CARL VON OSSIETZKY universität OLDENBURG

Oldenburg Discussion Papers in Economics

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V – 387– 16

January 2016

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Transnational Environmental Agreements with Heterogeneous Actors

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Abstract

This paper explores transnational environmental agreements on climate change. As the Paris agreement of 2015 contains no binding emission reduction targets for nation states, understanding other forms of cooperation as complements to the United Nations Framework Convention on Climate Change (UNFCCC) process becomes increasingly important. We thus aim to identify directions for further research on agreements with heterogeneous contracting parties. By building on empirical examples of emerging transnational environmental agreements, and on insights from the global governance literature, we discuss the scope and limits of the current economic literature on international environmental agreements. We argue that further game theoretical research would benefit from extending the analysis (i) to consider actors that are not nation state governments, and (ii) to consider multiple environmental agreements that are in force at the same time. We underpin this claim by suggesting two proposals for economic models that analyze climate clubs and city alliances. The results show that transnational environmental agreements can be individually rational and can improve the effectiveness of climate policies.

JEL-Classification: C72, Q54

Keywords: heterogeneous actors, international environmental agreements, transnational agreements.

1 Introduction

There is unequivocal scientific agreement on the dangerous interference of anthropogenic greenhouse gas emissions with the climate. But efforts to find cooperative solutions on an international level have been mostly unsatisfactory so far. The recent UN climate negotiations in Paris have led to some agreement about global targets, but not about the individual nations' contributions to the global public good. This state of affairs motivates the search for complementary approaches for global emissions reductions. Some suggestions are in the air. For example, some authors think about minilateralism (Eckersley, 2012), climate clubs (Widerberg and Stenson, 2013; Falkner, 2015) or a building blocks approach (Stewart *et al.*, 2013). Lobby groups and NGOs influence climate and energy policy. City alliances grow in parallel to nation state based coalitions. This paper aims at exploring some of such transnational initiatives or patterns of cooperation. Although there has been some research on those patterns in the global governance literature (related to political science), we aim at making this topic conductive for economic analysis, in particular game theory. How can such patterns of cooperation be explained? Can we expect cooperation to be effective?

In this paper we call a contract that stipulates rules for contributions to a global environmental good "transnational environmental agreement" (TEA) if it has heterogeneous contracting parties, i.e. of different type. Parties can be national, subnational, international, or of different quality. Such contracts can be explicit or implicit. They might directly aim at emissions reductions, or only indirectly (e.g. by stipulating monitoring procedures). We chose the term "transnational" to generalize from the established "international" environmental agreement (IEA) framing. Transnational agreements are not undertaken within single jurisdictions (which would not be international either), but the main actors involved do not necessarily need to be national governments (cf. Andonova *et al.*, 2009; Hale and Roger, 2014).

TEAs are not an invention from theory. For example, the C40 Cities Climate Leadership Group (C40, 2015) with more than 80 megacities (from the South and the North) took leadership in signing the Greenhous Gas Protocol for Cities in 2014. As of December 2015, the number of signatories increased to 428 cities (GHG Protocol, 2015). Weischer *et al.*, (2012) map 17 climate clubs, being non-universal and partially overlapping agreements of nation states that cooperate on climate change. In total, 122 countries are members of at least one of those clubs. Some of these clubs include non nation state partners. A first study roughly estimates that non-state initiatives might reduce greenhouse gas emissions by 3 gigatons in 2020 (UNEP, 2015). Although the empirical fact that many TEAs already exist might seem impressive at the first glance, some skeptical questions warrant attention. It is well-known, after all, that global public goods suffer from free rider incentives. So what does actors then motivate to be frontrunners and sign a non-universal TEA? And if they do so by some reason, why shouldn't they not just pretend to reduce greenhouse gas emissions? These questions will be further explored in this paper.

