when conditional commitments are permitted. With no club good, conditional commitments prove ineffectual with two exceptions: China will join an EU–US coalition and the Vulnerable 30.[63] If the United States or the European Union is a lone enthusiast, China will also join; however, the club will collapse, being unprofitable to the founder.

Table 4. Simulated equilibrium membership and emission coverage (% of global emissions) by enthusiastic-actor constellation and club-good benefit size. Vulnerability weight = 1. With conditional commitments.

	No club good		***CGB scale* = 0.1**	
Enthusiasts	Emissions covered	Members	Emissions covered	Members
China	0	None	0	None
US	0	None	47	US, China, India
EU	0	None	50	China, US, EU
China, US	0	None	47	China, US, India
China, EU	0	None	50	China, US, EU
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	51	BASIC, US
BRICS	42	BRICS	55	BRICS, US
Vulnerable 30	30	Vulnerable 30, China	44	Vulnerable 30, China, US
	***CGB scale* = 0.2**		***CGB scale* = 0.25**	
China	76	11 actors	100	All actors
US	77	12 actors	100	All actors
EU	79	13 actors	100	All actors
China, US	77	12 actors	100	All actors
China, EU	79	13 actors	100	All actors
US, EU	79	13 actors	100	All actors
China, US, EU	79	13 actors	100	All actors
BASIC	77	12 actors	100	All actors
BRICS	79	13 actors	100	All actors
Vulnerable 30	80	42 actors	100	All actors

Combined with a small (0.1) club good, conditional commitments broaden every club, except the one initiated by China, by attracting either India or the United States. With the intermediate club good (set at 0.2, conditional commitments enlarge all coalitions to account for around 80% of

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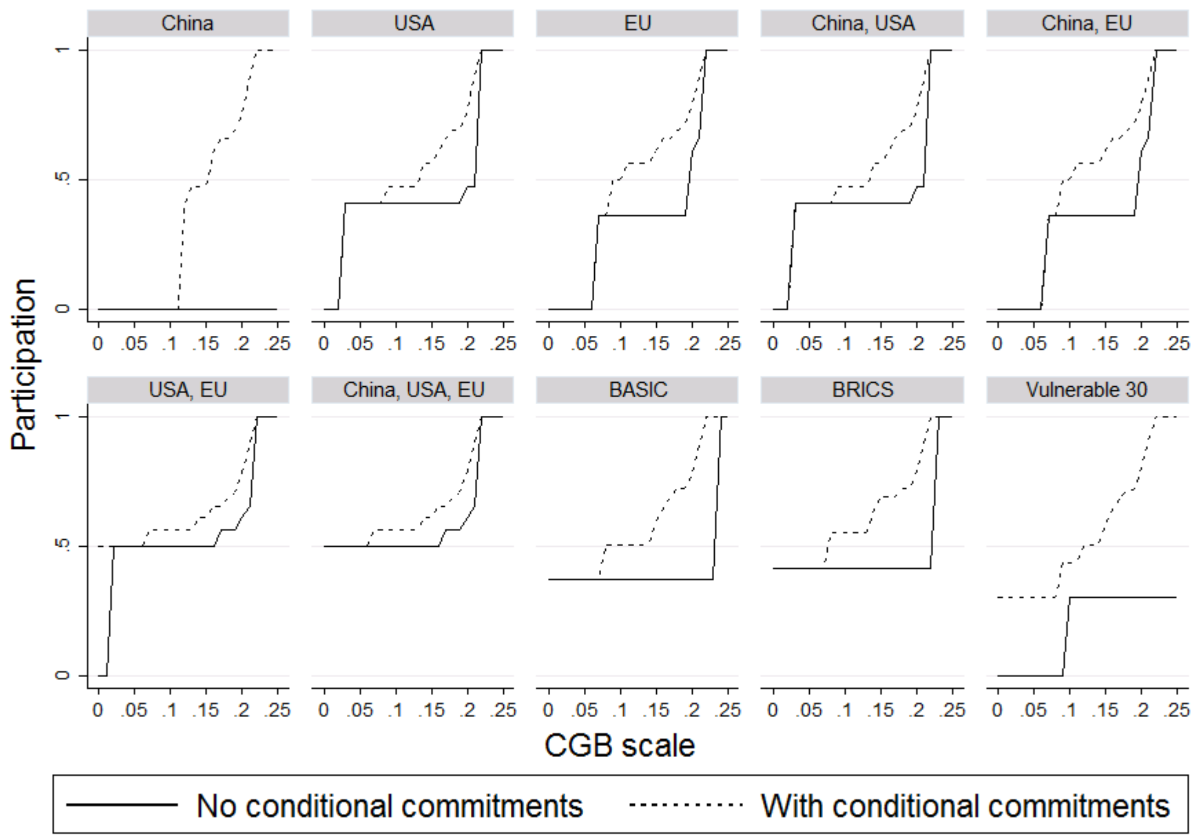
[63] The latter coalition barely manages to recruit China; the 30 most vulnerable countries would fail.

global emissions. Finally, combined with the largest club good (0.25), conditional commitments ensure universal participation in both scenarios where this is not achieved already. Across all runs, enthusiasts' expenditures on conditional commitments equal 0.1%–1.2% of GDP. Besides broadening participation, these commitments cause a moderate deepening of cooperation.

Figure 3 shows that conditional commitments are particularly effective in broadening participation for *CGB scale* values between the two spikes identified above. Conditional commitments smoothen the participation curve for two reasons. First, they effectively broaden participation from including only the top 3–5 emitters to include also other top 15 emitters, with each new emitter representing an incremental increase in the share of global emissions covered by the club. Second, while club growth means that more and more actors offer conditional commitments, cascade effects are moderated because each actor's marginal mitigation costs increase with the mitigation level, as captured in the quadratic cost function. Overall, conditional commitments appear to produce a substantial increase in club participation even when combined with only moderate levels of club-good benefits.

Figure 3: Participation (share of global emissions contained in the club) as a function of *CGB scale,* in various scenarios.



Notes: 1. The header identifies the enthusiasts. 2. Participation refers to the share of global emissions covered (with "1" representing 100%)

Sensitivity to assumptions on damage cost magnitude and distribution

Appendix 5 analyses the main results' sensitivity to alternative assumptions concerning the damage costs' size (*Global damage cost)* and distribution (*Vulnerability weight)*. Rerunning the model with *Global damage cost* 50% lower than the baseline, yields little cooperation except when the club-good benefit is large. Conversely, setting *Global damage cost* 50% higher than the baseline, increases participation in most scenarios and does not reduce it in any. While both intuitive and consistent with observations of how individuals act in cooperation-game experiments,[64] these results contradict certain game-theoretic predictions concerning treaty participation.[65] Another effect of increasing *Global damage cost* is enhancing the effectiveness of conditional commitments, and thus somewhat reducing the need for club-good benefits. The reason is that the higher marginal returns from cooperation increases conditional commitments' leverage.

