Mapping institutions and actors in global climate governance: A network approach

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Abstract

In our efforts to address climate change globally the traditional multilateral negotiations under the United Nations Framework Convention on Climate Change (UNFCCC) have been complemented by a range of new international and transnational governance initiatives involving state and non-state actors such as cities, regions, advocacy groups, companies and philanthropists. These developments have led to an increasingly dense institutional structure in global climate governance, resulting in functional overlaps and fragmentation. This paper suggests a novel network-based approach to map and measure the structural properties of global climate governance. It moves beyond current mappings, that mainly rely on lists and typologies, by focusing on the relations between actors and institutions. Two networks are created, one based on membership data in different institutions and one based on hyperlinks on homepages. The networks provide different pictures of the governance architecture which corroborate as well as questions current thinking about global climate governance. Finally, the paper engages in a forward-looking discussion on how to measure the degree of fragmentation in climate governance by using network metrics such as degree and centralization.

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1. Introduction

Over the past 20 years, global efforts to combat climate change have become a complicated matter. The central forum for multilateral global climate governance, the United Nations Framework Convention on Climate Change (UNFCCC), has been complemented by numerous cross-border initiatives comprising both state and non-state actors including NGOs, companies, academia, cities, and international organizations (Biermann et al. 2009; Keohane and Victor 2011; Abbott 2011; Bulkeley et al. 2014). The broader institutional structure has thus developed from a single regime to a regime complex, and is now rather characterized by fragmentation and functional overlaps than by coherence and hierarchy (Keohane and Victor 2011, 15; Biermann et al. 2009). In Ostrom's words, global climate governance is best described as a polycentric system with "multiple governing authorities at different scales rather than a monocentric unit" (2010, 552). However, while fragmentation is largely accepted in theory as an ubiquitous phenomenon in global climate governance, we have few empirical methods for mapping, visualizing and measuring fragmentation (Zelli and Van Asselt 2013). A central problem is that current mappings generally are confined to lists and typologies that provide little information on how the dots are connected (see e.g. Keohane and Victor 2011; Abbott 2011; Bulkeley et al. 2014).

To bridge this knowledge gap, this paper introduces a novel way to map actor-constellations and institutional architectures in global climate governance. It focuses on the public actors involved in international and state-led transnational institutions to address climate change and combines traditional insights on global governance and institutions with the burgeoning scholarship on networks and new techniques for gathering data. To this end, two networks of actor-constellations are created, first a membership network where actors are connected via their involvement and membership in institutions, and second, a virtual policy network (VPN) which is a web-based issue network made up of hyperlinks between websites (McNutt 2010). The results show how countries, regions, and cities form a tightly knit yet fragmented network of institutions and actors within the field of global climate governance.

The article is structured into five sections. First, an overview of current mapping attempts sets the scene and identify gaps in knowledge. Second, the analytical framework and methodological approach are described in detail. Third, the results of two mapping attempts consisting of a Virtual Policy Network and membership network are presented. Fourth, the results are discussed with a view towards measuring fragmentation. Finally, the conclusions summarize the observations and propose further research topics.

2. Mapping fragmentation in global climate governance architectures

Ever since the observation that global governance architectures were becoming more densely populated by different institutional arrangements – also described as treaty congestion, fragmentation, or regime complexity – (Brown Weiss 1993; International Law Commission 2006; Raustiala and Victor 2004), there has been a wide array of attempts to map the new and emerging structure, in particular within climate change. Most of the studies mapping the current climate governance architecture can be categorized into either listings and typologies, or conceptual maps.

The first type of mappings lists and categorize institutions active in international and transnational climate governance. Data entries are based on expert judgments and analyses rely on descriptive statistics of attributes such as governance function, type and origin of members and type of institutions. Bulkeley and colleagues, for example, list 60 transnational climate initiatives and divide them into two distinct groups: one which is involved in providing funding and often are hybrid, and a second which is focused on rule setting and tending to be private (2012, 609). Several other scholars such as Hoffman (2011), Weischer and collegues (2012) and Hale and Rogers (2013) also engage in similar exercises of listing institutions. Abbott (2011), based on a list of 67 transnational organizations, moves one step beyond simply listing and describing the institutions by placing them into a "governance triangle" (Abbott and Snidal 2009) which improves our overall understanding of how the global climate governance architecture is structured. While the result of these type of studies have provided us with a rather stable set of 60 to 100 mainly transnational institutions constituting the global climate governance complex, they fail to show relationships between the institutions.

The second type of mappings tries to go beyond lists and typologies toward visually depicting the global climate governance architecture and theorize about its structure. Three studies in particular stand out. First, Biermann and colleagues have created an "onion" model (see figure 1) with the UNFCCC at its core surrounded by three consecutive layers including multilateral forums on energy and climate, other environmental institutions and organizations, and international non-environmental institutions and organizations (Zelli 2011).

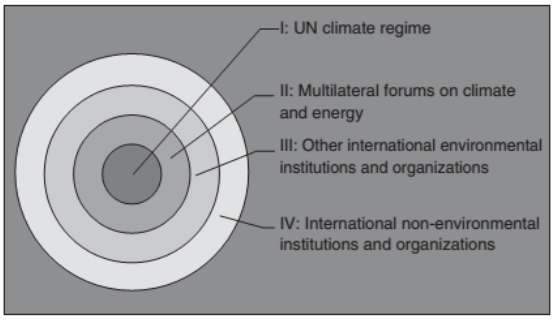

Figure 1 The Onion model

A slightly more detailed mapping has been suggested by Keohane and Victor's (2011) who make a coarse overview of international climate related institutions. The authors include UN agreements such as the UNFCCC and the Montreal Protocol on Ozone Depleting Substances but also expert assessments (IPCC), clubs (e.g Major Economies Forum, G8), bilateral initiatives and geoengineering governance (see figure 2).

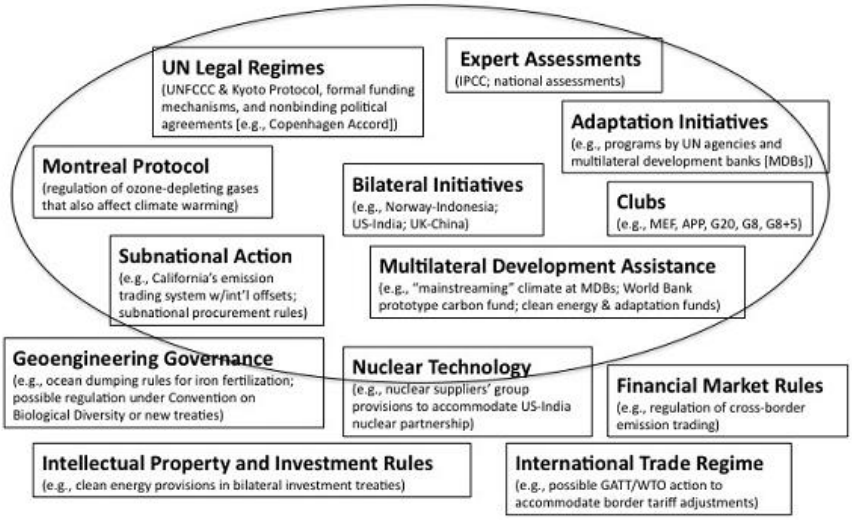

Figure 2 Climate regime complex

The third mapping is carried out by Abbott (2011) who observed that the climate regime complex suggested by Keohane and Victor omits the large number of transnational institutions active in global climate governance. By using a 'governance triangle', first developed by Abbott and Snidal (2009), Abbott is able to visually map and categorize the transnational climate regime complex by function and membership type, to a more detailed extent than both the previous mapping attempts (see figure 3).

