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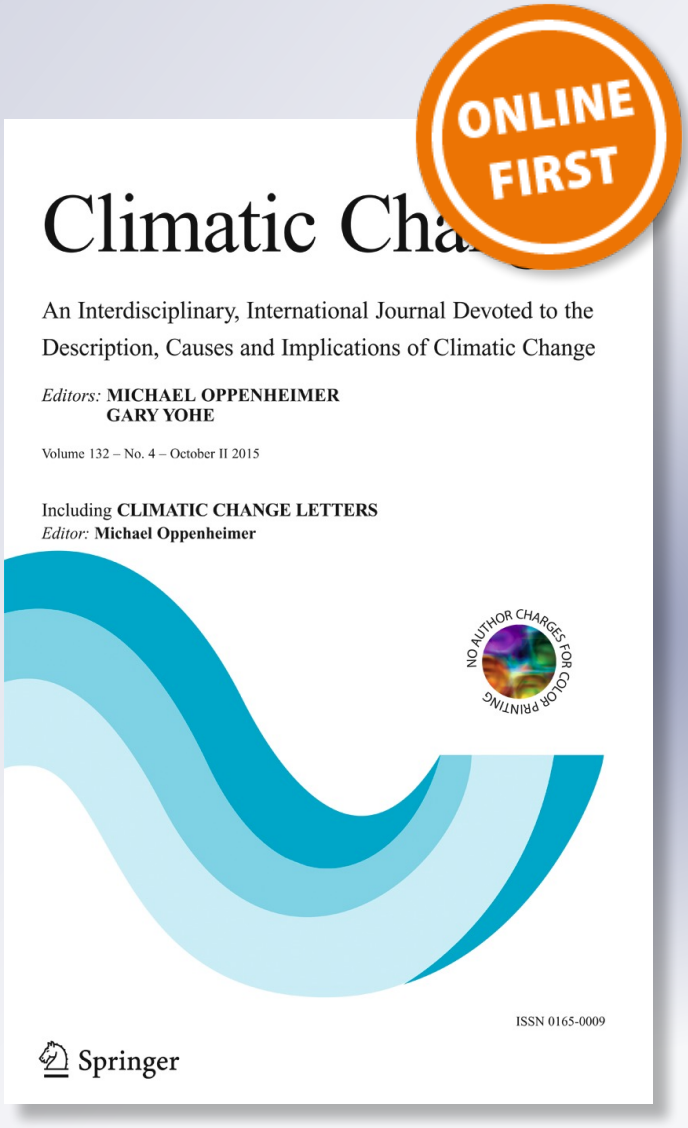

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Incomplete cooperation and co-benefits: deepening climate cooperation with a proliferation of small agreements

Phillip M. Hannam[1] · **Vítor V. Vasconcelos**[2,3,4] · **Simon A. Levin**[4,5,6] · **Jorge M. Pacheco**[2,7,8]

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Abstract Case study and model results lend some optimism for the potential of small coalitions with partially excludable public goods to substantially deepen international cooperation on energy and climate issues. Drawing motivation from other issue areas in international relations ranging from nuclear non-proliferation, transboundary air pollution and liberalized trade, we use an evolutionary-game-theoretic model to analyze regimes that yield domestic incentives to contribute to public goods provision (co-benefits). Co-benefits may be limited, but can create a nucleus for formation of coalitions that grow while deepening provision of global public goods. The Climate and Clean Air Coalition (CCAC) is a prime example of an agreement that employs partially excludable club benefits to deepen cooperation on non-CO_2

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✉ Phillip M. Hannam
phannam@princeton.edu

[1] Science, Technology & Environmental Policy program, Woodrow Wilson School of Public and International Affairs, Princeton University, Princeton, NJ 08544, USA

[2] Applications of Theoretical Physics Group, Centro de Matemática e Aplicações Fundamentais, Instituto para a Investigação Interdisciplinar, P-1649-003 Lisbon Codex, Portugal

[3] Centro de Física da Universidade do Minho, 4710-057 Braga, Portugal

[4] Department of Ecology and Evolutionary Biology, Princeton University, Princeton, NJ 08544, USA

[5] Resources for the Future, Washington, DC 20036, USA

[6] Beijer Institute of Ecological Economics, SE-104 05 Stockholm, Sweden

[7] Centro de Biologia Molecular e Ambiental (CBMA), Universidade do Minho, 4710-057 Braga, Portugal

[8] Departamento de Matemática e Aplicações, Universidade do Minho, 4710-057 Braga, Portugal

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greenhouse gases. Our game-theoretic results support two important insights for the building blocks approach to addressing climate change: sustained cooperation in club agreements is possible even when public goods are not entirely excludable and some members of the population free-ride; and second, cooperation in small club configurations yields larger non-excludable public goods benefits than cooperation in more inclusive forums. This paper lends positive support that a proliferation of small agreements under a building blocks approach at the UNFCCC may be more effective (not just more likely) for deepening climate change cooperation than a fully inclusive approach.