There are only few papers in economic journals that address TEAs, some of which are discussed in more detail below. The theme of city alliances seems to be broadly neglected (but see Sippel, 2010; Millard-Ball, 2012 for some data analysis). Subnational emission reductions are not analyzed, to our knowledge, from the perspective of cooperation between actors from different countries. The exception is the game theoretic literature on environmental agreements that explain non-universal cooperation (more on that below). Studies that admit for multiple climate clubs are sparse (e.g. Asheim *et al.*, 2006; Finus, 2008; Hagen and Eisenack, 2015). National lobby groups are addressed by Dietz *et al. (*2012), Habla and Winkler (2013) and Altamirano-Cabrera *et al.* (2007), but not from a transnational perspective (for a literature review on the political economy of the formation of international environmental agreements see Wangler *et al.*, 2013). Our paper is not intended to fill

all these gaps, but contributes by arguing for the relevance of this research field. It provides structure in transferring insights from global governance research, where much more has been published on transnational climate governance than in economics, to game theory. First, we report on the global governance literature and empirical examples of emerging transnational climate agreements. Then we give an overview of the existing economic literature on the scope and limits of international environmental agreements. Building on these two pillars we follow up with two proposals for game theoretic models. They analyze strategic effects of climate clubs and city alliances as examples for TEAs. We then take a look at the larger picture again and contextualize these approaches in an outlook on promising future research.

2 Current transnational approaches in the global governance literature

This section tears together some selected and documented empirical observations of transnational environmental agreements, and summarizes relevant publications from the global governance literature. Climate clubs can be understood as "Club-like arrangements between states that share common climate-related concerns, and sometimes in partnership with non-state actors such as companies and Non-Governmental Organizations […]" (Widerberg and Stenson, 2013, p. 1). Climate clubs are also coined as 'minilateralism' (Eckersley, 2012). They are currently analyzed in the discourse on fragmented global governance (e.g. Biermann *et al.*, 2009; Keohane and Victor, 2011; Isailovic *et al.*, 2013). This literature acknowledges that there is no monolithic and rational global governance architecture, but a carpet of loosely-coupled international institutional arrangements and regimes, not all being universal but many overlapping. Although they may address multiple issues, their scope can be synergistic, cooperative or conflictive. One set of overarching questions address the conditions under which fragmentation is conducive or detrimental to regime effectiveness (e.g. Gehring and Oberthür, 2008; Biermann *et al.,* 2009).

Weischer *et al.* (2012) analyze existing climate clubs and explore their contribution to climate action as well as the incentives for becoming club members and taking action. Similarly, Widerberg and Stenson (2013) find different types of clubs, from political and technical dialogue forums to country strategy and project implementation groups. Examples are the Asia-Pacific Partnership on Clean Development (2006-2011, including the US and China) and the International Energy and Climate Initiative – Energy + (since 2010, International Energy and Climate Initiative – Energy+, 2015). The latter, led by Norway, has 16 national government members (from Africa, Asia and Europe), and multiple non-governmental partners, e.g. the World Bank and the World Business Council for Sustainable Development (WBCSD). It aims at promoting energy efficiency and renewables by incentivizing commercial investments. While some papers focus on the legitimacy of climate clubs (e.g. Karlsson-Vinkhuyzen and McGee, 2013), others focus on their effectiveness (see Moncel and van Asselt, 2012 for an overview).

Different arguments are put forward to underpin the potential of climate clubs. It might be easier to reach agreement in smaller clubs of countries that are more willing to push forward climate protection (based on the argument of Olson, 1971). Falkner (2015) distinguishes three dominant rationales of climate clubs. First, club benefits are created for the members. Second, a re-legitimation of the climate regime by giving great powers a privileged position in the negotiations while acknowledging their greater responsibility at the same time. Third, the potential of climate clubs to enhance the bargaining efficiency of the international negotiations by facilitating agreement amongst smaller groups of players. Further pros and cons of climate clubs will be discussed below.

Another case for TEAs are contracts between cities from different countries. City networks on sustainability issue have some tradition. The International Council for Local Environmental Initiatives (since 1990) has more than 1,000 cities, towns and metropolises from all continents as members (ICLEI, 2015). Over 1,700 cities and municipalities are members of the Climate Alliance (since 1990, Climate Alliance, 2015), and have voluntarily committed to reduce greenhouse gas emissions reductions by 10% every 5 years. The C40 Cities Climate Leadership Group (since 2005) pushed the Compact of Mayors (2015), which is currently signed by cities with more than 5% of the global population. The Compact of Mayors has adopted a common monitoring, reporting and verification standard, the Greenhouse Gas Protocol for Cities (GHG Protocol, 2015). The standard is built on experience with a private sector initiative, the Carbon Disclosure Project (CDP, 2015), and has established a joint carbon registry.