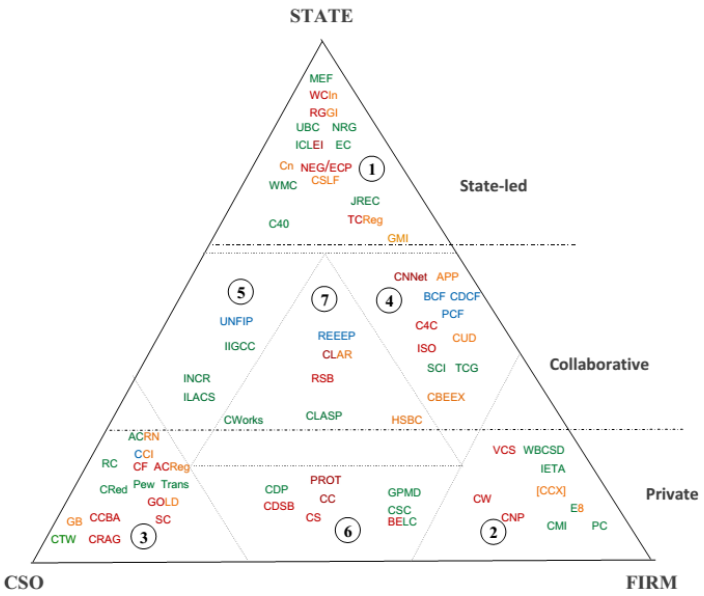

Figure 3 The transnational climate regime complex

Comparing the three mappings depicted in figure 1, 2 and 3, we observe an increasing level of detail and information embedded in the figures. However, the lack of relational data, i.e. how the different institutions and actors connect, impedes further analysis on to what extent we can describe the structure as fragmented.

The two types of mappings – lists and typologies (type 1) and conceptual maps (type 1) – are complementary in the sense that they provide both a conceptual understanding of the structure of the architecture and adding much detail to each institution in the architecture. However, both types share at least two important short-comings: first, a division is made between international and transnational levels. If complexity and fragmentation in architectures partly are a result of a proliferation of non-state actors and shifts in authority away from states, then the two levels should be linked or at least part of the same map. Second, mappings have hitherto been unable to analyze or even plot the relationships between the different actors on the level of the architecture. To address these two short-comings and move beyond theorization about the fragmentation of global climate governance towards empirical testing and reproducible results, we need new methods to connect the dots.

3. A network approach to mapping governance architectures

Popular concepts such as architecture, regime complex, polycentrism and fragmentation refer to the global structure of governance. According to the Oxford English Dictionary, structure can be defined as

"[a] combination or network of mutually connected and dependent parts or elements; an organized body or system" (OED). While previous mappings outlined in section 2 have been successful highly successful in listing the discrete elements, few have investigated the constitutive relationships that connects and aggregates them. One way of conceptualizing global governance in line with relational thinking is in terms of networks, which is the focus of the coming sections.

3.1. Networks and network analysis

The study of networks is occupied studies the relations between discrete objects and has been applied in a wide-range of disciplines including computer science, biology, economics and sociology. In particular sociology, has been applying network theory to study the meaning of social structures between, for example, individuals, companies or organizations, and developed what is called Social Network Analysis (SNA). SNA includes a range of quantitative tools and measures to measure global and local structural properties (i.e. the topology) of a network consisting of nodes connected by edges. For example, SNA allows us to explore properties on individual node-level and answer questions such as: who is the most important player? And also explore global and regional level and check for example clustering tendencies, network density and shortest paths between nodes.

Networks-based approaches have recently gained in popularity in International Relations in general and studies on global environmental and climate governance in particular (Kahler 2009; Slaughter 2004; Hafner-Burton, Kahler, and Montgomery 2009; Pattberg 2010; Kim Rakhyun 2013). For example, in global climate governance studies, network-based approaches have been used to examine relationships between different carbon trading and standards. In more detail, Green (2013) explores how private carbon standards relate to the rules created under the Kyoto Protocol by developing an exhaustive list of private carbon standards and examining to what extent they recognize other standards. She shows how public rules acts as an "anchor" for private rules and that a certain degree of policy convergence have occurred in global emission trading. In another study, Paterson and colleagues (2013) describe how the design and implementation of different emission trading schemes in Europe and the US were diffused through a network of individuals and organizations taking part in several governance processes. The next section outlines the methodological choices and case – selection for this paper.

3.2. Methodological considerations and case-selection

Since a network consists of nodes and edges, two decisions need to be made: what constitutes a node and what constitutes an edge.

First, I consider public institutions in global climate governance as nodes. Public institutions are understood as international treaties and regimes, regional and mini-lateral initiatives, involving countries and international organizations, as well as sub-state initiatives by public actors such as regional governments and cities. To identify the nodes, I focus on the top-triangle (Zone 1) in the transnational climate regime complex governance triangle (see figure 3) created by Abbott (2011). Abbott's mapping provides a good starting point as it clearly separates between public, hybrid and private institutions, of which the former is the focus of this paper. Since Abbott's paper was published in 2011, institutions have appeared and disappeared and the list has therefore been updated using more recent studies by Hale and Roger (2013) and Bulkeley and colleagues (2012). I have also added formal regimes, notably the UNFCCC and the Kyoto Protocol, to study how the international and transnational public actors connect. The criteria for inclusion or exclusion of institutions are based on a conceptual framework for measuring fragmentation created by Pattberg and colleagues (2014). The result of the exercise yields the following list of starting institutions or nodes:

Table 1 Public institutions selected as nodes

Abbreviation	Institution	Abbreviation	Institution
ACCCRN	Asian Cities Climate Change Resilience Network	ICAP	International Climate Action Partnership
C40	C40 cities	KP	Kyoto Protocol
Carbon*n*	Carbon*n* Cities Climate Registry	MEF	Major Economies Forum
CEM	Clean Energy Ministerial	NA2050	North America 2050
CAECIRP	Climate Alliance of European Cities with Indigenous Rainforest Peoples	NEG/ECP	New England Governors and Eastern Canadian Premiers' Annual Conference (NEG/ECP)
CSLF	Carbon Sequestration Leadership Forum	R20	R20
CM	Covenant of Mayors	SC	Solar Cities
EC	Energy Cities	TCG	The Climate Group
EUROCITIES	EUROCITIES Declaration on Climate Change	WCI	Western Climate Initiative
FCPF	Forest Carbon Partnership Facility	WMC	World Mayors' Council on Climate Change
GMI	Global Methane Initiative	UNFCCC	United Nations Framework Convention on Climate Change
ICLEI Ecomobility	ICLEI Initiative for Ecomobility	UBC	Union of Baltic Cities

The list contains 24 public cross-border institutions involving states, regions, and cities. While the selection should not be considered an exhaustive list of all public institutions active in global climate change governance, it is an attempt to create a comprehensive set of starting points based on the state-of-the-art in climate governance mapping.