Varying the value of *Vulnerability weight* results in smaller changes than those obtained when varying *Global damage cost*, indicating that for participation rates, the mean damage cost matters more than the variance. Changing *Vulnerability weight* has a non-linear effect on participation and the sign of this effect depends on who the enthusiasts are.

Including non-climate relations

Our baseline model omits all relationships outside the climate change mitigation domain. While useful for a transparent first assessment of clubs' potential, this simplification overlooks the complexity of international relations. We now explore to what extent our results change when we include political costs and benefits derived from actors' bilateral relationships concerning trade, similarity of policy preference expressed in voting in the United Nations General Assembly (UNGA), and militarized interstate disputes (MID). We limit this analysis to relations among the top 10 emitters, who have emerged as the main drivers of our results thus far.

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[64] Ambrus and Pathak 2011.

[65] For example, our result contradicts the prediction that a positive shift in the cost of making a contribution will cause the the level of cooperation to increase (Barrett 2003 and elsewhere). Experimental results, too, lend very little support to this prediction (e.g., Helland and Hovi 2008).

Strong trade relations may increase the likelihood of climate cooperation. We implement such a relationship by making the club-good benefit a function of a country's trade with other members. Figures 4 and 5 present the results when equation 2 is modified by replacing GDP_m with the share of *i*'s total trade (imports plus exports) that flows to or from member *m.* The Technical Appendix offers further methodological details. Figures 4 and 5 show that the changes relative to our baseline results are few, negative, and mostly small (see the "With trade" column). The reason they are negative is that, in our data, trade flows are somewhat more dispersed than GDP is, so that the largest economies are less dominant than in the baseline – and hence less effective at attracting new club members.

Countries interact in many other issue areas as well, and some of these issue areas will likely involve functional linkages to – or be considered as more pressing than – climate change. In such instances, concerns other than climate change may well influence decisions concerning climate clubs. For example, at a time when the United States and many other countries imposed economic sanctions on Iran to compel its government to refrain from developing nuclear weapons, offering Iran preferential market access in return for joining a particular climate club would probably not be considered appropriate. More generally, we assume that countries are inclined to treat "friends" better than "enemies," other things being equal.

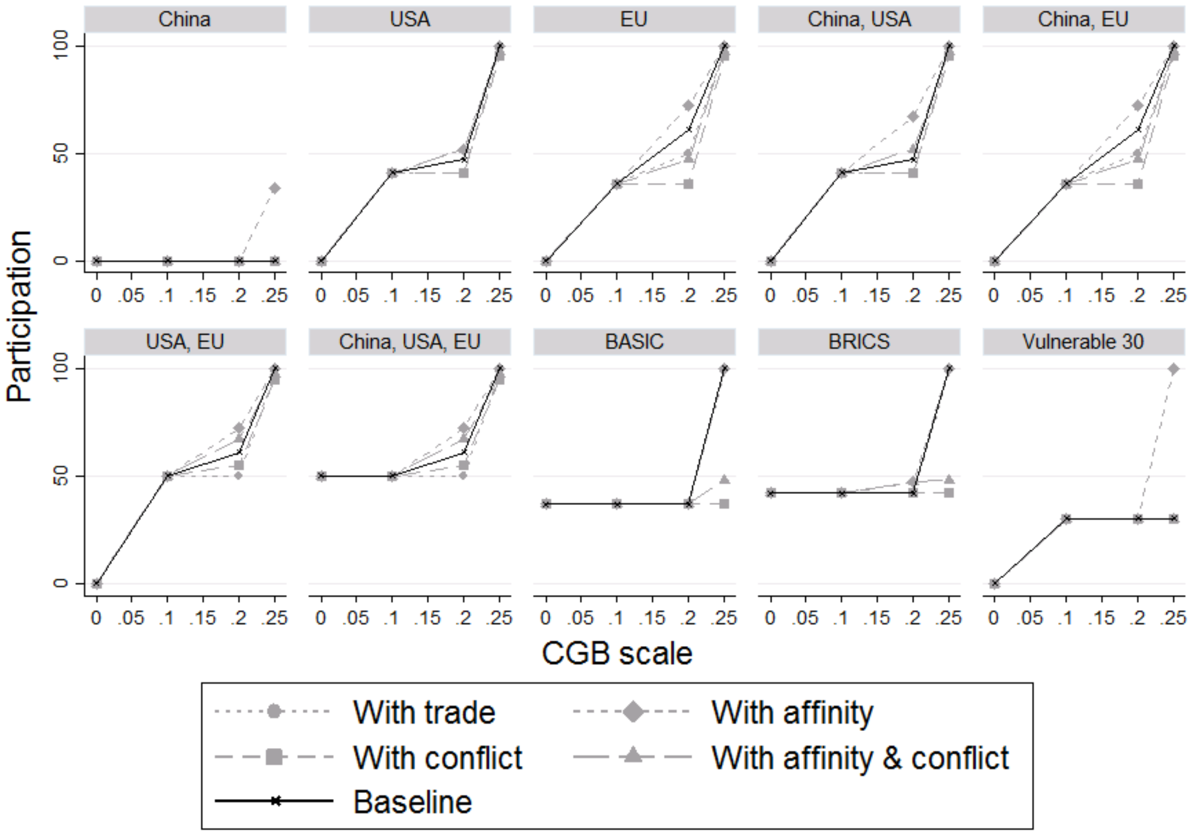
To explore how this inclination might affect our results, we include political benefits derived from bivariate affinity and political costs derived from bilateral conflict relationships for the world's 10 largest GHG emitters. We measure affinity as similarity of voting records in the United Nations General Assembly (UNGA) during the 2005–2014 period. We measure conflict as involvement in Militarized Interstate Disputes (MIDs) with other main emitters during the 2001–2010 decade.

We model affinity and conflict by adding a separate estimate of political benefits and costs of membership. The Technical Appendix explains how we identified 21 affinity relations and 10 MIDs among the top 10 emitters. The relative weights of affinity and conflict are set so that the weighted sum of estimated positive and negative costs equals zero. The weight given to this political calculus relative to other costs and benefits is set (somewhat arbitrarily) so that the club-good benefit increases by .1% of GDP for every "friendly" member and declines by .16–.24% of GDP for every "enemy" member. These political costs and benefits influence outsiders' decisions about joining both directly and indirectly (via insiders' willingness to offer conditional commitments).