1 Introduction

Problems of collective action rarely achieve optimal results, because of incentives for individual members to free-ride on the public goods provided by others. The initiation of cooperation commonly involves a grouping of cooperators, i.e., the "coalition". In the simplest conception, coalitions will grow when members outside see the costs of joining a coalition as being smaller than the excludable benefit. Benefits resulting from the non-excludable public good provided by the coalition members will be available to members and non-members alike. Coalitions (either peripheral to a regime or within an existing one) can deepen cooperation under either of the following conditions: (a) the coalition's membership grows so to make collective action rational; or (b) coalition members develop sufficient leverage over the non-coalition population to influence their preferences, and thus regime outcomes.

The first mechanism "(a)" requires that the number of coalition participants is sufficiently large. Schelling (1978) discusses the parameter k: the minimum size at which a coalition becomes viable. However, the total number of potential participants, Z, is also significant if the actions of the (Z-k) members undermines or makes irrational the action of the k group (Schelling 1978; see also Snidal 1985 and Hardin 1982). If coalitions that grow to include new members are unable to change the preferences of those they include, then the coalition fails to have increased agency over the issue area.

The second mechanism "(b)", that coalition members gain leverage over external participants to achieve their preferences, is similar to what Barrett (2004, p.395) calls a "tipping effect", using the example of technical standards. Enough countries adopt a standard that it becomes only practical for others to follow, because the dominant technology becomes cheaper (economies of scale), or because the technology becomes necessary to accomplish other goals (network effects).

Examples of incomplete cooperation are common in both nature and human relations, oftentimes sustained by the partially excludable benefits cooperation entails. Nitrogen-fixing plant species, which constitute a surprisingly consistent percentage of flora in several ecosystems, undergo a costly process of symbiotic di-nitrogen fixation, making nitrogen available to both themselves and, eventually, their neighbors, as well as herbivorous predators. Non-nitrogen fixing species (or individuals) effectively free-ride on the fixing species; yet the excludable benefit of nitrogen fixation for the species itself makes fixation a stable strategy, contributing substantially to forest growth and recovery.

Taking a human example, the abolition of slavery proceeded in an uncoordinated manner, with Britain outlawing slavery in 1833, some 32 years before the United States banned the practice. With economies and international competitiveness tied to holding of slaves, abolition was considered akin to "econocide" in the U.S. and West Indies, at least in the view of some

scholars (Fogel 1989). The co-existence of slave and non-slave states within the U.S. throughout the 18th and 19th centuries is another example, despite the practice being at the "peak of economic success" when finally abolished federally (Fogel 1989). Abolishing the Atlantic slave trade was a mutli-decadal and incremental process plagued by defection (Du Bois 2007). The elimination of slavery in Europe was ultimately driven by anti-slavery advocacy groups that pushed the political calculus toward abolition (Keck and Sikkink 1998). These same groups used Britain's moral authority to pressure the U.S. toward the same goal. The economic case for abolition would have been clearer if all competing economies had undertaken coordinated action to abolish slavery, though had the problem been framed in this manner one could conceive that abolition may never have happened.

Framing climate cooperation as a prisoner's dilemma makes a universal and binding agreement the optimal governance regime. But unilateral and multilateral action – however modest at present – is not atypical. Even the Montreal Protocol, hailed as the only international treaty with universal participation, started as an incomplete agreement. Some incomplete agreements are doomed to stagnate, such as the Kyoto Protocol (Frankel 2007; Aichele and Felbermayr 2012). Nonetheless, the European Union has adopted ambitious carbon mitigation targets and policies, and did not back down despite defection from the Kyoto Protocol by Canada, failure by Japan, New Zealand, and Russia to accept second commitment period targets, and refusal by the two largest global emitters China and the U.S. to participate meaningfully in the treaty (Victor 2006). Within the U.S., over 1000 cities have committed to local efforts to achieve emissions reductions in line with the U.S. Kyoto targets had they been adopted, growing from 141 cities when the initiative began in 2005 (U.S. Conference of Mayors 2009). Sub-national cap-and-trade schemes such as the Regional Greenhouse Gas Initiative (RGGI) in the eastern U.S. also sustains substantial participation, despite failure of some major states (Pennsylvania) from joining, and others leaving the Initiative altogether (New Jersey). The U.S. and China in November 2014 jointly committed to emissions plans with the expectation of stimulating more ambitious action by other nations.

These motivating examples of growing coalitions are rather typical of many governance regimes that provide important global public goods. Under what conditions could the building blocks approach (an instance of incomplete cooperation) lead to sustained, and deepened, cooperation on climate change?