Second, two types of edges have been chosen: membership affiliations and hyperlinks, which enables the creation of two networks, one Membership Network and one hyperlink network (also called Virtual Policy Network (VPN)). The rational for creating a membership network is based on the premise of affiliation network theory that social ties matter and are developed between actors that attend common events, i.e. being part of an institutions increases the likelihood of two actors having a social relation in some way (Wasserman and Faust 1994). Besides attending the same meetings, network affiliations are also more likely to foster resource and knowledge exchange, policy diffusion, and policy innovations (Jordan and Huitema 2014). The Virtual Policy Network connect actors via Hyperlink Analysis (HLA) to establish the boundaries of a linked community in cyberspace which, according to its proponents argue to some extent mirrors real-world structures and dynamics (Park 2003) and has been applied, for example, online social movements (Lusher and Ackland 2010), global public policy networks (McNutt and Pal 2011), and Transnational Advocacy Networks (Carpenter 2007). In climate governance research, McNutt (2012) has analyzed VPNs in the context of Canadian national climate adaptation policy to assess the level 'policy capacity' meaning the capacity of a government to coordinate as well as to collect and produce information to be used in decision-making.

The data collection has been carried out in two steps. For the membership network, public authorities (countries, regions, and cities) that in some way show explicit adherence to the rules, norms and decision-making procedures of the starting nodes have been selected. The results have been collected in a 2-mode data matrix (N_{Actors} = 7964, $N_{Institutions}$ = 24) where X_{ij} = 1 when actor *i* is affiliated with institution *j* and X_{ij} = 0 otherwise. Moreover, to enable more extensive analysis, two 1-mode affiliation networks were created based on Actors (X_A) and Institutions (X_I). For example, two institutions are connected if they share *at least* one member. Data-gathering and cleaning was made in Microsoft Excel (2010), R (R Core Team 2014), and Gephi; all network measures were calculated using UCINET 6 (Borgatti, Everett, and Freeman 2002).

4. Results

The coming sections report on the results of the network-based analysis. The first section describes the results of the memberships network and the second section describes the result of the VPN.

4.1. The membership network

The Membership Network was created by connecting institutions that share members. For example, if the UNFCCC and the KP share a member, then an edge is created. "Membership" has been defined on a case-by-case basis, but the most common type are signatories and official members to the legal framework of the institutions (the treaty). For example, a signatory country to the UNFCCC is considered a member.[1] In some cases, for example with the ACCCRN, only the core members have been included in the data-set. An original data-set of 7964 unique actors was collected and include countries, regions and cities that are members to the 24 institutions listed in table 1. The number of members per institution is displayed in table 2.

Table 2 Number of members per institution

Institution	No. of Members	Institution	No. of Members
ACCCRN	10	ICAP	30
C40	69	KP	191
Carbon*n*	422	MEF	17
CEM	22	NA2050	20
CAECIRP	1693	NEG/ECP	11
CSLF	23	R20	46
CM	5296	SC	5
EC	150	TCG	64
EUROCITIES	49	WCI	5
FCPF	57	WMC	282
GMI	39	UNFCCC	194
ICLEI Ecomobility	12	UBC	95

A 1-mode network matrix was constructed with institutions (X_I) and analyzed with network analysis software. Figure 4 shows the 1-mode membership network organized by institutions.

[1] The case-by-case assessment is on file with author.