As with climate clubs, there is also some research on city alliances. A special issue in Local Environment reviewed the early studies (Betsill and Bulkeley, 2007). Interesting questions are the motivations for joining city alliances, and their environmental effectiveness. The early literature is mostly descriptive in nature and undertakes single or comparative case studies. For example, Betsill and Bulkeley (2004) show for six case studies of municipalities in the UK that membership in Cities for Climate Protection (CCP) is mostly motivated by the availability of additional financial and political resources, and not so much by transfer of technical and best practice knowledge. International recognition of the local engagement and the re-framing of existing measures in terms of climate change helps increase legitimacy and place those activities higher on the local agenda. Gustavson *et al.* (2009) explore the potential of city networks for Swedish cities. Kern and Bulkeley (2009) analyze modes of cooperation in three transnational municipal networks (Climate Alliance, CCP and Energie-Cités). Members are active to quite different degrees in terms of information and communication, funding, recognition, benchmarking and certification.

Bulkeley and Broto (2013) collected an impressive database with more than 600 'urban climate change experiments' from 100 systematically selected global cities. All these experiments are explicitly targeted at reducing greenhouse gas emissions or at adapting to climate change. Most experiments are found in Europe, Latin America and Asia. Less of them relate to adaptation, but many to urban infrastructure, the built environment and energy. Half of the experiments involve partnerships, for example between local governments and the private sector. More recently, Hakelberg (2014) collected a sample of 274 European cities of which 41% became members of city networks until 2009. The econometric analysis shows that membership in a city network increases the likelihood of adopting a local climate strategy. In contrast, there is no such effect on geographically neighboring cities. Top-down governmental policies have a stronger effect on local climate strategies than city network membership.

Some studies explore the reasons why city alliance exist and might (not) be effective. Bulkeley (2010) generally stresses the changing role of cities and states in political systems, and highlights political economy reasons. Furthermore, urban areas are expected to be particularly vulnerable to climate change, though some more so than others (e.g. IPCC, 2014; Corfee-Morlot *et al.*; 2009; Gill *et al.*, 2007; Campbell-Lendrum and Corvalan, 2007). This might contribute to urgency in climate change adaptation and mitigation in some cities. Generally the local approach offers potentially easier stakeholder engagement, concrete action, resource mobilization and investment, mostly because actors are directly involved (e.g. Corfee-Morlot *et al.*, 2009; Sippel and Jenssen, 2009). On the other hand, urban action cannot be understood as being disconnected from national law. While the latter sets the context for the former, the former can help enforcing national action by contracts, building trust and through the political process. As a further reason, there might be local co-benefits due to investments, local pollution, or first-mover advantages if a city specializes in technological solutions

(although e.g. Urpelainen (2009) shows that local co-benefits are not sufficient to motivate local frontrunners). Further pros and cons of city alliances will be discussed below.

Approaches to study city alliances, climate clubs, and other modes of transnational environmental agreements resonate with different literature streams. Some scholars study subnational climate policies from the multi-level perspective (e.g. Betsill and Bulkeley, 2006; Monni and Raes, 2008). Hooghe and Marks (2003) disentangle different modes that might be helpful to characterize different transnational governance patterns. Type I governance refers to hierarchically nested arrangements (like in a classic federal system), while Type II governance refers to arrangements that cross hierarchies or overlap between jurisdictions. The literature on fiscal federalism (Oates, 1972; Oates, 2005) and environmental federalism (Shobe and Burtraw, 2012) uses more economic concepts to study the allocation of policies between subsidiarity and centralization. This approach might be helpful to study TEAs.

The debate on transnational climate governance got further impetus from Elinor Ostrom after her Nobel laureate speech (Ostrom, 2010; Ostrom, 2012). She rooted the considerations on addressing climate change both down from the top and up from the bottom in the concept of polycentric governance. In such governance modes many centers of decision making, which are formally independent from each other, make mutual adjustments for ordering their relationships (Ostrom *et al.*, 1961). This line of inquiry was taken up further by Cole (2011) and recently by Jordan *et al.*, (2015).

3 Scope and limits of international environmental agreements

The analysis of international environmental agreements with a focus on climate agreements is analyzed in the economic literature since the 1990s. It has led to the development of various models that serve as a starting point for the analysis of TEAs. This section gives an overview of this strand of research and its main assumptions and results.