This paper first draws motivation from a number of models of incomplete cooperation in international organization and governance. As with climate change, these issue areas have attempted, and failed, to sustain cooperation with near-universal participation but found greater success through clubs or coalitions. Here, clubs produce excludable benefits for participants – as is the standard conception of clubs in economics (Buchanan 1965) – but they also generate non-excludable public goods spillovers for non-club members. The cases examine the power of the G10 and G7 in pressing for stricter global financial standards, the incremental growth and growing influence of the Nuclear Suppliers Group in limiting the export of dual use nuclear technology, the liberalizing effect of concessions by small groups of countries for the trade regime, and the normative impact of informal ministerial settings for reducing pollution in the North Sea.

Though not an intentional factor in case selection, each case incorporates elements of the building blocks approach proposed by Stewart et al. (2013), including exploiting homogenous interests by subsets of countries with co-benefits for public goods (club strategy), using smaller existing institutional settings to reduce coordination costs (linkage strategy), and efforts by the largest actors in the system to strongly influence regulatory norms according to their interests

(dominant market actor strategy). Just as the building blocks approach represents a complement to the broader multilateral UNFCCC process, so too do many of the cases in this paper interact with an international organization with more universal participation. For instance, cooperation outside the Non-Proliferation Treaty by the Nuclear Suppliers Group and the International Monetary Fund by the Financial Stability Forum was critical to deepening cooperation in these broader multilateral forums.

The structure of these examples motivates the second part of the paper, which is an evolutionary-game-theory model of incomplete cooperation. Cooperation evolves in coalitions that provide members – conceived as nations or sub-national actors – with goods that are only partially excludable. The public goods games themselves are motivated by excludable benefits of cooperation, though it is the public good spillover that has benefits for the climate. Lending support to the building blocks approach, we find that an international regime organized around smaller, overlapping, coalitions with partially excludable benefits for members achieves deeper cooperation than a more inclusive regime, when cooperation is incomplete.

The final section concludes with discussion of the paper's implications for deepening climate cooperation within and outside the UNFCCC.

2 Building blocks approach in international politics

A coalition may form as a part of a broader regime or issue area to deepen cooperation where it was unattainable with a different or broader composition of members. Particularly for issues like climate change, an interacting ecosystem of agreements, coalitions, and initiatives across multiple levels of governance is more likely than a single comprehensive regime with universal participation (Keohane and Victor 2011; see also Ostrom 2010, 2012 and Cole 2011). Overlapping institutions with varying memberships allow subsets of countries to learn and change their preferences in one institution, which can have spillover effects in other institutional settings.

Incomplete agreements are commonplace in international relations, and may provide important public goods. Regional trade agreements, for instance, have proliferated in global efforts to reduce trade barriers, where cooperation is feasible because the number of actors is low and actions are targeted. Many security arrangements, such as the North Atlantic Treaty Organization, are also organized as clubs because of the excludable benefits that membership entails.

There are economies of scale as the size of a regime increases. The costs of administration decline and availability of information grows. But if the regime grows too large, diverse interests can overwhelm the system with complexity, and transaction costs can make agreement impossible. Conversely, a coalition that is too small may be devoid of leverage. For example, small climate agreements alone may fail to capture a sufficient share of global emissions to avoid dangerous thresholds. Unilateral action in small coalitions may be irrational because of non-excludability of climate protection and competition with non-coalition members. International relations (IR) offers several models for overcoming these challenges to sustain international cooperation.

According to the realist tradition of IR, cooperation is a public good that is only feasible when a single dominant actor is willing and able to provide it. This builds on the observation that members with much to gain from a public good in the international system will tend to be exploited by smaller members — the "systematic exploitation of the great by the small" (Olson

1965, p.29). Dominant-actor models have also been discussed in the context of market regulation (the California effect) and in climate change proposals to leverage large market actors to influence regulatory norms (Stewart et al. 2013). The Montreal Protocol fits in this model, given the coherence of interests between the U.S. and its industrial lobby in seeing the growth of a market in non-CFC chemicals. The dominant actor(s) pursuing their own interests provide non-excludable spillovers in the process.

Drawing on work with biologist William Hamilton (Axelrod and Hamilton 1981), Robert Axelrod (1984) studied the conditions under which cooperation can emerge when individuals follow their own interests, without central authority, and through repeated interactions. Axelrod explains how the "live-and-let-live" system in trench warfare emerged during World War I through reciprocal recognition of the opponent's leniency. Even cooperative arrangements intended to facilitate short-term exploitation of mutual gains need not be short-lived. Writing about the hegemonic model of cooperation in the realist tradition, Robert Keohane (1984) notes that "even after the conditions that facilitated their creation have disappeared: regimes acquire value for states because they perform important functions and because they are difficult to create or reconstruct" (p. 14). The choices of one large actor in the system can drive others to adopt the same choice, either because mimicry avoids the cost of coordinating with the large actor, or because mimicry avoids paying the cost of developing a separate system (Barrett 2004).