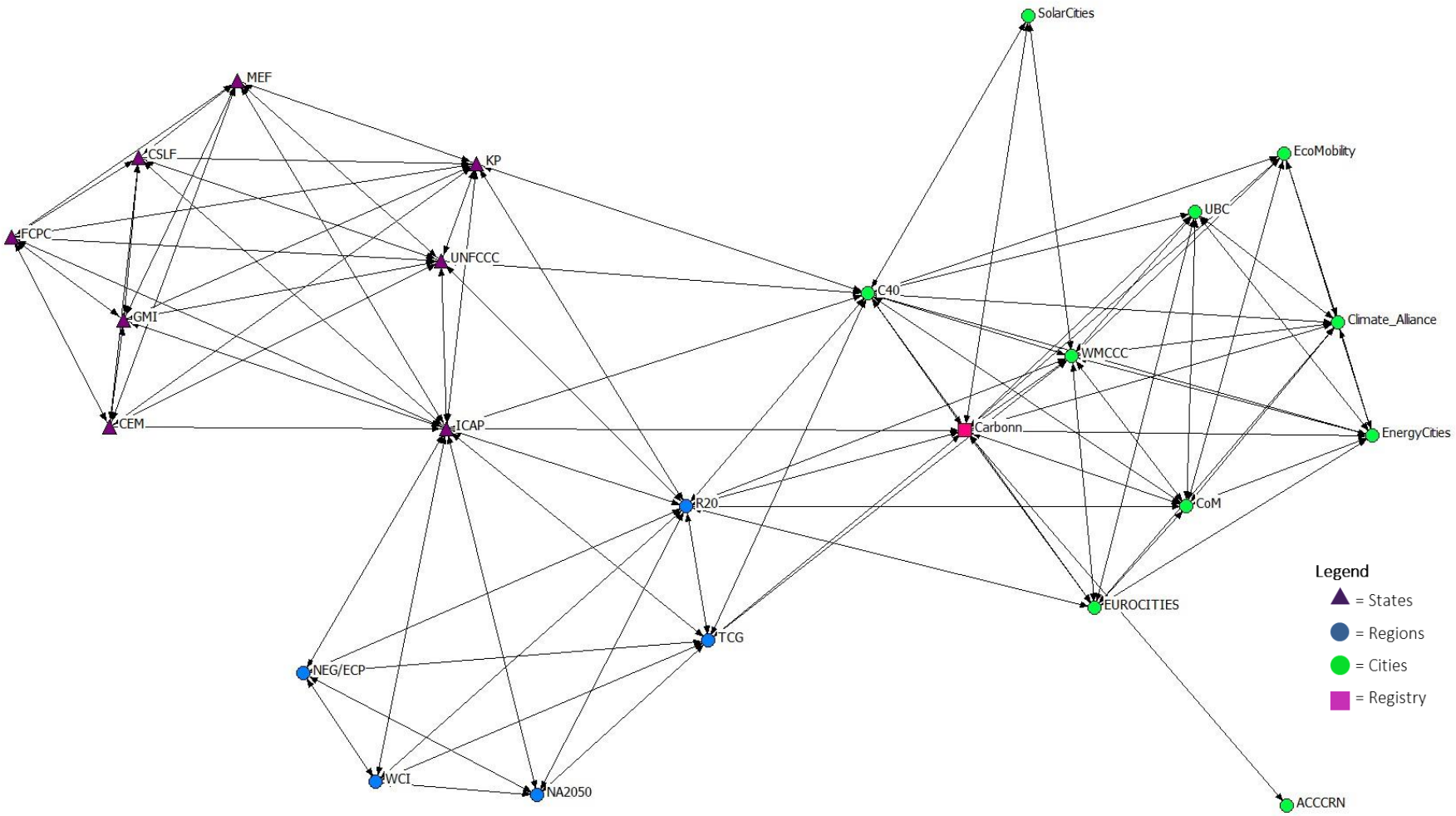

Figure 4 Membership network by institutions

The first observations concerns to what extent some types of institutions have a tendency to cluster together. In the network three clusters can be identified and have been highlighted in the graph using three different colors and shapes, purple, green and blue. The upper-left cluster (purple triangles) comprise institutions which are exclusive to countries, the lower-left cluster (blue circles) consists of institutions that focuses on regional cooperation, and finally, the right-side cluster (green circles) is constituted by institutions including mainly cities.

A second observation is to see if there are nodes that are important for connecting the clusters. These can be found by using a node-level measure to calculate the central actors called "betweenness centrality". The betweenness of a node is a number on the shortest path from all edges to all other edges that pass through that node, i.e. betweenness scores can identify those nodes where most other nodes needs to travel too to reach other nodes in the network. The variation in the network is quite high (mean = 10,25 and standard deviation = 4,051) and half of the nodes have zero betweenness score, meaning that some nodes have a very high score indicating bridging functions. A few institutions act as bridging nodes between the three clusters, in particular ICAP (63.8) followed by C40 (53,8) and Carbon*n* (44,2). Beyond these three bridging organizations, there appears to be a low level of connectivity across different clusters in the network. However, a few edges that connect clusters are somewhat counter-intuitive. The UNFCCC and C40, and the Kyoto Protocol (KP) and C40 are connected in the network even though they focus on nation-states and cities respectively. The shared member between the three is Singapore which, in a sense, is a mixture between a city and a state. For instance, the Singapore fact-sheet on the C40 homepage lists the current Prime Minister, Lee Hsien Loong, instead of the city mayor as head of governance[2]. Moreover, the UNFCCC and the R20 are connected via the republic of Mali which, according to the R20 membership list, is a member of the regional organization[3].

To further analyze the structural properties of the network we can zoom in on specific sections by creating sub-networks. Two such partitions have been made based on membership type, a "country-only" sub-network, and a "sub-national authorities" sub-network.

The "state-only" sub-network represents the upper-left cluster in figure 4, we can discern a tightly knit group consisting of only nation-states (see figure 5) where all institutions share at least one member with one another (centralization = 0) .

[2] http://c40.org/cities/singapore
[3] http://regions20.org/regions-in-action/members

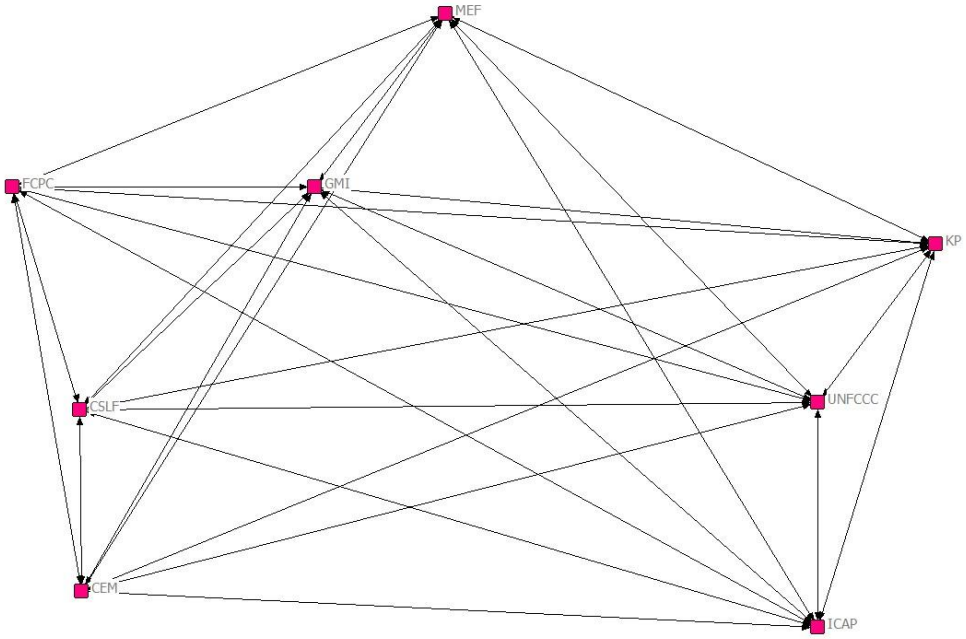

Figure 5 Country cluster in the Membership network

Taking weighted degree into account, however, the UNFCCC and the KP are by far the most connected, simply because they have the most members of the institutions in the cluster.

Figure 6 presents the second sub-network consisting of sub-national actors (cities and regions) as well as one registry.