Figures 4 and 5 show that including affinity alone has limited effects. Including conflict alone has somewhat larger effects, the main reason being that China has had conflicts with the United States and India. Particularly, deals based on conditional commitments between the major emitters suffer, as seen for $CGB = 0.1$. Another change is that Iran is left out even under the most optimistic club-good benefit assumption. When both affinity and conflict are included, conflict mostly dominates.

Overall, the main results from our baseline model appear robust to the inclusion of bilateral relations outside of climate change. While some point predictions change, the general pattern persists. Because the more complex model increases data requirements and complexity considerably, particularly if extended to all actors, the simpler baseline model seems generally preferable. The effect of including such bilateral relations would increase if these relations were given greater weight in the cost-benefit calculus. Anecdotal evidence suggests, however, that climate cooperation in the presence of conflict (MIDs) is indeed possible and may even be of a format that can make a real difference. For example, China and the United States announced their new mitigation targets to the UNFCCC as part of a bilateral agreement.[66] Moreover, China and India work through the same UNFCCC negotiation blocs.

Figure 4: Sensitivity of simulated participation (% of global emissions). Without conditional commitments.



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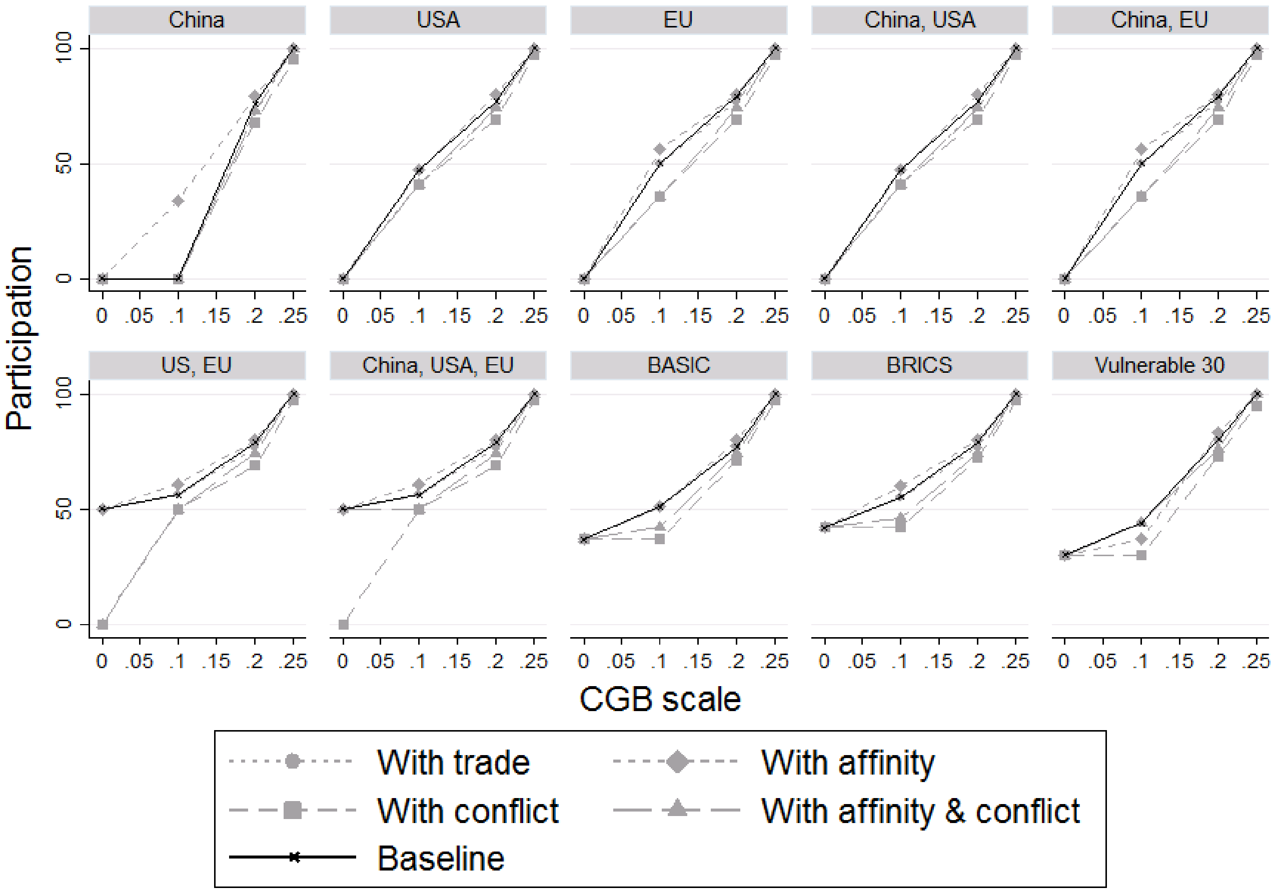
[66] See Goodell 2014.

Figure 5: Sensitivity of simulated participation (% of global emissions). With conditional commitments.



Summary of Results

We summarize our main results in eight points. First, with no conditional commitments universal participation emerges only under very optimistic assumptions concerning the club-good benefits a climate club can produce.

Second, more modest club-good benefits enable some constellations of enthusiastic actors to persist and to induce other top 5 emitters to join. Hence, if club goods can be provided, the prospects for club emergence increase substantially.

Third, without any club good, conditional commitments are effective only under a limited set of conditions. Hence, Weischer et al.'s condition that club success requires club-good benefits largely holds (albeit with a few important exceptions).[67]

Fourth, under a range of conditions, the combination of club-good benefits and conditional commitments facilitates clubs covering the majority of global emissions. Conditional commitments effectively enhance cooperation in the presence of club-good benefits and vice versa.

Fifth, enthusiasm from the United States and the European Union greatly increases a club's prospects. Enthusiasm (as defined in the model) from China is less necessary, because China's strong self-interest in mitigation makes it easier to entice it. Tipping China's own benefit-cost ratio in favor of mitigation seems the only chance small countries have of initiating a viable club. However, that would require a large number of them to act jointly, and would lead to further club growth only under optimistic assumptions about club-good benefits.

Sixth, higher marginal returns from cooperation (captured through the *Global Damage Costs* parameter) tend to increase participation.

Seventh, indirectly our results also explain why existing club-like arrangements have been no more effective than the UNFCCC has been in mitigating climate change. These clubs neither provide exclusive benefits for members nor make conditional commitments to reduce their emissions further if reluctant countries join. They might nevertheless serve other useful functions, such as coordinating diplomatic initiatives or creating a conducive setting for raising political

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[67] Weischer, Morgan, and Patel 2012.

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* considered in this paper.

Finally, our main results seem reasonably robust. Including political costs and benefits derived from bilateral relationships concerning trade, voting affinity in the UNGA, and militarized conflicts has only a moderate bearing on them. Likewise, increasing or decreasing the variance of actors' vulnerability does not alter the aforementioned seven results. However, increasing or decreasing such variance sometimes changes *which* actors become club members and affects the abatement cost distribution.