The literature on IEAs started with the seminal work of Carraro and Siniscalco (1993) and Barrett (1994). The basic idea is to transfer concepts from the theory of economic cartels (D'Aspremont *et al.*, 1983; Chander and Tulkens, 1995) to the study of stable coalitions that contribute to a public good. A large set of publications that refined the first contributions followed suit, with further analytical and simulation studies up to date. Most of this research is based, inter alia, on the following propositions:

1. Global environmental problems are about provision of public goods.
2. Players are aspiring and achieving individually rational decisions in a game theoretic framework.
3. International environmental agreements need to be self-enforcing.
4. Players are nation states, their payoffs are determined by national welfare.
5. Full global cooperation (the grand coalition) would yield the first-best outcome.
6. The social optimum is ideally achieved, in principle, by a single global policy instrument (e.g. a uniform carbon tax or an emission trading scheme).

Based on these propositions, some standard insights have been consolidated over a broad range of settings. Some of them can be stated in a stylized way as follows. [i] The social optimum cannot be achieved due to free rider incentives. [ii] If some countries or coalitions undertake unilateral emission reductions, their effect is dissipated due to carbon leakage. [iii] Cooperation is either broad

but shallow, or deep but small. Thus, if we assume that reducing carbon emissions is associated with high mitigation costs and small damage reductions, a stable coalition will not have many signatories.

Although scientifically robust, these results are politically mostly frustrating. They do a good job in explaining the long-lasting stalemate and questionable effectiveness of the climate negotiation process under the UNFCCC.

Taking on that, two questions remain. First, if these results are valid for the climate case, is there any chance to avert the greatest market failure ever (Stern, 2007) or, more pathetically, loss of life and quality of life for billions of people? Is there no alternative to accepting the inevitable? Second, are these results indeed valid for the climate case?

Some skeptical remarks may deserve attention. For example, some studies have determined social costs of carbon of just a few dollars per ton (in particular for higher discount rates, IPCC, 2014). Several other studies have shown that the costs of mitigating emissions to limit greenhouse gas concentrations below 430 – 480 ppm by 2100 lead to a reduction of consumption growth by 0.04 to 0.14 percentage points over the 21st century (IPCC, 2014), i.e. these costs might be relatively low. If at least one of these kind of conclusions is valid, it seems that the gains from cooperation are shallow. The theory would thus imply broad cooperation. This implication is falsified by over 20 years of slow progress in climate negotiations.

Furthermore, the empirical examples of TEAs outlined above cannot be explained by the standard insights. Why should multiple climate clubs on overlapping issued be formed? Why do some climate clubs engage, although probably on a low level, in unilateral action? Why do cities from different countries start cooperation on emissions reductions, although most of their national governments do not, although there is no (single) global policy instrument in place, and although there are still many cities that do not participate in city networks? Instead, theory would predict cities to be free riders.

Solving such puzzles seems to be important both for climate protection and for scientific inquiry. One starting point for analysis could be to reconsider some of the six propositions outlined above. In the following, we want to explore how proposition (3), (4) or (5) might be relaxed, while keeping the remaining propositions.

4 Proposals for theoretical analysis

In this section we give two selected proposals for economic models that concentrate on transnational environmental agreements: climate clubs and city alliances. Both can be observed empirically. However both have got little attention in the economic literature so far even though they offer interesting concepts. We give general outlines for these two approaches that can serve as seeds for further model development. In addition, we give a detailed outlook on promising lines of further research in these and related areas.

4.1 Climate Clubs

One way to open up the classical approach of one single international environmental agreement is to allow heterogeneous countries to form climate clubs. As described in the global governance literature, climate clubs may have different effects and may improve over one monolithic agreement through different rationales (cf. Falkner, 2015).

The aspect of club benefits for the members of a climate coalition is analyzed by Nordhaus (2015). He finds that a climate club that imposes trade sanctions on non-participants can induce a larger stable coalition with more abatement than a coalition without sanctions. Asheim *et al.* (2006) model the case of symmetric countries and two coexisting agreements. The countries are partitioned in two regions and can choose whether they sign an agreement for that region or not. They conclude that a larger number of cooperating signatories can be sustained, compared to the standard case of a single IEA. The case of two coexisting TEAs is further analyzed in a numerical study by Osmani and Tol (2010) who additionally consider two asymmetric country types in a three-stage sequence of play between the coalitions and the non-signatories. Their results show that the possibility of two coalitions could increase as well as decrease emission abatement in comparison to the standard case with one coalition.