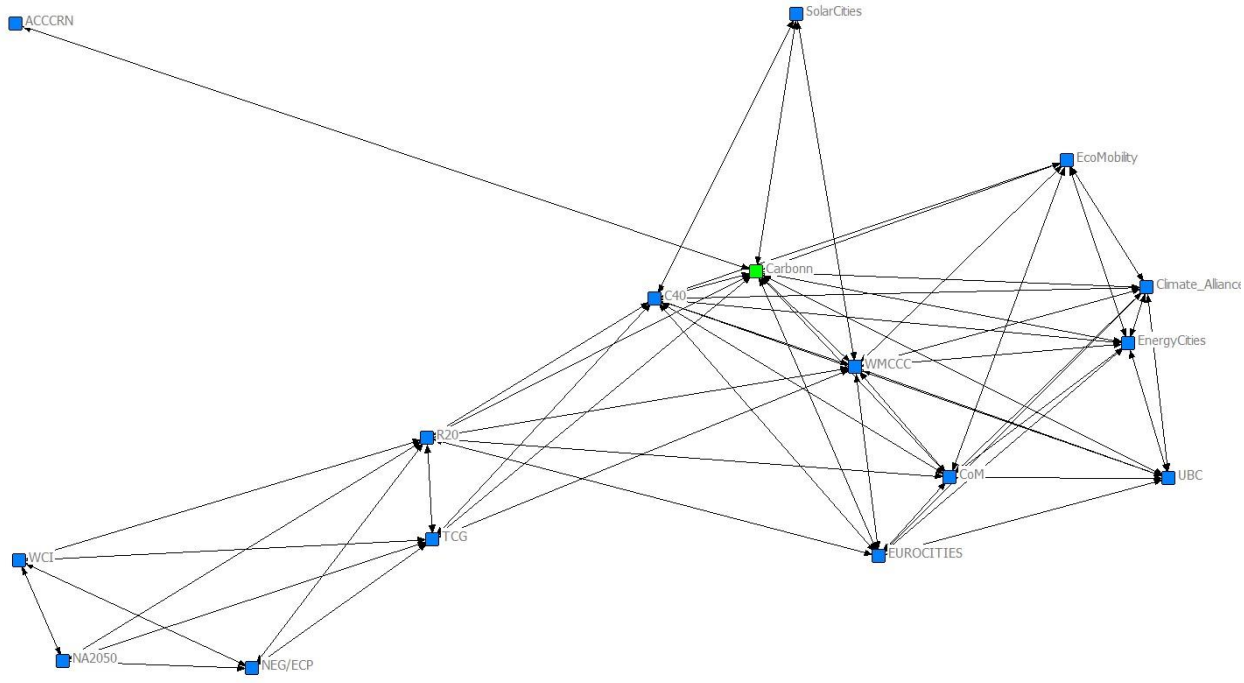

Figure 6 Sub-national actors (cities and regions) cluster in the Membership network

Figure 6 shows how the institutions that include sub-national actors are connected in the network. Three observations can be made. First, there is a clear division between those involving cities and those involving regions. On the lower-left side of the network, the regional institutions including WCI, R20 and NEG/ECP cluster together. On the upper-right side, the large city networks form a second cluster. Second, there is a geographical gradient moving from left to right in the sub-network moving from North America to Europe. The lonely node in the upper-left corner represents the only institution with Asian cities. Third, a central institution in the sub-network is the Carbon*n* registry which has by far the highest betweenness score (23,79, mean = 5,125) and thus connects a large number of the institutions in the sub-network.

4.2. The Virtual Policy Network

The Virtual Policy Network was collected using the homepages of the 24 institutions in table 1 as starting seeds (see annex 1), which were fed into IssueCrawler which is an online webcrawler (issuecrawler.net). It "crawls" the web and gathers information on what homepages that connect via hyperlinks. The software allows for control of several different parameters and types of crawls. For the purpose of this paper, a co-link analysis has been carried out at 2 depth. This means that homepages are connected if they share at least two seed-hyperlinks. 'Depth 2' means that the crawler iterates the operations two times. A sensitivity analysis increasing the depth to 3 yielded nearly identical results. The crawl returned 103 hyperlinks from which four were removed (twitter.com, addthis.com, euractiv.com, subsite.kk.dk) and duplicates which refer to the same homepage were merged (e.g. klimabuendnis.at, climatealliance.eu, and climatealliance.org). The final dataset thus include 91 hyperlinks made up by a large variety of actors, including international organizations, companies, advocacy campaigns, national and regional agencies, philanthropic organizations and NGOs. Figure 7 shows the network in full and figure 8 shows a part of the network where the type (state, region, city) has been attributed to each node via a color code. Figure 8 omits 25 nodes where the type does not fall into the three categories states, regions, cities.

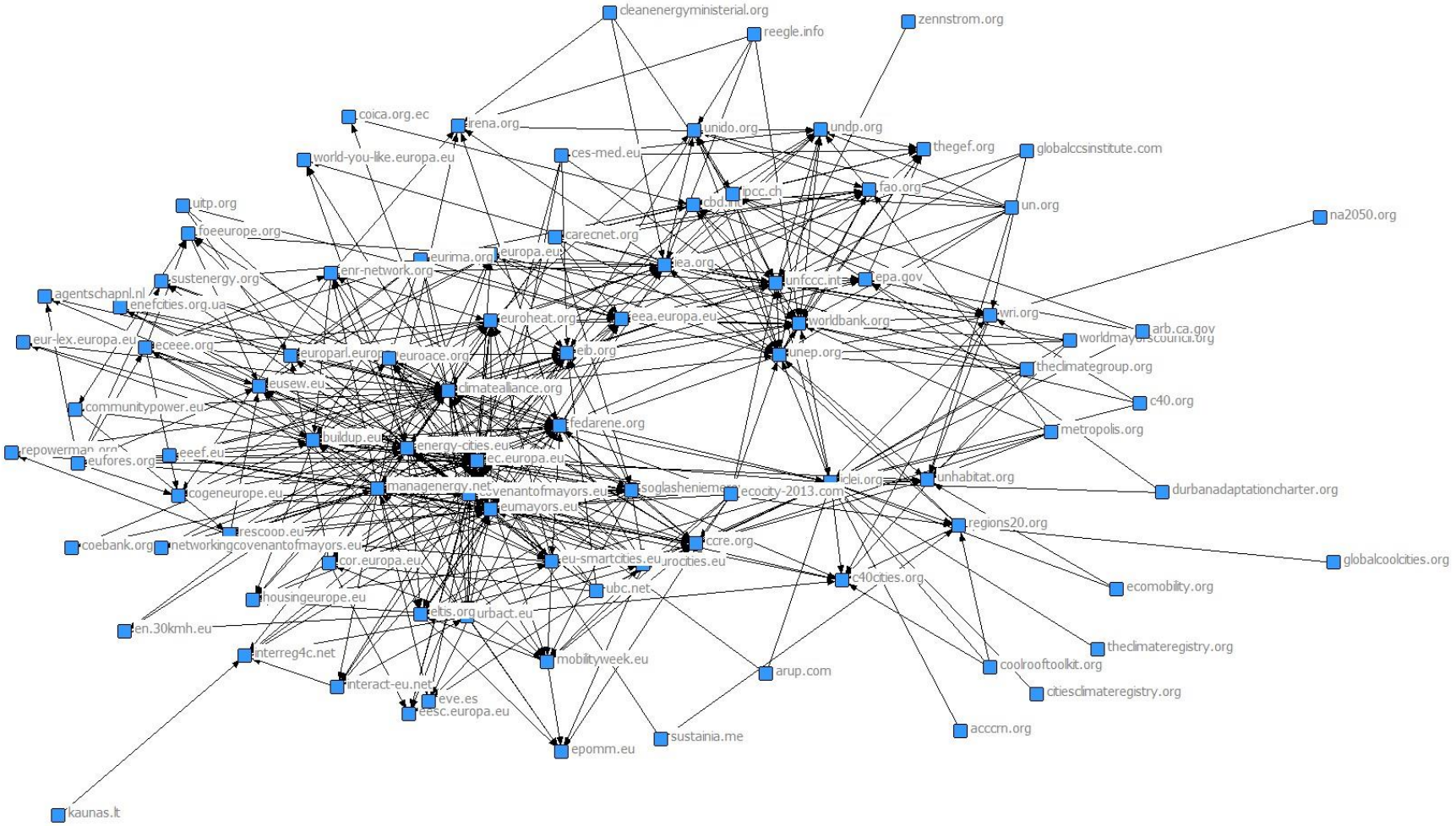

Figure 7 VPN of institutions (co-link analysis, depth 2)