Conclusions

Overall, our results support Victor's advice to build on what enthusiastic and powerful nations are willing and able to contribute. In particular, our results suggest that if one or more major economies were willing to lead and to use a combination of significant club-good benefits and conditional commitments, substantial potential would exist for inducing reluctant actors to follow suit.

Our results also provide additional insights that would be hard to reach through theoretical reasoning alone. For example, we find that if used separately, club goods and conditional commitments are effective only under a restricted set of favorable conditions. By contrast, in *combination* they are effective in a much broader set of circumstances.

A particularly interesting finding concerns the potential role of conditional commitments in reducing GHG emissions. Climate change mitigation is a quintessential collective action problem. Thus, benefits produced through ambitious actors' mitigation efforts cannot be withheld from reluctant actors. However, credible conditional commitments by enthusiastic actors with large emissions can change a reluctant country's cost-benefit balance both by reducing its indirect costs of climate action and by increasing the climate benefits of its mitigation efforts (through triggering additional mitigation efforts by others). Since the overarching purpose of a climate club is to provide a pure public good, the members will benefit from broadening membership. Moreover, since the actors most likely to respond positively to current club members' conditional commitments probably will share the founding members' general concerns about the impact of climate change, agreement on how much each actor will contribute to mitigation efforts should be easier to reach in a club setting than in the setting of UNFCCC global conference diplomacy. A climate club can also circumvent the least-ambitious-party logic of the UNFCCC; in particular, it can implement ambitious climate mitigation without having to obtain the consent of the UNFCCC's most reluctant parties.

Model fit with the "real world"

Our ABM provides an innovative and empirically grounded formalization of climate club dynamics. Nevertheless, modeling involves simplification, and some of the conditions for climate clubs to emerge and grow posited by our ABM are not currently fulfilled in the real world.[68] Readers are therefore advised to interpret our results as indicating the prospects for effective club-based climate change mitigation under relatively favorable conditions. Below we call attention to four assumptions that, at least when seen together, tend to underestimate challenges in developing effective climate clubs

One is the assumption of no carbon leakage (see p. 18). In the real world, the risk of carbon leakage will vary with, inter alia, the size and composition of the club. At the founding stage, some industry and business companies in the few countries involved may well be tempted to take advantage of lower taxes or other privileges in non-member countries. If the club grows, such temptations will in most instances decline. Yet, by not incorporating carbon leakage as a possibility our model seems overly optimistic, at least with regards to the founding stage. In further development of our model this bias calls for attention.

Second, our model assumes that all conditional commitments are fully credible and instantaneously actionable. This assumption is no doubt overly bold and since credibility is vital for conditional commitments to work, plausible modifications could further enhance the model's real-world relevance.

Third, our model assumes no problems concerning compliance. While this assumption seems plausible for enthusiastic countries, reluctant country members might be expected to drag their

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[68] Nordhaus 2015.

feet in fulfilling their membership requirements. If so, the enthusiastic countries may incur additional costs.

Finally, while 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.[69] Further model refinements could explicitly include aspects of domestic politics, for example the roles of veto players and winning coalitions.

To balance the picture, we should add that a couple of our other assumptions likely err on the side of caution. One of these assumptions says that climate change mitigation will have no (positive) side effects for the country involved. This is not correct; in several countries, China being a good example, positive side effects (co-benefits) sometimes seem to be the main driver of mitigation measures. Our main model also assumes that neither friendship nor hostility affects countries' willingness to cooperate with each other in a climate club context. However, our sensitivity tests indicate that at least involvement in military disputes can make a difference. Another study, focusing on the field of international political economy, reports that cultural similarity is "consistently important in explaining policy choice."[70]

Other potential extensions

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[69] Mayer 1992; Putnam 1988.

[70] Simmons and Elkins 2004, 186.

Several other extensions and refinements could help further improve the model as a research tool. First, the model does not include *adaptation* to climate change. We believe that clubs can contribute also as tools for enhancing adaptation but the results reported here cannot be generalized beyond mitigation.

Second, we do not incorporate timing in the estimates of damage costs and abatement costs. Damage costs will likely become greater the longer it takes to address emissions, while abatement costs may fall over time as a result of technological development. If so, clubs that fail to form initially may become viable later.

Third, our notions of costs and benefits might be further developed to include, for example, transaction and transition costs or *indirect* effects more generally.

Fourth, most policymakers and stakeholders care about distributive (and procedural) fairness.[71] The model could be extended to include fairness principles by, for example, treating norms as "filters" excluding policy options that clearly fail to meet one or more of these principles.[72]

Fifth, game-theoretic models suggest that side payments can drastically increase mitigation when actors are strongly asymmetric.[73] In contrast to conditional commitments, side payments work through offering benefits *exclusively* to potential entrants. An extension of the model therefore includes side payments.[74]

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[71] Dannenberg, Sturm, and Vogt 2010.

[72] Underdal and Wei 2015.

[73] Barrett 2003.

[74] Sælen 2016.

Sixth, trade restrictions constitute another potential instrument for incentivizing membership. Nordhaus[75] found that import tariffs can sustain an equilibrium with high levels of cooperation. However, as mentioned, he does not model club growth. We have found that positive trade incentives can facilitate club growth. Thus, it seems plausible that negative trade incentives could do so, too; however, further studies are required to establish whether this intuition is warranted.

Finally, the kind of analysis reported here may provide inputs to further refinement of general club *theory*. In particular, it may serve as a basis for further clarifying the relationship between the goods provided by voluntary clubs and the instruments available for recruiting new members. As indicated above, the role of conditional commitments in enhancing the supply of public goods will depend on – among other things – the exact nature of these goods.[76] This reasoning could be extended to, for example, further analysis of the interplay between club goods, conditional commitments, and side payments in alternative club settings.

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[75] Nordhaus 2015.

[76] Olson 1965.

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Technical Appendix

This appendix provides a complete technical description of the model expressed through equations and pseudocode, plus supplementary information that would not fit in the main manuscript. The model code is available from the authors upon request.