Going beyond numerical examples, Hagen and Eisenack (2015) study the effect of multiple coexisting climate clubs in an analytical game theoretic setting. The paper allows for asymmetric countries and investigates if global cooperation for emission abatement can be improved if countries can form coexisting TEAs. This very general analytical approach to climate clubs helps to get insights in the effects of negotiating coexisting climate clubs without being bound by specific assumptions on the concrete costs and benefits of countries emissions abatement. The rationale of this analysis will be introduced for the simplest version of this game theoretic climate clubs model. Its main results are derived and discussed.

The model is set up in the widely-used two-stage game structure with countries first choosing to join a coalition or not (e.g. Carraro and Siniscalco, 1993). In the second stage the members of a coalition decide cooperatively on the amount of emissions abatement that is undertaken by the coalition. The game is solved by backward induction. In contrast to the bulk of the existing literature, coexisting agreements are possible. Each stage of the model is set up as a simultaneous Nash-game.

The simplest version of the model already allows for important insights to the idea of climate clubs. It considers two types of asymmetric countries and two possible TEAs. The number of abating countries of type i $(i = 1, 2)$ is denoted by z_i. We assume linear benefits of global emissions abatement and a binary choice for countries between abatement, which is associated with abatement costs c, and pollution. An abating country of type i gets the payoff $\pi_i^a = -c + \alpha_i(z_1 + z_2)$. Asymmetric benefits of the countries are expressed by the parameter α_i where α_2 is normalized to $\alpha_2 = 1$ and $\alpha_1 \in [0,1]$. A type 1 country therefore benefits less or at most as much as a type 2 country from abatement. The net benefit of own abatement of each country is negative since $c > 1$. Thus, playing pollute is the dominant strategy if there is no TEA and all countries play pollute in the non-cooperative Nash equilibrium. In the first stage of the game countries decide about their TEA-participation. The case of one agreement is compared to that of two coexisting agreements. In the first case countries of both types can choose to join or not to join the agreement. In the other case each agreement consists of similar countries, representing e.g. regional agreements (cf. Asheim *et al.*, 2006). Solving the second stage of the game first, the agreements cooperate internally in their decisions about their emissions abatement. In the two agreements case the agreements take their decisions independently and simultaneously. Maximization of the respective joint payoffs yields the second stage equilibrium with agreement i playing

$$z_i^* = k_i \ (abate) \ if \ \alpha_1 k_1 + k_2 > c \tag{1}$$

$$z_i^* = 0 \ (pollute) \ if \ \alpha_1 k_1 + k_2 < c \tag{2}$$

with k_i denoting the number of type i signatories. This result already shows that the decision of each agreement depends on the number of its members, but not on the abatement decisions of the other

countries. The application of the criteria of internal and external stability solves the first stage of the game. As playing pollute is a dominant strategy for non-signatories, internal stability is only given if the members of an agreement choose to abate and would change from abate to pollute if one country would leave the agreement so that $c > \alpha_1(k_1^* - 1) + k_2^* > \alpha_1 k_1^* + (k_2^* - 1)$. The stability conditions together with this linchpin condition indicate that a stable abating agreement may consist of countries of both types with the number of signatories satisfying

$$c + \alpha_1 > \alpha_1 k_1^* + k_2^* > c. \tag{3}$$

Setting either the number of type 1 or of type 2 members in the agreement to zero we get the results for the size of the single agreement if it consists only of type 1 (4) or of type 2 (5) countries:

$$c + \alpha_1 > \alpha_1 k_1^* > c \tag{4}$$

$$c + 1 > k_2^* > c. \tag{5}$$

As the abatement decisions in the case of two agreements are mutually independent, the total number of abating countries in this case can be found by adding (4) and (5) and thus has to satisfy

$$2c + \alpha_1 + 1 > \alpha_1 k_1^{**} + k_2^{**} > 2c. \tag{6}$$

By comparing the equilibrium abating stable coalitions in the case of one single and two coexisting agreements we find that two agreements lead to a greater number of agreement members as well as to a greater amount of global emissions abatement and welfare. This effect would be replicated for any larger number of admitted climate clubs. It is caused by the coalitions' and the outsiders' dominant abatement strategies which stem from the linear payoff-structure of the model.

As shown by Hagen and Eisenack (2015) linear benefits of abatement always lead to dominant abatement strategies, while other cost and benefit structures from emissions abatement may lead to non-dominant reaction functions. In the extreme case of linear costs and concave benefits from abatement, only one agreement would undertake emissions abatement while all other countries do not abate any emissions regardless of their potential membership in other agreements. The findings of Eisenack and Kähler (2015), who show that individual countries with convex benefits from abatement may have increasing reaction functions so that emissions abatement becomes a strategic complement, give rise to the question about the strategic behavior of clubs that consist of such countries. In light of the previous analysis and the already existing economic literature we may conclude that climate clubs improve the outcomes of climate negotiations in some cases. Even in the least desirable cases we find that the outcome of negotiations with climate clubs leads to the same amount of global emissions abatement as would be achieved with one single IEA.