Coalitions can be conceptualized as the construction of a hegemonic (or dominant) actor in the system or as a means to create one. Coalitions can mobilize resources and pressure others to cooperate. The hegemonic stability model is conceptually equivalent to a co-benefits approach, where provision of a public good becomes the rational choice simply because of the excludable share of benefit from its provision. Thus the building blocks model of climate governance is not new to studies of other issues in international politics.

3 Motivating coalitions and co-benefit structures

Four examples of transformative coalitions illustrate the power of incomplete agreements to influence short and long-term provision of important public goods including global security, financial stability, and transboundary pollution mitigation. The role coalitions played in deepening cooperation allows for identification of common elements of successful regimes while simultaneously demonstrating the broad application of the building blocks approaches.

3.1 Club case: Financial Stability Forum in implementation of global financial standards

The U.S. and E.U. used small club settings in the late-1980s and 1990s to strengthen global financial standards and prevent systemic instability in global financial markets. The implementing countries sought to propagate the standards internationally to shore up the competitive positions of their domestic firms. By threatening market closure and sanctions for non-complying states, the club was able to leverage its dominant role in global markets to promote global adoption of the standards.

The rapid globalization of financial capital flows in the 1980s increased systemic risk in the financial sector and handicapped financial regulators from ensuring the soundness of activities by national commercial banks. Interests in financial regulation balance competitiveness of

domestic industry faced by less-regulated foreign institutions against the stability of markets where domestic firms operate (Helleiner and Pagliari 2011). Stability is provided through consistent international regulation, but raising standards through the International Monetary Fund (IMF) was prohibitive because of norms around unanimity (Drezner 2008). Regulation was viewed as a major benefit to investors in advanced economies where the security of overseas assets far exceeds the transaction costs of coordinating on standards. Developing countries, meanwhile, preferred less regulation as this allowed the short-term attraction of profit-maximizing firms, despite the long-term risk (Drezner 2008). Given this asymmetry of interests, the major economies looked beyond the IMF and toward a club setting.

International financial standards were adopted by the G10 through the Basel Accord in 1988. Some consider the creation of these standards by a club of countries as a provision of a global public good (Kapstein 1989; Morris and Shin 2002). Others have challenged this account; the U.S. could have reined in its commercial banks from risky behavior with unilateral domestic legislation, but would protect its competitiveness if other international banks joined along, particularly emergent Japanese competitors. Thus the U.S. and U.K. (which already had higher financial standards) forged a bilateral agreement and threatened to impose the regulation on firms operating in the U.S. and U.K. markets if the G10 (including Japan) did not adopt a similar multilateral agreement (Oatley and Nabors 1998).

The club approach was used again following fallout from contagion during the Asian Financial Crisis in 1998. The U.S. and E.U. wanted to strengthen financial regulations but were outnumbered by under-regulated states, making progress impossible at the UN General Assembly and IMF. Instead, the G7 initiated the Financial Stability Forum (FSF) as a "club among clubs" formed from representatives of existing institutions and regulatory bodies that were heavily weighted toward the interests of the G7 countries (Drezner 2008, p.136). Through tacit threats of sanctions by the G7, within a few years nearly three quarters of under-regulated countries made substantial revisions to their regulatory standards.

3.2 Club case: Nuclear Suppliers Group

The Nuclear Suppliers Group was formed in 1975 by a group of seven countries to strengthen export controls for technology that could be used in the production of nuclear weapons, thus strengthening global nuclear security (a non-excludable public good). As the exclusive suppliers club has grown, it has influenced the adoption of higher standards in global nuclear institutions, despite defections and nuclear export potential outside the regime.

The Nuclear Non-Proliferation Treaty (NPT) entered into force in 1970 with the intention to halt the global expansion of nuclear weapons capabilities. The agreement was viewed as a grand bargain by non-weapons states that were promised civilian nuclear assistance in exchange for forgoing nuclear weapons ambitions. The ease with which civilian nuclear technology could be commandeered for military purposes, however, was viewed as the Achilles heel of the NPT.

Fifteen of the NPT members formed the Zangger Committee to clarify ambiguities in the NPT regarding nuclear technologies that would "trigger" review by the International Atomic Energy Agency (IAEA). The insufficient protections of the NPT and Zangger Committee became evident when India tested a nuclear explosive device in 1974 (Nye, in Carnesale and Haass 1987). The U.S. and U.K. sought to strengthen export safeguards, but had to go beyond the Zangger Committee because important nuclear exporters (France and Japan) were not NPT members. The U.S. and U.K. involved France and Japan, as well as Canada, the Federal

Republic of Germany, and the Soviet Union to form the Nuclear Suppliers Group (NSG) in 1975. The NSG adopted export controls that applied to all non-weapons states regardless of their NPT membership (Strulak 1993).