1. Model Parameters and Variables

Table A.1. Model parameters and variables

Variable or parameter	Explanation	Measurement units
Global input parameters		
CGB scale	Scaling factor for exclusive club good. See Table 1 (in the main text) 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 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). $\in[0,1]$	-
$Enthusiast_i$	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*.	$\frac{\%\ of\ GDP_i}{\%\ of\ GGP}$
$Expenditure_i$	Member *i*'s expenditure on mitigation. Without conditional commitments, it is always equal to *Club fee*. A conditional commitment raises it above *Club fee*.	% of GDP_i
Benefit from $expenditure_{ji}$	The benefit to *j* of *i*'s mitigation expenditure $Global\ Damage \times Vulnerability_j \times Emissions_i \times \sqrt{Expenditure_i}$ Implies that domestic expenditure (abatement cost) is a quadratic function of mitigation. Benefits are proportional to *i*'s share of global emissions.	% of GDP_j
Marginal benefit from $expenditure_{ji}$	The first derivative of the above with respect to $Expenditure_i$ $\frac{Global\ Damage \times Vulnerability_j \times Emissions_i}{2 \times \sqrt{Expenditure_i}}$	% of GDP_j

Club benefit$_i$	The exclusive club-good benefit earned by member *i.* $CGB\ scale\ \times \ln\,(\sum_{m\neq i}^{members} GDP_m)$	% of GDP$_i$
Benefit of entry$_i$	The private benefit of becoming a member equals club benefits plus the privately captured benefits from own mitigation expenditure of 1% of GDP (in terms of damage costs avoided). $Club\ benefit_i + (Benefit\ from\ expenditure_{ii} \mid Expenditure_i = 1)$	% of GDP$_i$
Club benefit(+j)$_i$	The exclusive club good benefit earned by member *i* if non-member *j* joins. $CGB\ scale\ \times \ln\,(\sum_{m\neq i}^{members} GDP_m + GDP_j)$	% of GDP$_i$
Benefit from expansion$_{ji}$	The benefit to member *i* if non-member *j* joins equals the increase in the club-good benefit plus *i*'s benefit from *j*'s mitigation. $Club\ benefit(+j)_i - Club\ benefit_i + (Benefit\ from\ expenditure_{ij} \mid Expenditure_j = 1)$	% of GDP$_i$
WTP$_{ij}$	Additional expenditure *i* is willing to undertake to induce *j* to join $\frac{Benefit\ from\ expansion_{ji}}{1 - Marginal\ benefit\ from\ expenditure_{ii}}$ The denominator captures that *i* will enjoy a marginal benefit from its own additional effort, which increases its willingness to make such efforts.	% of GDP$_i$
Benefit from conditional commitments$_j$	The sum of benefits to *j* from members' *WTP*$_{ij}$ $\sum_{i=1}^{Members} WTP_{ij} \times Marginal\ benefit\ from\ expenditure_{ji}$	% of GDP$_j$
Ratio$_j$	The ratio between *Benefit from conditional commitments*$_j$ and *j*'s net cost of joining $\frac{Benefit\ from\ conditional\ commitments_j}{Club\ fee - Benefit\ of\ entry_j}$	-
Payoff$_i$	*Payoff* incorporates (i) *Club benefit*$_i$, (ii) *Expenditure*$_i$ on mitigation, and (iii) the benefit to *i* from the club's mitigation. For non-members, (i) and (ii) both equal zero. Payoff is normalized to be zero in the no-club scenario. $Club\ benefit_i - Expenditure_i + \sum_{j=1}^{members} Benefit\ from\ expenditure_{ij}$	% of GDP$_i$

2. Model pseudocode

Initialization

```
Each agent $i$:
   Calculate $Vulnerability_i$
   Calculate $Damage\ cost_i$
```

Execution

Step 1

```
Each enthusiast:
   Become member
Loop:
   Each non-member $i$:
      Calculate $Benefit\ of\ entry_i$
      Agent with greatest $Benefit\ of\ entry$:
         If $Benefit\ of\ entry_i > Club\ fee$:
            Become member
                  Else:
            End loop
```

Step 2 (applicable only if conditional commitments are allowed)

```
Loop:
   Each non-member $j$:
      Calculate $Benefit\ of\ entry_i$
      If $Benefit\ of\ entry_i > Club\ fee$[1]:
         Become member
      Else:
         Ask each member $i$:
            Calculate $WTP_{ij}$
         Calculate $Ratio_j$
   Non-member with the largest $Ratio_j$:
      If $Ratio_j > 1$:
         Become member
         Ask other members $i$:
            Increase $Expenditure_i$ by $WTP_{ij}/Ratio_j$[2]
      Else: End loop
```

Step 3

```
Loop until no more enthusiasts want to leave the club:
   Each enthusiast $i$:
      Calculate $Payoff_i$:
      If $Payoff_i < 0$:
         Become non-member
   If any enthusiasts left the club:
      Each reluctant member $i$:
         Calculate $Benefit\ of\ entry_i$
```

---

[1] This inequality could in theory hold when another country has entered because of conditional commitments and hence enlarged the club-good benefit since the last time the country concerned declined to join.

[2] The club's additional mitigation is distributed in proportion to WTP_{im}. Dividing by $Ratio_j$ implies that the members undertake the additional effort necessary to make *j*'s net cost of entry zero.

```
        If Benefit of entry$_i$ < Club fee:
            Become non-member
    Repeat Step 2[3]
Else: model stops
```

3. On sequencing, stochasticity, and stability

In agent-based models (ABMs), a command is executed by agents sequentially (i.e., one agent at a time). The default sequence is random order. In this model, the order in which non-members negotiate with the group can affect outcomes. It seems more realistic that the club will prioritize negotiating with the most likely candidate than that it will choose a random candidate. We therefore code negotiations as the following two-step loop: 1) Identify the candidate with the most favorable benefit-cost ratio for membership 2) Negotiate with that candidate. A negotiation round is defined as one such loop. Step 1 is repeated if and only if Step 2 leads to club expansion. The number of negotiation rounds before membership stabilizes is therefore generally equal to the (equilibrium) number of reluctant actors recruited.

The above procedure effectively makes the model deterministic, eliminating the need for multiple runs for each input vector.

4. List of vulnerable countries

Table A2. The 30 most vulnerable countries included in the model, according to the Notre Dame Global Adaptation Index 2014 (vulnerability scores for 2012). Listed in descending order of vulnerability, by row.