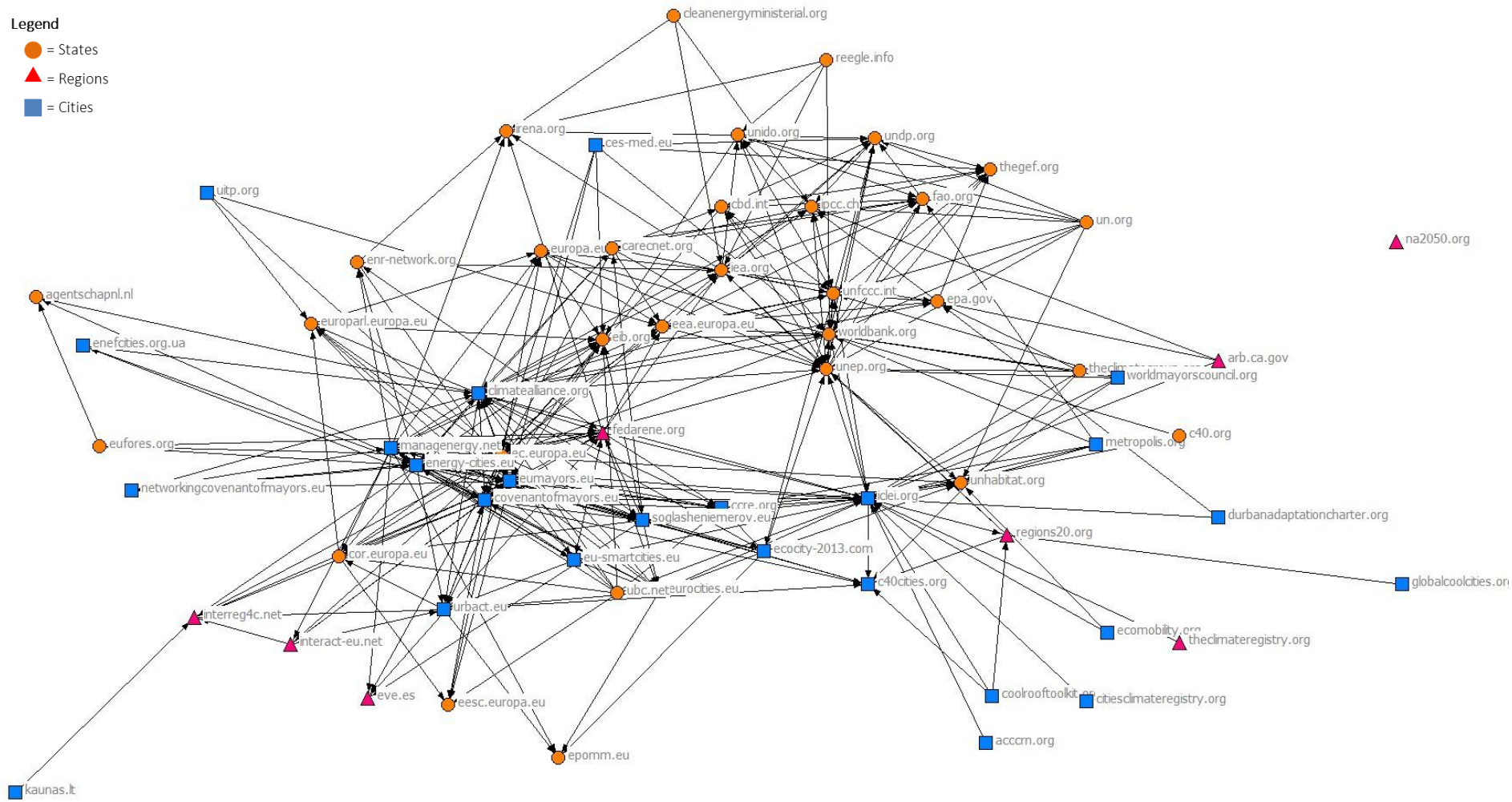

Figure 8 VPN of institutions colored by type (co-link analysis, depth2)

While the VPN network is less clearly clustered compared to the membership network, both figure 7 and 8 reveal clustering tendencies. Figure 7 appears to show two clusters. One large cluster on the left comprising mainly European nodes with the European Union website ec.europa.eu at its core. On the right a less densely populated cluster has formed around the UN organizations including the UNFCCC, World Bank, UNEP and the UNDP. Figure 8 show a different type of clustering which is more similar to the membership network. Here the nodes have been assigned a value depending on their type (state, region or city) and given a color and shape based on their attributes. This unveils two clearly observable clusters, one on top (circles and orange that show the placement of state-related nodes) and one below (squares and blue that indicates city-related nodes). Only the region-related nodes are less visible in the VPN. Moreover, the VPN networks in both figure 7 and figure 8 appears to mirror the geographic gradient moving from Europe on the left to the US on the right. For example, on the far left we find homepages for the European chapter of Friends of Earth and the European Forum for Renewable Energy Sources. On the far right we find the homepage of North America 2050 and California's Environmental Protection Agency.

Some network statistics provide more insights. By calculating the in-degree, i.e. the number of times a node is referred to by other nodes, and out-degree, i.e. the number of time a homepage 'sends' a hyperlink the following homepages appears central.

No.	Homepage	In-degree	No.	Homepage	Out-degree
1	ec.europa.eu	37,00	1	energy-cities.eu	27,00
2	iclei.org	22,00	2	eumayors.eu	27,00
3	unfccc.int	19,00	3	covenantofmayors.eu	27,00
4	worldbank.org	18,00	4	managenergy.net	24,00
5	energy-cities.eu	17,00	5	ec.europa.eu	21,00
6	unep.org	16,00	6	fedarene.org	21,00
7	eumayors.eu	15,00	7	soglasheniemerov.eu	17,00
8	buildup.eu	15,00	8	buildup.eu	15,00
9	eib.org	15,00	9	eu-smartcities.eu	14,00
10	climatealliance.org	15,00	10	euroheat.org	13,00

The EU's website is the homepage which by far attracts the most homepages by in-degree, which can be explained by the domination of EU-based homepages on the out-degree ranking. However, thereafter the homepages attracting the most edges are large international organizations and agencies including the World Bank, the United Nations Environmental Program (UNEP) and ICLEI – Local Governments for Sustainability.