NSG members sometimes face economic and political incentives to export nuclear technology. Such a defection from the NSG occurred with the transfer of nuclear technology from France and the U.S. to Israel, and with Russia protecting export relationships with Iran and India (Anthony et al. 2007). Countries outside the NSG including India, Iran, Israel, North Korea, and Pakistan have the capability to export nuclear equipment and raise competitive industrial interests among the NSG members. Where possible, the NSG minimizes incentives for members to defect by bringing potential competitors into the regime. But this creates a tension between growth and stringency as expansion makes consensus decision-making more burdensome and generates more internal variance in preferences (Anthony et al. 2007). NSG membership entailed status as a responsible technological leader. China sought membership in the NSG in 2004 in an effort to become party to the group that was, by that time, the principal rule-setter in issues of nuclear export and trade (U.S. House of Representatives 2004). By 1977 the group expanded to 15 key players, 26 states by 1991, and 47 by 2007.

The NSG is not a regulatory regime, has been delegated no authority over its members, and has not been used as a forum for seeking sanctions against non-members. Nonetheless the group carries the weight of a governing body, capable of making collective decisions, such as supporting the export of equipment to India for civilian nuclear power in 2008. NSG control lists were references for UN Security Council decisions regarding trade restrictions with North Korea and Iran. Despite challenges, the group is a durable cooperative success outside any binding or inclusive international forum.

3.3 Club case: "bridge club" within the trade regime

Early multilateral trade agreements in the General Agreement on Tariffs and Trade (GATT) and World Trade Organization (WTO) tended to result from concessions agreed in bilateral and club settings and then propagated more broadly. Winham (1986) describes trade liberalization as "pyramidal", where concessions were agreed by major powers at the top and later multilateralized. Free trade zones are essentially a complex regime with hundreds of overlapping bilateral, plurilateral, and regional trade schemes which complement and enhance the GATT/WTO.

In the years leading up to the Kennedy Rounds under the GATT starting in 1964, several of the major global economies were interested in trying a "linear" approach to reducing tariff barriers. Instead of line-by-line haggling over tariff reductions, which was perceived by major powers as stagnating in effectiveness (Norwood 1969), the linear approach applied the same percent reduction for all tariffs across-the-board for participating countries (Rehm 1968). Linear cuts had been under discussion in the U.S. and Britain for years, and slowly gained traction in France and the Benelux countries. The European Economic Community extended any cuts to all member nations, but was hesitant of U.S. proposals for linear cuts. Canada and Japan were similarly initially cautious of liberalization that did not allow exceptions (Norwood 1969). By allowing limited exceptions, the U.S., Japan, Finland, U.K., Austria, Denmark, Norway, Sweden, Switzerland – and to a lesser extent Canada – agreed to follow the linear rule.

Linear-rule nations, known as the "bridge club", undertook closed negotiations to achieve fifty percent reductions in barriers. Upon opening the negotiations to non-bridge club nations,

the bridge club members saw "no reason to justify their exceptions to countries which had not obligated themselves to the same rigorous rule" (Norwood 1969). As negotiations with non-club nations commenced, bridge club members felt entitled to use their "respectably short" lists of exceptions to vigorously challenge non-linear countries' terms, which were far more protectionist (Norwood 1969). Application of the linear rule was voluntary and attracted industrialized countries for which liberalization was in their interests (Winham 1986; Kahler 1992). Nonetheless, it created a cohesive negotiating coalition that resulted in deeper tariff reductions beyond the bridge club members (Norwood 1969).

3.4 Club case: "International North Sea Conferences" in the North Sea regime

The legally-binding Oslo (1972) and Paris (1974) Conventions, known collectively since 1992 as the OSPAR Convention, sought to reduce ship, aircraft and land-based pollution among European countries in the north-east Atlantic. Achieving significant cooperative agreements on the North Sea, seen as a particularly pressing area of environmental concern, was hobbled by these conventions' unanimous consent requirements. Non-North Sea states including Spain and Portugal, which had little interest in North Sea pollution, and the U.K., which was the largest North Sea polluter, objected to stronger binding protections. To increase ambition despite objections from laggards, in 1984 Germany initiated ministerial-level "International North Sea Conferences" (INSCs), which excluded non-North Sea states (Skjærseth et al. 2006). Although the U.K. could still oppose deeper cooperation in the INSCs, the higher-level yet non-binding setting allowed for political commitments with immediate effect. This put diplomatic pressure on the U.K.. The periodic meetings in the INSC setting also increased transparency and led to a series of "far-reaching commitments" throughout the 1980s and 1990s (Skjærseth et al. 2006). Many of these soft commitments were eventually adopted into legally-binding conventions including OSPAR and E.U. rules. Though a number of other factors contributed to the interaction between INSCs, OSPAR, and E.U. rules in North Sea governance, the creation of high-level political expectations in a non-binding forum with control over membership was critical (Skjærseth 2008).