Burundi	Mali	Yemen, Rep.
Sierra Leone	Solomon Islands	Uganda
Afghanistan	Madagascar	Rwanda
Central African Republic	Tanzania	Benin
Togo	Haiti	Angola
Liberia	Guinea-Bissau	Mozambique
Congo, Dem. Rep.	Burkina Faso	Nigeria
Ethiopia	Kenya	Cote d'Ivoire
Guinea	Niger	Papua New Guinea
Chad	Sudan	Cambodia

5. Sensitivity analysis

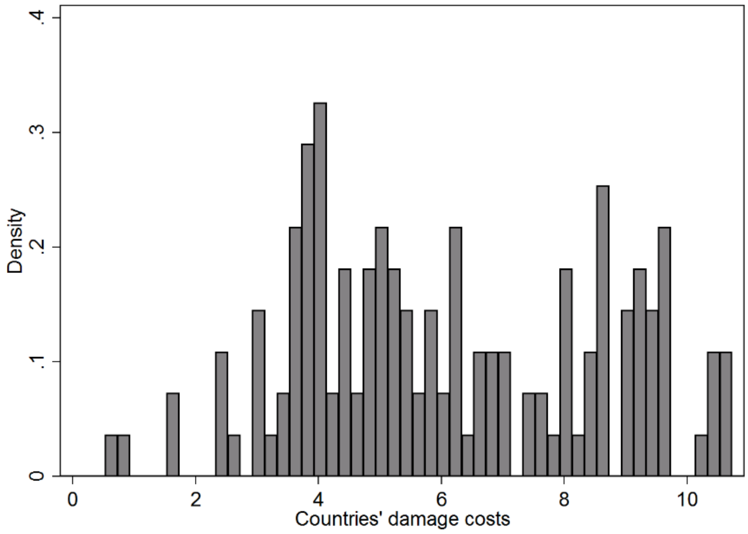
Damage cost magnitude and distribution

Figures A1 and A2 report the sensitivity of our results concerning the magnitude and distribution of damage costs. *Global Damage Costs* are varied by +/- 50% and *Vulnerability weight* is changed from the baseline value of unity to zero (i.e., damages are proportional to GDP as $Vulnerability_i$ equals 1) and 2 (i.e., damage costs are distributed with larger variance, as shown in Figure A1). To keep the number of scenarios manageable, we limit the analysis to four *CGB scale* values (0, 0.1, 0,2, and 0.25).

---

[3] New negotiations start between any remaining members and non-members.

Figure A1. Histogram of actors' BAU damage costs (% of GDP) when *Vulnerability weight* equals 2 and *Global damage cost* equals 3% of GGP.



Reducing the club's effect on climate damage, so that spending 1% of GGP yields benefits of only 1.5% (rather than 3%) of GGP, entails that no coalition persists for a zero or only a small (0.1) club good, with or without conditional commitments.

Figure A2. Sensitivity of simulated participation (% of global emissions) to *Global Damage Costs* and *Vulnerability weight.* With conditional commitments.

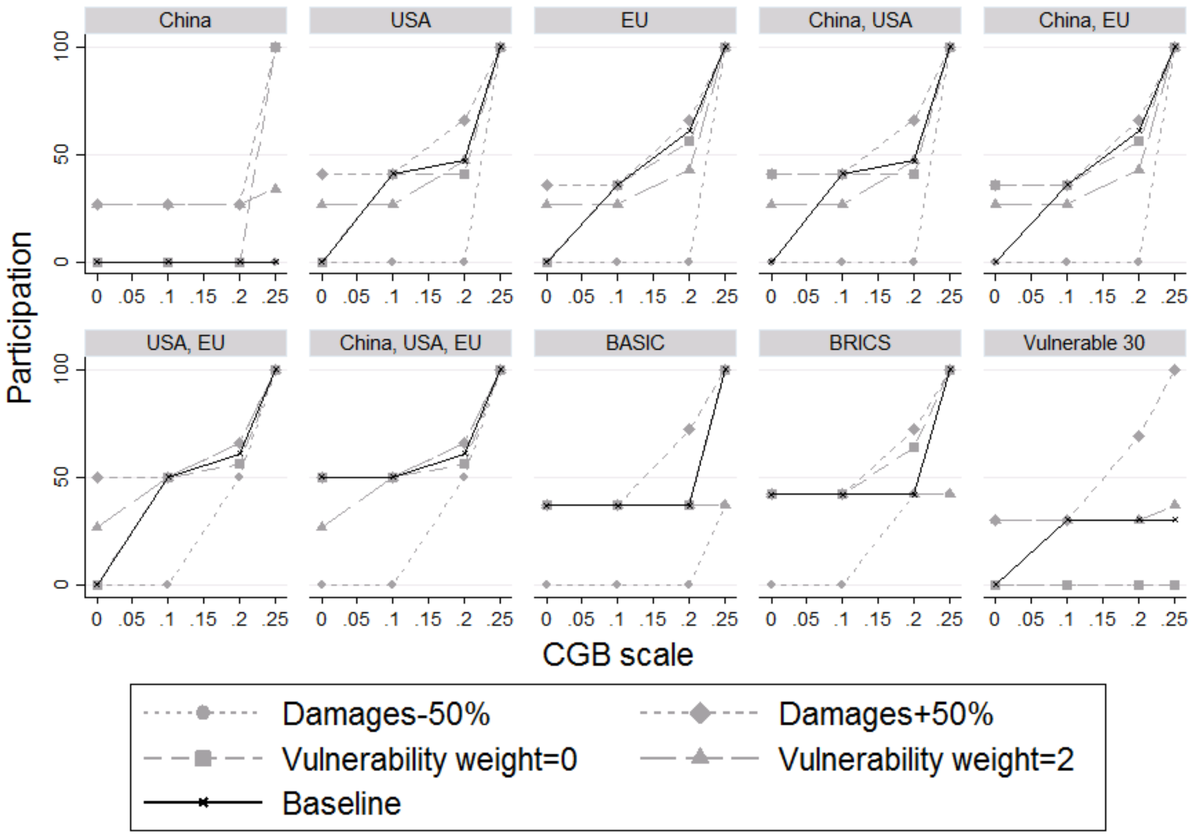
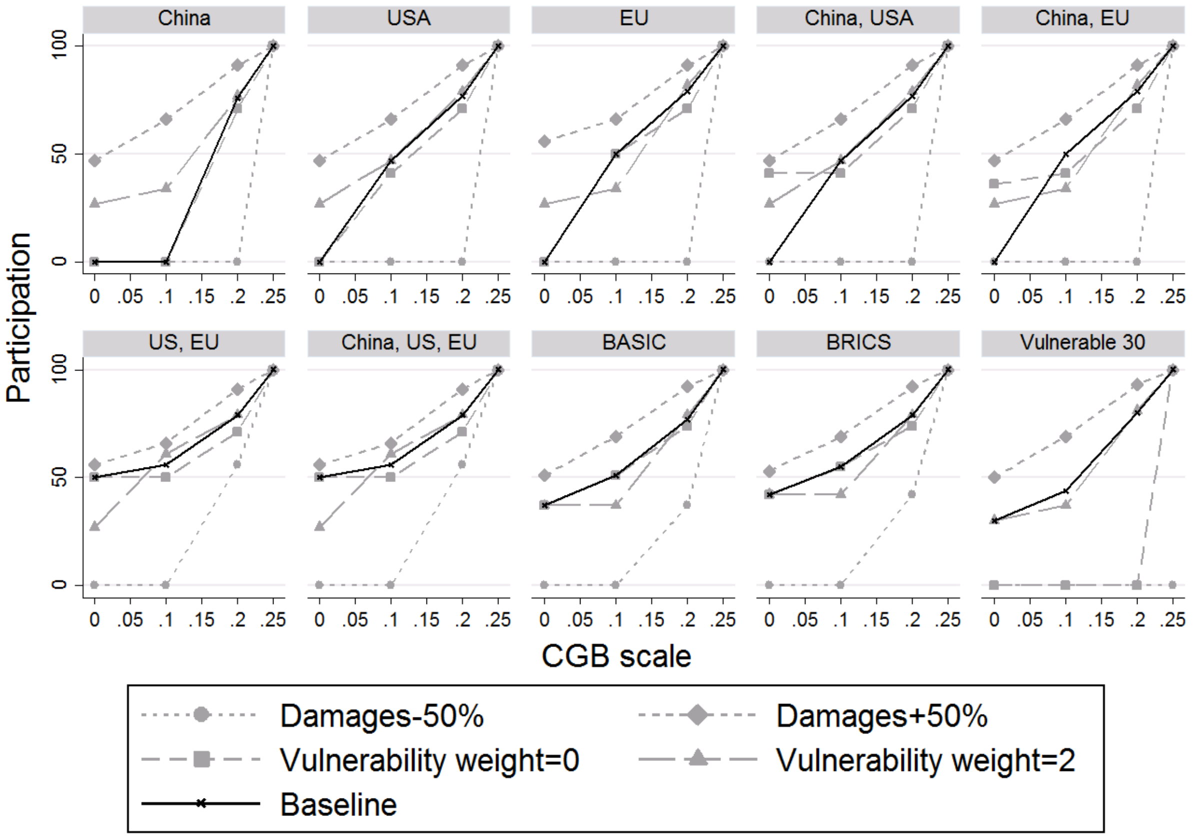