5. Discussion

The coming section discusses the results presented in section 4 in two ways. First, the results are interpreted with a view towards current mapping and global climate governance literature as well as discussing some caveats in the methods. Thereafter follows a brief discussion on the possibilities for using the network-based approach for assessing fragmentation in global climate governance architectures.

5.1. Interpreting the results and methodological caveats

The network-based approach taken in this paper allows us for the first time to visualize the global climate governance architecture involving public actors. The membership network clearly reveals the fairly strict divide between state, region and city level governance initiatives. The membership network contests the conceptualization by Biermann et al about the UNFCCC taking up a central role in global climate governance and more appears to suggest a polycentric character with governance level as organizing principle. Moreover, the few links between the state level and the sub-state level is made up by a couple of single states, Singapore and Mali. If one increases the constraints of the model to demand institutions to share at least two members then the links between the state level and the sub-state level would be confined to one institution namely the ICAP. The VPN network corroborates the results from the membership network by showing the clustering of governance levels also in cyberspace.

An interesting feature of the VPN network is the high score on in-degree for organizations such as ICLEI, the World Bank and UNEP which could corroborate the research made on the existence of "orchestrators", which often are states or international organizations that "bring new capacities and resources to the provision of global public goods by strengthening or catalyzing transnational governance schemes" (Hale and Roger 2013) in global climate governance. In particular UNEP and the World Bank has been mentioned in repeatedly as potential "regime entrepreneurs" (Abbott 2013) or "initiating orchestrator" (Hale and Roger 2013).

To measure level of fragmentation in actors and actor-constellations by analyzing the structure of the network is not without problems. First, the accuracy of the results will hinge on the quality and quantity of the data collected. The data collection effort required is often considerable. The only remedy for the data-collection problem is to acknowledge this short-coming, be transparent with our assumptions and honest about how representative our sub-set of the total population is. Second, the results are highly dependent on what relations we decide to look at. Here the conceptualization of

institutions and 'memberships' in institutions are points for discussion. By building the initial data-base of institutions on a long range of literature and typologies, the paper certainly 'inherits' methodological short-comings from previous projects. Similar to the first problem, the only way to address the challenge is to be open and honest about the choices made and the limitations to the approach. Third, an analysis of the social network within an issue area will not provide answers on the effects of a particular structure. Whether a certain number of constellations are moving actors towards solving problems in an issue area is beyond the scope of the mapping exercise. Fourth and finally, the existence of clusters and other structural characteristics do not tell us much about the quality of network components or explanation for the structure. Why do actors choose to cluster? Do they share norms with other members of the constellation and what discourses are prevalent? What is the relationship between clusters and institutions? Nevertheless, network-based approaches move us towards a relational perspective where transactions are central units for analysis and, according to Emirbayer, actors "derive their meaning, significance, and identity from the (changing) functional roles they play within the transaction" (1997, 287). Hence, the method could have large potentials when exploring how norms, resources and discourses travel and changes throughout a network. While merely exposing a network structure of global climate governance is not equal to showing all the transactions that take place within the network, I would argue that mapping the structure of the network is important to show where interaction such as learning, exchange of best-practice, policy diffusion and spread of norms, is more likely to take place.

5.2. Towards measuring fragmentation

If fragmentation indeed is an ubiquitous characteristic of the global governance architectures, then we have surprisingly few methods or approaches to map and measure it (see however Hollway 2011). Current attempts have been largely based on dyadic relationships exploring the interaction between two formal regimes (Oberthür 2001) or anecdotal evidence that qualitatively elaborates on the characteristics and attributes of fragmentation (Biermann et al. 2009). To start measuring degree of fragmentation would thus be a welcome next step to allow for a longitudinal analysis of changes in the architecture and comparative studies on the degree of fragmentation in different issue areas such as biodiversity and oceans.

Network analysis provides a number of tools and metrics for measuring how fragmented a network is. Section 4 reported on the conclusions one can draw simply by looking at the network. It also introduced a few node-level measures to determine centrality in the network such as betweenness and degree. To measure fragmentation, however, requires network-level metrics.

One approach suggests to use the measures for centralization and average degree to calculate fragmentation (Pattberg et al. 2014) and have been used by sociologists to measure cohesion on a global network level (Nooy, Mrvar, and Batagelj 2005). The two measures are interesting for a number of reasons. First, I argue that it would be wrong to assume that more actors automatically leads to more complexity. A school of fish can comprise thousands of individuals yet carry out advanced moves in a split second. It therefore seems reasonable to assume that a fragmentation measure should control for size. Moreover, size-neutral metrics are also more flexible than size-dependent metrics since they allows for comparison across issue areas. Second, the degree, i.e. how many edges that are present in a network, can be unevenly distributed and most real world networks, have a tendency to divide into communities and groups (Newman 2006). Biermann and colleagues for example, argue that the level of support for an institution by actors is a key determinant for deciding what type of fragmentation that is present (Biermann et al. 2009, 19). The metrics should therefore be able to check for (in)equality in the distribution of edges across the network, i.e. are there institutions that hogs all the connections or are they evenly spread across nodes?

Two structural network properties that meet the abovementioned conditions are average degree and centralization. Average degree is a straight-forward measures on how connected actors are on average. Centralization measures the spread of connections in the network by measuring centralization which can be understood as the inequality (or variance) of a network as a percentage of that of a perfect star network of the same size (Hanneman and Riddle 2005).[4] A high centralization number means that the edges are unequally distributed across the network. Since calculating centralization includes finding the node with the highest centrality, one needs to decide on what measure of centrality to use (Freeman 1979; Freeman 1977; Bonacich 1987)), i.e. there are different measures for centralization. Centralization is expressed in percentage where 100 % indicates that all edges are centralized to one node.

According to Pattberg and colleagues (2014) once the average degree and centralization measures have been established one can move towards establishing the degree of fragmentation. The two measures create four possible situations depicted in the figure 5 below:

[4] Not to be confused with centrality which is a micro-level property.