3.5 Case implications for climate change

These coalition examples were non-binding and "bottom-up", forming outside of multilateral forums. Nations with the most to gain domestically in the club setting tended to initiate cooperation, but there were important spillovers for global public goods and deepening of the broader regime. In the FSF, advanced economies were interested in a robust global agreement so to protect their investors holding overseas assets, the NSG nations with advanced nuclear technology created a supplier's "cartel" to have more control over spread of nuclear technology, the "bridge club" could more quickly realize the benefits of trade liberalization in a smaller forum, and the INSCs allowed North Sea nations most interested in stronger pollution controls to escape an unfocused process.

Domestic interests and the excludable share of the public good may have motivated the initiation of cooperation, though growing power – in terms of market share or normative influence – enabled the coalition members to bring other countries into the group, stabilizing the coalition or eliminating free-riding. By controlling their memberships, these coalitions were able to manage incentives better than regimes with broader and less exclusive participation, consistent with club theory (Downs et al. 1998). Experiments with students have shown

that coordination in large groups is improved when groups grow slowly and entrants learn group history and norms (Weber 2006). In the NSG and FSF cases, the club faced a balance between growth (eliminating competitive pressure) and depth (inclusion of actors favoring weaker cooperation). Managing participation at the outset (as in the North Sea and "bridge club" regimes), and throughout the regime's operation (as in the NSG and FSF) enabled coalitions to create and sustain a nucleus of deep cooperation, even in the presence of occasional or repeated defection (as in the NSG case).

The club approach is not without drawbacks. The use of NSG and FSF as forums for rule setting instead of more (albeit imperfect) democratic institutions led to animosities that can spill over to other diplomatic issues. Threats of coercion to expand membership (as in FSF) must be applied with caution to climate change, which is fraught with ethical issues of historical responsibility and development rights. Furthermore, voluntary programs may lack effectiveness (Prakash and Potoski 2007), and not all states will have strong domestic interests in club participation. Nonetheless, operationalization of a co-benefit approach to climate policy, anticipating that different actors have different motivations for action (Rayner 2010), may be the best chance for nations like India to engage seriously in mitigation (Dubash et al. 2013).

The Climate and Clean Air Coalition (CCAC) is an apt example. Established in 2012, CCAC was developed as a complement to the UNFCCC process with aims to use knowledge and financial transfers to facilitate emission reductions in black carbon, methane, and hydrofluorocarbons (non-CO_2 greenhouse gases). CCAC overcomes inter-generational and trans-national free-riding concerns typical to climate change mitigation because of the strong local health and economic incentives to mitigate these short-lived climate pollutants (Shindell et al. 2012). CCAC involves the U.S. and a growing club of developed and developing countries. Club members face no binding obligations, but targeted mitigation projects motivated by local interests have positive global externalities for the climate. For CCAC, the net benefits of participation far exceed the non-excludable public goods for climate stabilization, reducing club members' sensitivity to states that enter the agreement but do nothing. However, this feature also attracts membership, which could lead to decreasing returns as transaction and coordination costs grow.

Excludable benefits can sustain incomplete agreements and are central to both hegemonic stability theory and the dominant actor models of cooperation. The model below examines whether a "building blocks" approach, which fosters a proliferation of small arrangements motivated by domestic benefits, can achieve greater non-excludable global public goods spillovers (i.e., mitigation) than exclusive reliance on a larger, more inclusive multilateral approach.

4 A model of club formation and growth

In this section, we use an evolutionary-game-theoretic model to examine the relationship between the size of coalitions within a building blocks approach, and their ability to deepen cooperation on climate change.

Countries join a coalition intended to promote mitigation, paying a cost c to participate in the agreement (this could be either the diplomatic costs of involvement, or a recurring membership fee). Investments in domestic mitigation c_m are made voluntarily by each country, with no penalty for joining the initiative but not complying. Countries that join the initiative

but do not pay for mitigation are called Members, *M*s, while those that pay for mitigation are called Cooperators, *C*s. Countries uninvolved with the initiative are simply called Outsiders, *O*s.

In our model, only *C*s produce any public goods through their payments toward mitigation, but these benefits (*B*) are only partially excludable. *C*s get a share p of the benefit produced by their paying cost c_m as a domestic co-benefit. The rest of the benefit, a share 1-p, remains to be divided among the players. Because *M*s are part of the initiative through which *C*s produced the benefit, *M*s are entitled to some "club good". The club good is apportioned between *C*s and *M*s according to a share χ. The remaining spillover, 1- χ, is divided equally among all players, including *O*s who simply free-ride on the non-excludable share of the benefit. This component is a pure public good. Equations 1–3, below, represent the payoffs (*P*) for *C*s, *M*s, and *O*s, respectively:

$$P_C = -c_m - c + B\left(\frac{p}{j_C} + (1-p)\left(\frac{\chi}{j_C + j_M} + \frac{(1-\chi)}{j_C + j_M + j_O}\right)\right) \tag{1}$$

$$P_M = -c + B\left((1-p)\left(\frac{\chi}{j_C + j_M} + \frac{(1-\chi)}{j_C + j_M + j_O}\right)\right) \tag{2}$$

$$P_O = B\left((1-p)\left(\frac{(1-\chi)}{j_C + j_M + j_O}\right)\right) \tag{3}$$

Where j_C, j_M, and j_O are the numbers of cooperators, members, and outsiders, respectively, and B is a linearly increasing function of j_C.