Figure A3. Sensitivity of simulated participation (% of global emissions) to *Global Damage Costs* and *Vulnerability weight.* With conditional commitments.



With an intermediate club good (0.2), only three coalitions persist absent conditional commitments. Conditional commitments facilitate one additional coalition, while enlarging two that would persist even without conditional commitments.

For the largest club-good size (0.25), the reduction in *Global Damage Costs* has less effect, although it reduces participation in two clubs without conditional commitments and eliminates the club based on the Vulnerable 30 with and without conditional commitments. The Vulnerable 30 coalition is hence unable to initiate a club in any scenario with the reduced environmental benefits. This result is due to China's reduced incentive for mitigation. In sum, when the *Global damage cost* is small (1.5%), a large club-good benefit is often a necessary condition for cooperation.

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 a purely selfish incentive for acting *unilaterally*.[4] Second, the conditional commitments' leverage increases; indeed, they now make a difference in most cases – including all cases with zero club-good benefits. An

---

[4] This is a rare instance where clubs can emerge absent enthusiasts. With conditional commitments, participation rates reach 47%, 66%, 91%, and 100% under the respective club-good benefit sizes. Without conditional commitments, other countries join only for the largest club-good benefit size, in which case all join.

exception concerns the most optimistic club-good benefit scale assumed (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 the increased environmental benefit ensures considerable participation even with small (or even zero) club-good benefits.

Varying the value of *Vulnerability weight* results in smaller changes than those obtained when varying *Global damage cost*, indicating that for participation rates, the mean damage cost matters more than the variance. Changing *Vulnerability weight* 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), the mitigation incentives of the European Union and the United States increase (relative to our baseline scenario), while the mitigation incentives of emerging economies decrease. Stronger mitigation incentives increase reluctant actors' likelihood of joining the club. Assuming a more unequal distribution of vulnerability than in the baseline scenario (*Vulnerability weight* = 2) changes relative incentives in the opposite direction, giving China (once again) an incentive for unilateral action because by spending 1% of its GDP on mitigation, it avoids damages to itself worth more than 1% of its GDP.[5]

Overall, the vulnerability distribution has systematic effects on who participates but not on total participation. The vulnerability distribution shows no systematic interaction with the effectiveness of club-good benefits or of conditional commitments.

Trade relations

To incorporate trade relations among the top 10 emitters, we assume that the benefit to two such actors in a club together is a function of the amount these two countries trade. Because trade data is included for only the top 10 emitters, the benefit of being in a club with any other actor is a function of that actor's GDP, as before.

Let *Mt10* be the set of members that are among the top 10 emitters of GHGs (see Table 2), let *Mr* be the other members, and let *n* be the set of all actors. Subscript *ij* denotes a trade flow between countries *i* and *j.* For $i \in Mt10$, Equation 2 is changed to

$$Club\ benefit_i = \text{CGB scale} \times \ln\left(\frac{\sum_{j=1}^{Mt10}\left(exports_{ij} + imports_{ij}\right)}{\sum_{j=1}^{n}\left(exports_{ij} + imports_{ij}\right)} + \sum_{j \neq i}^{Mr} GDP_j\right)$$

As before, *GDP* is measured as a share of GGP. For $i \in Mr$, Equation 2 in the main text remains unchanged.

Data on trade flows involving the European Union have been obtained from the European Commission.[6] All other data are from the OECD.[7] All data are from 2013, with the exception that the most recent data available on Iran is from 2011.

Affinity and hostility (conflict)

---

[5] This is another instance where clubs can emerge absent enthusiasts. With conditional commitments, participation rates reach 27% (China alone), 34%, 77%, and 100% under the respective club-good benefit sizes. Without conditional commitments, only India joins (and it does so only for the largest club-good benefit).

[6] European Commission 2015.

[7] OECD 2015.

The assumption underlying the tests that include affinity and hostility (conflict) is that countries tend to treat friends better than enemies, everything else constant. In a climate club context, this inclination may be expressed in an actor's tolerance of another actor's free riding and/or in its attitude towards differentiation of membership terms. For both dimensions we assume that a country will have a certain zone of indifference, implying that the behavior hypothesized will be found only when affinity/hostility scores *exceed* a certain threshold (see specifications below).

Affinity

To measure affinity, we use Voeten et al.'s UN General Assembly voting similarity index,[8] which is defined as

$$\frac{total\ number\ of\ votes\ where\ both\ states\ agree}{total\ number\ of\ joint\ votes}$$

We use data from the 10 most recent years available (2005–2014), taking the average index scores over this period. Because we treat the European Union as a single actor, and we calculate the (unweighted) average scores across its members. For every actor, we use the average voting similarity with the world (all countries except itself) as a benchmark.

Table A3 lists, for each top 10 emitter, the other top 10 emitters that vote most similarly. For the modelling, we include up to three relations for each actor. We require, as a further criterion for inclusion, that the voting similarity must be at least 10% above the actor's average voting similarity with the world. Relations that fail this criterion are displayed in parentheses. Twenty-one affinity relations are hence included in the analysis. We weight all these relations equally, and assume that there is a political benefit of club membership equal to .1% of GDP per "friend" that is also a member. Hence, *i*'s affinity benefit of being in a club with *j* – denoted $Affinity_{ij}$ – takes the values zero and .1.