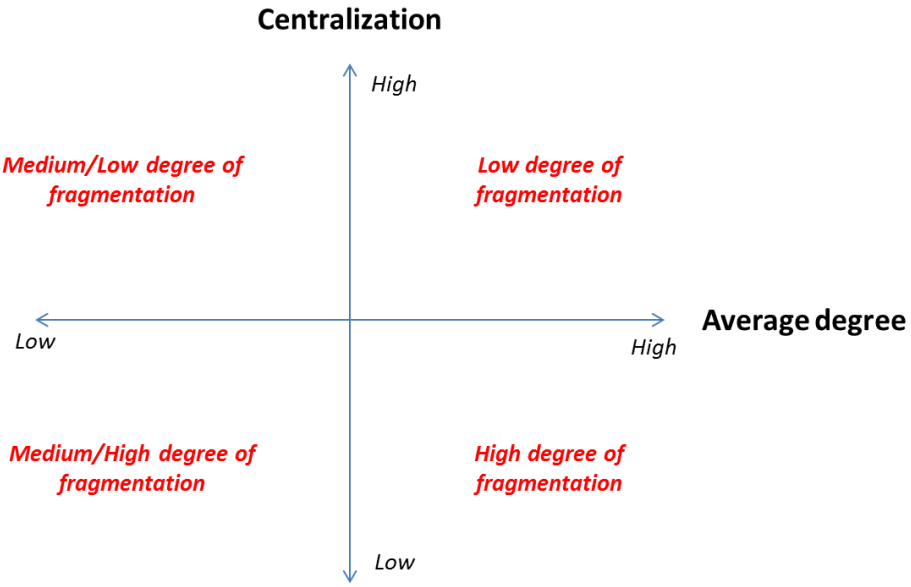

Figure 9 Centralization and average degree of actor network and degree of fragmentation

In the upper-right corner, average degree and centralizations is high. This means that the network is densely populated and there is a core actor-constellation leading to low fragmentation. In the lower-right corner, when average degree is low and centralization is high, there is a dense network but it lacks a center which leads to high fragmentation. On the lower-left corner, both average degree and centralization are low which creates a sparsely populated and disperse actor-constellation network leading to a medium/high fragmented network. Finally, when average degree is low but centralization is high, then actors-constellations are not very well connected but there is a clear core constellation in the network, leading to a medium/low fragmented network.

Applying the measures for fragmentation to the networks created in this paper, requires a decision on what network to examine. Given that the collection of VPN is based on an algorithm with predefined conditions and collects hyperlink on the World Wide Web which may contain inherent biases towards certain properties (such as a Small World phenomenon), I have chosen to apply the fragmentation measures to the Membership Network.

The Membership Network has a density of 0.344 meaning 34 % of all possible ties are filled and a centralization of roughly 29 % meaning that there is some centralization in the network where a few nodes are attracting the majority of the edges, however, it cannot be considered a high degree of centralization. According to the framework presented by Pattberg and colleagues (2014) suggests that public actors and institutions in global climate governance, form a medium/low degree of

fragmentation with a fairly high level of centralization and medium average degree. However, these observations are subject to at least a couple of methodological disclaimers. First, the lack of reference studies to compare what actually constitutes a "high" or "low" degree of centrality and average degree in the context of global governance and institutions inhibits calibration of the methodology. Second, the observation in section 4 that both networks have a tendency to cluster into two or three sub-networks, somewhat contradicts the statement that the network display a rather low level of fragmentation. Finally, some authors have suggested to compare the network structure with ideal types of different degree of polycentrism, where one extreme type is fragmentation (Gallemore and Munroe 2013; Galaz et al. 2011). While this is certainly an interesting avenue for further research, it is still in its infancy.

Finally, the implications of different structural characteristics of networks are highly under-researched (for exceptions see Rydin 2012; Bodin and Crona 2009; Newig, Guenther, and Pahl-Wostl 2010). For example, based on literature from formal network theory, Rydin (2012) has suggested that a 'hub-and-spoke' structure of a policy network – where most nodes in the network could be reached with only a few steps – could be superior to other structures for efficacy of the resource exchange that is a pivotal activity for networks. Also Bodin and Crona have started to examine the meaning of structure of natural resource governance on a local level (2009). Nevertheless, while it would be highly interesting to connect evaluation concepts from the social sciences such as effectiveness, legitimacy and efficiency to the structural characteristics of a global governance architecture, we first need a robust method for mapping and comparing different issue areas and points in time.

6. Conclusion

This paper presents an attempt to map the relations between public actors and institutions in global climate governance architecture. To this end, two networks were created, one Membership Network and one Virtual Policy Network. Both networks display clustering tendencies towards a polycentric and multilevel structure that separates states, regions and cities. The method provides an empirically grounded, reproducible and transparent approach to validate or dispute the many theoretical claims that has been made in the context of governance architectures, regime complexes, polycentrism and fragmentation.

The measures for fragmentation showed that the network exhibits low to medium degree of fragmentation, however, these observations should be read with utmost care due to the early stages of the field.

The next steps of this research is to increase the number of data in the network to include private and hybrid institutions. The methods should also be refined to further investigate what appropriate measures for degree of fragmentation are. In this quest, comparative studies between different issue areas would be highly beneficial to calibrate the models and methods.

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Annex 1

Homepages used for seeds to create the VPN-network.

Abbreviation	Long name	Webpage
ACCCRN	Asian Cities Climate Change Resilience Network	http://www.acccrn.org/
C40	C40 cities	http://www.c40.org/
Carbonn	Carbonn Cities Climate Registry	http://citiesclimateregistry.org/
CEM	Clean Energy Ministerial	http://www.cleanenergyministerial.org/
CAECIRP	Climate Alliance of European Cities with Indigenous Rainforest Peoples	http://www.climatealliance.org/
CSLF	Carbon Sequestration Leadership Forum	http://www.cslforum.org/index.html
CM	Covenant of Mayors	http://www.covenantofmayors.eu/index_en.html
EC	Energy Cities	http://www.energy-cities.eu/
EUROCITIES	EUROCITIES Declaration on Climate Change	http://eurocities.wordpress.com/climate-change-declaration/
FCPF	Forest Carbon Partnership Facility	https://www.forestcarbonpartnership.org/
GMI	Global Methane Initiative	https://www.globalmethane.org/
ICLEI Ecomobility	ICLEI Initiative for Ecomobility	http://www.ecomobility.org/
ICAP	International Climate Action Partnership	https://icapcarbonaction.com/
KP	Kyoto Protocol	http://unfccc.int/kyoto_protocol/items/2830.php
MEF	Major Economies Forum	http://www.majoreconomiesforum.org/
NA2050	North America 2050	http://na2050.org/
NEG/ECP	New England Governors and Eastern Canadian Premiers' Annual Conference (NEG/ECP)	http://www.coneg.org/
R20	R20	http://regions20.org/
SC	Solar Cities	http://www.iscicities.org/
TCG	The Climate Group	http://www.theclimategroup.org/
WCI	Western Climate Initiative	http://www.westernclimateinitiative.org/
WMC	World Mayors' Council on Climate Change	http://www.worldmayorscouncil.org/the-mexico-city-pact.html
UNFCCC	United Nations Framework Convention on Climate Change	http://unfccc.int/2860.php
UBC	Union of Baltic Cities	http://www.ubc.net/