4.2 City Alliances

Cities are important actors regarding global climate change, both on the emitting and on the damage side. It might generally make sense that they organize an alliance among themselves in order to tackle these problems. In our proposed model we focus on the economic arguments of vulnerability, local co-benefits and enforceability.

The problem of enforcing an environmental agreement can be greatly diminished as cities are not ''above the law'' like nation states in the international system. They can be bound to abide to contracts by national laws. This makes trust, compliance and enforcement less challenging problems.

Generally, there are political, social and cultural links between rural and urban areas of one country. Additionally, a city alliance can introduce a voluntary and legal link between urban areas of multiple countries. The combination of these links might yield more cooperation than the usual economic approach of considering only a voluntary and self-enforcing agreement between countries.

Cities are potentially more vulnerable to climate change than other regions (Hallegatte and Corfee-Morlot, 2010). Therefore they have stronger incentives to reduce climate change impacts. There can also be local co-benefits in mitigation, e.g. with the removal of air pollution (Harlan and Ruddell, 2010; Bollen *et al.*, 2009) or a specialization on business opportunities from technological solutions like green energy (Jochem and Madlener, 2003). Particularly early movers may have an advantage here.

For technical reasons we characterize the actors in this section by their benefits and damages from emissions (in contrast the model specifications in section 4.1). In our model each country *i* consists of one *city* and one *rural* region. The payoff of each city $\pi^i_{city}(e^i_{city}, e) = B^i_{city}(e^i_{city}) - D^i_{city}(e)$ and each rural region $\pi^i_{rural}(e^i_{rural}, e) = B^i_{rural}(e^i_{rural}) - D^i_{rural}(e)$ depends on the benefits B^i_{city}/B^i_{rural} from its own emissions e_i, and, as usual, on the damage D^i_{city}/D^i_{rural} from global emissions $e = e^i_{city} + e^i_{rural} + e^{-i}$. The local emissions are an essential (but partly substitutable) factor of industrial production, they are linked to local benefits. Global emissions change the climate, which in turn creates local damages. In line with standard IEA literature (e.g. Hoel, 1991) we assume for all regions positive but decreasing marginal benefits from local emissions $B^{i\,\prime} > 0, B^{i\,\prime\prime} < 0$ and positive and increasing marginal damages from global emissions $D^{i\,\prime} > 0, D^{i\,\prime\prime} > 0$.

We further assume the following properties of the benefit and damage functions:

$$D'_{city}(e) > D'_{rural}(e), \tag{7}$$

$$B'_{city}(e^i_{city}) < B'_{rural}(e^i_{rural}), \tag{8}$$

$$B''_{city}(e^i_{city}) > B''_{rural}(e^i_{rural}). \tag{9}$$

The first property corresponds to the comparatively higher vulnerability of cities. The second and third inequalities result from assuming local co-benefits from emissions reductions in cities (e.g. lower air pollution or a head start in green technology development). These co-benefits compensate for the loss of benefits from emissions reduction and therefore lead to a lower net loss of benefits from local greenhouse gas production.

The model comprises two stages: First, each city decides whether it wants to participate in a TEA by entering an alliance with all other willing cities. Second, each country decides on the emission level of its city and rural region. The entry decision $(c^i \in \{A, \neg A\})$ in the first stage is based only on the payoff of the city: Is π^i_{city} higher as an alliance member? The payoff of the rural regions or the other cities does not enter consideration here.

In the second stage of the game, countries choose the emissions that maximize their respective payoffs Π^i. If the city region of a country has entered an alliance, we assume that the country considers the damages to foreign cities of the alliance $D^{A\setminus i}_{city}$ to some degree. This works similar as in stable agreements between nation states that fully internalize all damages from the emissions to all other agreement members. The degree of internalisation of foreign cities in an alliance where

domestic cities are members is represented by a weight $x \in]0,1[$ because cities may not be able to force their national governments to fully integrate a city alliance into their emissions planning.