We think of the excludable component of the benefit created by a coalition as "club goods". Traditional conceptions of "clubs" in economics (Buchanan 1965) analyze clubs as arrangements of optimally exclusive membership and entirely excludable goods (thus, p=1). The possibility for club goods not to be entirely excludable (particularly in the long term, such as with the diffusion of technology) raises possibilities for spillovers as well as free-riding by non-cooperators.

When p=0 and χ=0, all countries share the benefits generated by mitigation equally; in this case mitigation is a pure public good. When $p \neq 0$ and χ=0, *C*s retain a share of the benefit as co-benefits, but *M*s and *O*s share the spillover equally; there will be no *M*s since there is no incentive to pay the cost c of entering the initiative. However, when $\chi > 0$, *M*s retain an additional share of the spillover from *C*s (such as a technological spillover or learning resulting from participation in the coalition).

Next we briefly introduce the evolutionary-game-theoretic approach, though more detailed descriptions can be found in Traulsen et al. (2007), Pacheco et al. (2009), Santos and Pacheco (2011), Vasconcelos et al. (2013), and Vasconcelos et al. (2014). Each country in the system responds to differences between the payoffs they received from their strategies and their observations of the payoffs of others in the system, but subject to informational constraints and errors.

The total amount of benefit produced is a linear function of the number of *C*s in a coalition. In our model, players act homogenously across all coalitions of which they are part. The result of these interactions, which we call fitness, drives their behavior. By defining the size of the coalitions as a function of the number of *C*s and *M*s in the population (of size Z), we are able to reproduce the phenomenon of overlapping institutional settings. Thus, we allow the size of the

interacting groups to be different from the total number of *C*s and *M*s in the population. Let us denote by x the fraction of individuals in the population that participate in coalitions.

We envisage a characteristic core club size, typically small, that is needed before multiple clubs can form. This core club composes a fraction g_m of the entire population. At an initial stage where a significant fraction of the population will comprise *O*s, there will be only one club of the size of the number of *C*s and *M*s. Once the club size reaches g_m, and to the extent that more *O*s join coalitions, we make use of a parameter α to control whether there will be a single club at all times ($\alpha=1$) or whether it will be possible that *C*s and *M*s engage in multiple overlapping club configurations ($\alpha>1$). Finally, whenever all individuals in the population join a coalition (there are no remaining *O*s in the population), we assume there will be one coalition comprising everyone. For $\alpha>1$, as the share of individuals in the population wishing to engage in coalitions grows, coalitions are permitted to get larger as a share of the population size. This model specification allows for the evolution of a governance regime whereby the existence of a single coalition (the early UNFCCC approach) or a multiple-clubs approach (regime complex, polycentrism) is endogenous to the model specifications. In this sense, α conceptually represents a choice between common participation in a single coalition ($\alpha=1$), and a building blocks approach ($\alpha>1$), when there is non-universal interest in cooperation.

Thus, we define a phenomenological relation that establishes the (fixed) size of any coalition in the population as a function of the fraction of individuals in the population engaging in coalitions (x). This fractional coalition size (fraction of the population in any one coalition), n, is given by Eq. 4, below:

$$n(x) = \min(x, g_m + (1-g_m)x^{\alpha}) \tag{4}$$

The behavior of n as a function of x is shown in Fig. 1, below, for $g_m=0.125$ and $\alpha=1$ (*solid line*), $\alpha=2$ (*dashed*), $\alpha=10$ (*dot-dashed*), and $\alpha=100$ (*dotted*).

Players' behavior is based not only on an imperfect imitation process, in which strategies with higher payoffs are more likely to be imitated, but also subjected to random exogenous events unrelated to game payoffs – such as the effect the Fukushima nuclear accident may have