The .1% figure is set somewhat arbitrarily and is difficult to ground truth. We deem the non-material benefits created by affinity to be an order of magnitude smaller than the material costs of reducing emissions that club members must shoulder (1% of GDP).We set the figure at the upper limit of what we find to be plausible values, because the purpose is to test our main results' sensitivity to including affinity relations.

The identified relationships largely mirror the general political divide between the G77 and the OECD countries. Historically, this divide has been very important in climate negotiations.

Table A3. High affinity relationships within our sample of main actors, based on United Nations General Assembly (UNGA) voting records

Main actor ↓	**Highest affinity score**	**Second highest**	**Third highest**
Brazil	(Indonesia)	(China)	(Iran)
Canada	EU	Japan	US
China	Iran	Indonesia	Brazil
EU	Japan	(Canada)	(Brazil)
India	China	Iran	Indonesia
Indonesia	Iran	China	Brazil
Iran	China	Indonesia	Brazil
Japan	EU	(Brazil)	(Canada)

---

[8] Voeten et al. 2009. We use the version that includes abstention from voting, counting it as half-agreement with a yes or no vote.

Russia	China	(Iran)	(Indonesia)
US	Canada	EU	Japan

Note: Parentheses indicate that the score fails to meet the > 10% requirement.

Hostility (conflict)

UNGA voting records are sometimes used to measure hostility or conflict levels as well. Doing so here would, however, have blurred the distinction between divergent voting expressing different overall political alignments and divergence expressing truly severe (bilateral) conflict.[9] Since the latter is the more important potential source of “disturbance” for our analysis, we have based our estimates of hostility levels on data identifying and describing *severe* conflict, at the level of “militarized interstate disputes” (MIDs).[10] To qualify as a conflict for this robustness test, we require that two top 10 emitters have been opponents in at least two MIDs during the period 2001–2010. An overview of such conflicts is displayed in Table 2.

Table A4. Conflict relationships within our sample of main actors, based on MIDA_4.01 and MIDB_4.01

“Offensive” actor	Initiator (number of disputes)	Hostility level	Opponent	Initiator (number of disputes)	Hostility level
China	5	2.7	Japan	2	2.1
China	5	2.8	USA	0	2.2
Russia	5	3.4	Japan	0	2.2
USA	4	3.4	Iran	3	2.3
India	2	2.3	China	1	1.7

Table A4 shows that some of these conflicts are *asymmetric* in at least two respects: one of the parties stands out as the initiator of the dispute, and one of the parties (usually the initiator) has higher scores on “hostility level” (~ militarization) of the dispute.[11] Other things being equal, we may expect a party’s offensiveness in a particular MID to reflect (a) its interest in having the opponent change a certain policy or behavior, and (b) a perception of being sufficiently powerful to persuade or coerce the opponent to do so. To the extent that these interests and perceptions “spill over” to international climate change politics, we would expect the asymmetry in MID behavior to be *reflected* in climate club considerations. It may, however, also be *softened* by functional and/or ideological distance between the MID dispute(s) and the climate policy domain.[12] To translate this line of reasoning into a template for differentiating offensiveness scores we have used a two-step procedure:

Step 1: Combining initiator role and level of hostility into an index of *“offensiveness”*

Aspect 1: *Initiator* (counting and weighting a party’s number of MID initiating roles):

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[9] To illustrate, the voting similarity score between the United States and Brazil is almost as low (.25) as that between the United States and Iran (.18).

[10] Palmer et al. 2015. Data available from http://cow.dss.ucdavis.edu/data-sets/MIDs. Since the Dyadic MID Data File has not been updated beyond 2001 we have ourselves extracted information about bilateral relations from the MID files referring to “disputes” and “participants.”

[11] Below we refer to the combination of these two dimensions as “offensiveness.”

[12] For illustrative empirical evidence from another setting, see for example, Kohl and Randall 1991.

0 = 0;   1–2 = 1;   3–4 = 2;   ≥ 5 = 3.

+

Aspect 2: *Level of hostility* (average for all parties 2001–2010 = 2.8):

≤2.3 = 1;   2.4–3.2 = 2;   ≥ 3.3 = 3.

Step 2: Specify *likely impact of offensiveness scores on preferences* (expressed in terms of change in our current GDP measures).

Because we have a moderate number of conflicts and actors to consider, we merge offensiveness scores into a dichotomous distinction between a “low” level of conflict (offensive scores 1–3) and a “high” level of conflict (offensive scores 4–6). In the model runs, “low” = 1 and “high” = 2. Table A5 displays, for each conflict in our sample, the offensiveness score and the conflict level. We assign level 2 conflicts 50% higher weight (importance) than level 1 conflicts. Because we have no basis for assuming that conflict is inherently more important than affinity (or vice versa), and because the two are measured in different terms, we balance the two by requiring that the weighted sums of conflicts and affinities cancel out. This balance is achieved by setting the political cost of co-membership with the opponent of a level 1 (2) conflict to .16% (.24%) GDP. Hence, *i*’s conflict cost of being in a club with *j* – denoted $Conflict_{ij}$ – takes the values zero, .16, or .24.

While several other approaches might be equally valid, the one outlined here facilitates producing a general impression of the effect of conflict on climate clubs.

Table A5. Offensiveness scores and conflict levels of MIDs among the top 10 emitters of greenhouse gases

Offensive party			Opponent (defensive party)		
Country	Offensiveness	Conflict level	Country	Offensiveness	Conflict level
China	5	2	Japan	2	1
China	5	2	USA	0	1
Russia	6	2	Japan	1	1
USA	5	2	Iran	3	1
India	3	1	China	2	1

Inclusion of affinity and conflict in the model code

The following modifications are made to equations from Table A1, with new terms in bold:

$$Benefit\ of\ entry_i = Club\ benefit_i + (Benefit\ from\ expenditure_{ii} | Expenditure_i = 1) \boldsymbol{+ \sum_{j \neq i}^{members} (Affinity_{ij} - Conflict_{ij})}$$

$$Benefit\ from\ expansion_{ij} = Club\ Benefit(+j)_i - Club\ Benefit_i + (Benefit\ from\ expenditure_{ij} | Expenditure_j = 1) \boldsymbol{+ Affinity_{ij} - Conflict_{ij}}$$

$$Payoff_j = Club\ benefit_i - Expenditure_i + \sum_{j=1}^{members} Benefit\ from\ expenditure_{ij} \boldsymbol{+ \sum_{j \neq i}^{members} (Affinity_{ij} - Conflict_{ij})}$$

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