The optimization problem of each country *i* in the second stage is:

$$\max_{e^i_{city},\ e^i_{rural}} \prod^i (e^i_{city},\ e^i_{rural},\ e^{-i}) = \begin{cases} if\ c^i = \neg A\colon\ \pi^i_{city}(e^i_{city}, e) + \pi^i_{rural}(e^i_{rural}, e) \\ if\ c^i = A\colon\ \pi^i_{city}(e^i_{city}, e) + \pi^i_{rural}(e^i_{rural}, e) - x \cdot D^{A\setminus i}_{city}(e). \end{cases} \quad (10)$$

We assume that all countries simultaneously play a Nash game at this stage.

In the first stage all cities determine simultaneously in a Nash game

$$\max_{c^i \in \{A, \neg A\}} \pi^i_{city}(e^i_{city}, e) = B^i_{city}(e^i_{city}) - D^i_{city}(e). \quad (11)$$

It is obvious that an alliance between cities is easier to reach than an agreement between countries. Due to their high vulnerability, cities value emissions reductions more; at the same time they are more likely to accept emission reductions because they have lower marginal benefits from emissions.

The largest part of the emissions reductions (in comparison to a status without any agreement) is borne by the cities in the alliance, because their benefits are reduced least if they lower emissions. They also have the largest reduction in damages. The rural areas (of the countries in which the cities are in the alliance) have to make some emission reduction effort as well, but their main contribution is not allowing any leakage. In a negotiation which only allows for nation states to form an agreement, even rural areas might want an agreement, but freerider incentives are much higher for them than for cities. Therefore they would prefer others to form an agreement and stay singletons themselves.

The national government is important in our model insofar as it ensures that no leakage of 'dirty' industry from cities to rural areas occurs. Of course the willingness of governments to engage in local climate policy is important as well. However in this model they don't have to enforce large emission reductions in (unwilling) rural areas, they only have to prevent them from increasing their emissions. Maintaining a status quo is more feasible in many political cases than enforcing unwanted change.

We conclude that if cities can form a mitigating alliance which national governments consider to some degree in their policy decision making, more cooperation and larger emission reductions can result. Cities have an incentive to enter a city alliance because they expect higher damages from climate change and have lower costs of emission reduction than other regions (particularly taking into account co-benefits from greenhouse gas mitigation).

4.3 Outlook

There are many further approaches tor transnational environmental agreements in addition to the analysis of those proposed above. We think that they offer promising extensions of the state of the art in research on international environmental agreements. We sketch some of them in the following.

Concerning climate clubs, one could think of overlapping clubs as an alternative to the proposed setting of coexisting disjoint clubs. If countries would be signatories of more than one climate club, this would change the strategic interaction of the clubs and possibly also the reaction functions in the game. Another way to include climate clubs as disjoint coalitions in the climate negotiations is to allow countries to form sub-coalitions in a first stage, followed by multilateral negotiations between the coalitions and remaining non-signatories. Possible effects of climate clubs in a broader sense include the generation of club-benefits as proposed, e.g., by Nordhaus (2015). By the creation of

such benefits that only favour signatories of a climate agreement, the incentives to join are strengthened. This could be implemented through issue-linkage. Existing international agreements on other topics as, e.g. trade, would then be linked to climate agreements. Existing research on IEAs and trade (e.g. Eichner and Pethig, 2015) could serve as a starting point here. Such multi issue clubs as well as climate clubs that do not negotiate on emission reductions but other issues like monitoring or technology sharing are a challenging but interesting modelling task. With regard to transaction costs we can say that, on the one hand, a shift towards smaller clubs of negotiating countries could possibly lower the transaction costs of forming a climate agreement, while possible interactions between clubs could impose additional transaction costs.

There are several economic arguments for an alliance between cities for emissions reductions. In our modelling approach we use vulnerability, local co-benefits and enforceability. In addition to these assumptions, we suggest three more possible reasons in favour of city alliances. First, transaction costs are potentially lower. The implementation of policy measures might be easier on a subnational than on a national level. Second, there is presumably less reason to behave opportunistically in moral hazard situations. The problem of individually rational but collectively harmful behaviour can be reduced if people directly observe each other. It might even be argued that urban areas are more likely to have a clientele that shares common norms, such as a collective commitment to behave responsibly and to abstain from opportunistic behaviour. Within such a group, information asymmetries are less problematic in a moral hazard configuration. Third, there can be learning effects. Transfer of policies between cities or even from a subnational to a national level could be modelled.