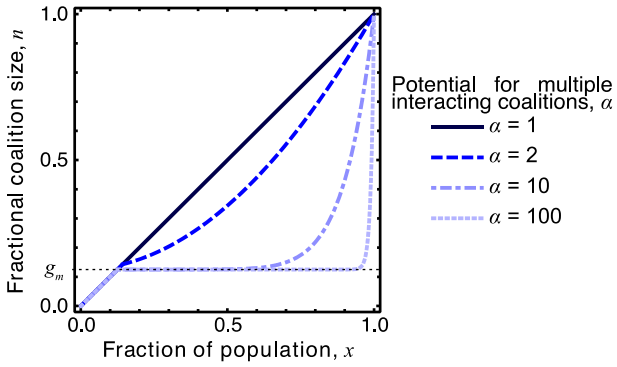

Fig. 1 Model specification relating coalition size and potential for multiple coalitions. The type of interacting regimes that exist in the population (of size *Z*, containing a fraction x of coalition members and the rest *O*s) can be varied by changing the parameter α to allow the occurrence of *i*) a single coalition at all times containing all *C*s and *M*s ($\alpha=1$ *solid line*); or *ii*) multiple overlapping and complementary coalitions of a fixed size ($\alpha=2$ *dashed*; $\alpha=10$ *dot-dashed*; and $\alpha=100$ *dotted*). The larger the value of α, the more constrained the rate of growth of coalition size with x, implying that, for intermediate values of x, individual countries may participate in separate coalitions, and each country may participate in several coalitions simultaneously. The *horizontal dotted line* at g_m represents the fraction of the population needed as a core club before multiple coalitions can form

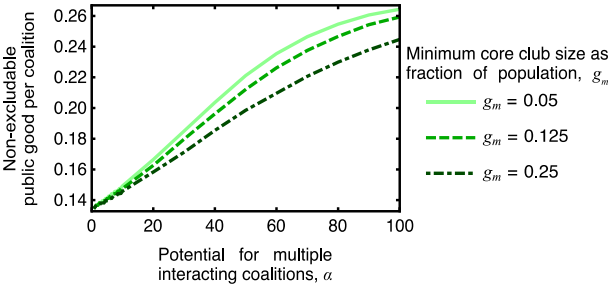

Fig. 2 Model output showing public goods gains for smaller, overlapping, coalitions, with total population Z= 200. Constraining the size of overlapping clubs and reducing the minimum coalition size increases the non-excludable public good produced within each group. The y-axis is the normalized amount of global public good spillover as a fraction of the fully cooperative outcome. The figure represents the average non-excludable public good generated by a single coalition as a function of α. [Here we set each level of spillover to 50 %, given by p= 0.5 and χ= 0.5]

on Japan's position in a climate change regime. This enables us to compute the probability of finding the population in a given configuration in the long run.

The model results indicate that scenarios comprising opportunities for smaller group interactions (where α is large) show substantially larger levels of group cooperation, as shown in Fig. 2, below . Thus the building blocks approach implies a larger non-excludable public good spillover, which is the variable of interest for climate change mitigation. Allowing small coalitions to form (where g_m is small) also leads to greater provision of public goods, particularly where α is large, implying that small groups are also more cooperative.

These results add theoretical support to the case study observation that smaller coalitions tend to be more productive in terms of producing non-excludable public goods spillovers. The result suggests that overlapping institutional arrangements – consistent with the polycentricity and building block concepts – may achieve greater levels of non-excludable mitigation benefits than a large single configuration courting broader membership. Deep commitments under a universal international climate treaty may be the "first best outcome", but this is only the case when agreements are self-enforcing (Barrett 2004). Given the improbability of this outcome, the building blocks structure of climate governance may still produce much greater – if insufficient – cooperation.

5 Conclusions

The demand for cooperative behavior in the international system is high, though designing effective institutions to enable and sustain cooperation is complex. The problem structure of climate change makes it particularly challenging, given demands for sharp reductions in emissions that will be costly, and incentives by individual countries to free-ride on the mitigation actions of others. The diversity inherent in climate change politics complicates efforts to achieve a deep centralized agreement. Despite these challenges, history offers a range of examples where clubs initially composed of a few countries did succeed in cooperating to achieve shared goals despite free-riding risks, but initially motivated by partially excludable club goods. Drawing motivation from these case studies, our model supports the hypothesis that the building blocks approach could lead to deeper mitigation pathways.

This evolutionary-game-theoretic model, while simplifying to homogenous actors with simple preferences and representing an ideal type of agreement formation (bottom-up club growth vis-à-vis top-down inclusive construction), lends some optimism to the potential for small agreements with managed growth to achieve substantial provision of both excludable (domestic) benefits as well as non-excludable public goods.

The model specification through which agreements start small but grow and centralize is conceptually consistent with the stated goals of the building blocks approach. Firstly, though domestic interests that motivate coalitions may be limited in the long term, they nonetheless may catalyze sufficient participation to surpass coordination points that attract outsiders to reap the rewards of fuller cooperation. Secondly, while keeping agreements small may lead to redundancy, it is also likely that overlapping institutions in the sequential construction of an international agreement allows actors to build trust and networks, and exploit synergies that can overcome the eventual challenge of aggregation into a single universal agreement.

Non-excludability of public goods and free-riding does not preclude deep cooperative agreements, though such agreements commonly begin with a proliferation of coalitions. The building blocks approach to climate governance involving multiple interacting coalitions may bode well for the initiation and sustainability of cooperation. The important work for policymakers will be to find issue areas where opportunities for new building blocks exist.

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