Our modelling proposal for city alliances can be combined with research on climate clubs. Cities within countries with low ambition could join climate clubs and exert their influence on the respective countries to join such agreements and take climate action. We actually observe that there are multiple city alliances in place, so these are, in our terminology, coexisting climate clubs of cities. What is the rationale and environmental effectiveness of cities forming coexisting TEAs, and how might cities strategically interact with national governments in heterogeneous TEAs where both cities and countries are members?

Apart from city-alliances and climate clubs there are many other actors that could participate in TEAs. Non-state-actors play an important role for adaptation to climate change as well as for mitigation of emissions. Industry lobbies and transnational NGOs influence governments and groups of countries in different ways while subnational governments and internal politics also play an important role for the decisions national governments take. Involving these actors in transnational agreements might open up new possibilities for negotiations and climate action but also raise threats to effective agreements. Whether they are within an agreement between nation states or within a coalition only consisting of non-nation state actors, their interests differ substantially so that the effects of heterogeneity on their outcomes are not clear. These effects should not be neglected and deserve more attention in further research.

5 Conclusions

This paper provides an exploration of some transnational initiatives for climate cooperation. The global governance literature finds ample empirical evidence for emerging TEAs. These can be only partially explained by the conventional economic literature which emphasizes the role of nation states with freerider incentives. We thus propose that more research is needed to understand and evaluate the role of TEAs in order to contribute to deal with climate change. We argue that this

particularly requires to consider the strategic interaction of heterogeneous actors, not only nation state governments, and to consider coexisting and possibly overlapping contracts that stipulate emission reductions or other institutions that are conducive to this aim.

To illustrate and underpin this claim, we extend already existing game theoretic approaches to IEAs in order to analyze the strategic effects of TEAs. Our two examples show that both climate clubs and city alliances may be able to lead to an increase in emissions abatement and in global welfare. Climate clubs offer an opportunity to cooperate in more than one agreement at the same time. Cites can form alliances in which they agree to mitigate greenhouse gases; the effectiveness of such TEAs will depend on the political influence cities have on national governments.

We find that cooperation can be individually rational, even in the presence of freerider incentives. Depending on the characteristics of the actors, negotiation structures can facilitate cooperation. Multiple agreements, for example, can stimulate more countries to cooperate than a single IEA. National political and legal institutions can be used to avoid the problem of non-binding agreements if actors other than nation states cooperate. Cities, rural regions and other subnational actors can be compelled by law to enact an agreement. Both examples of TEAs have shown that such agreements may indeed be effective and improve over the standard single IEA consisting only of nation states. Depending on the structure of costs from mitigation efforts and damages from climate change, the example of climate clubs shows that it is not in any case clear if TEAs take climate action beyond lip service.

Beyond these two examples, there are various other settings of heterogeneous actors that might be conducive to tackle climate change. Other forms, mechanisms, and players in transnational environmental agreements, like NGOs, issue linkage, policy learning, moral hazard and political economy warrant further attention. Also cooperative game theory may be used to model TEAs.

Although we have shown that game theoretic analysis might well be helpful to better understand the formation and effects of TEAs, it is clear that it also has its limitations. Some aspects like the re-legitimation of the climate regime (cf. Falkner, 2015) or potentially irrational behavior of agents are difficult to analyze in a game theoretic setting and might be better researched by other means. One can also question the legitimacy of TEAs with non-state actors in contrast to multilateral IEAs negotiated by national governments. Nevertheless, we argue that especially with regard to the slow progress of the international climate negotiations, and in light of the empirical development already going on, it is important to include non-state actors complementary to an IEA.

Non-cooperative game theory offers a conservative view on agreements, i.e. it tends to underrate cooperation incentives (Carbone *et al.,* 2009). Therefore our positive findings carry a particularly heavy meaning; we expect a real potential for TEAs. Institutions and negotiation structures for climate governance can improve if they allow for transnational actors. A combination of different scientific approaches sharpens the view. The global governance literature widens the horizon for economic analysis and challenges the conventional theory of IEAs, as it offers observations that cannot easily be explained by existing models. This is both a provocation and great opportunity for further theory building. Economics offer rigorous methods for the analysis of incentives for cooperation, and model results can give new ideas for TEA-structures and negotiation processes.

Understanding transnational environments agreements is of the highest importance, particularly in the light of the Paris agreement of 2015 which does not provide binding emission reduction targets for nation states. This challenges both the negotiating actors and research. Our paper sketches several promising policy options and avenues for further research.

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