Earth System Governance 4 (2020) 100064

Contents lists available at ScienceDirect

Earth System Governance

journal homepage: www.journals.elsevier.com/earth-system-governance

Where do novelties come from? A social network analysis of Transnational Municipal Networks in global climate governance

Marielle Papin

Political Science Department, Université Laval (Canada), Pavillon Charles-De Koninck, 1030, avenue des Sciences humaines, Québec, G1V 0A6, Canada

ARTICLE INFO

Article history:
Received 9 March 2020
Received in revised form
11 June 2020
Accepted 30 June 2020
Available online 12 July 2020

Keywords:
Transnational municipal networks
Global climate governance
Social network analysis
Novelty
Governance instruments

ABSTRACT

Climate-related Transnational Municipal Networks (TMNs) have gained prominence. Scholars have discussed their effects, including their capacity to generate novelties. Yet, some confusion remains in this area. Focusing on the governance instruments generated by TMNs, this article asks: why do some TMNs generate more novelties than others?

The research conducted for this article involved a social network analysis supported by qualitative data, using data compiled by the author on TMN memberships, partnerships and governance tools. Findings suggest that the most central TMNs, which also have diverse contacts, can draw on huge volumes of diverse information to generate novel governance instruments and evolve. Other variables, e.g. organisational age, are also involved.

This article contributes to the literature by offering an explanation for the capacity of some actors to generate novelties in global climate governance. It also provides a better understanding of the ways in which TMNs seek to steer their numerous city members towards climate action.

1. Introduction

Climate-related Transnational Municipal Networks (TMNs), structures that cities in different countries create or join to discuss and exchange good practices or collaborate on projects tackling various urban issues, have gained prominence.[1] More and more cities seek to join TMNs such as ICLEI-Local Governments for Sustainability (ICLEI), C40 Cities Climate Leadership Group (C40) or the Covenant of Mayors for Climate and Energy (CoM), which are increasingly vocal in transnational and international climate events. Despite scientific advancements regarding their role, how TMNs affect local and global levels is still up for debate. One important question relates to the ways in which TMNs generate novelties in global climate governance.

This article observes novelties in TMNs' governance instruments, i.e. combinations of governance characteristics and functions aiming to orient TMN members' behaviour towards climate action. Novelties are instruments appearing for the first time in the TMNs system. Observing their novel governance instruments indicates that some TMNs (e.g. C40 or Metropolis) have many, which confirms the literature's findings on their novel practices (Bouteligier, 2013). Yet, other TMNs have few to none (e.g. the Carbon Neutral Cities Alliance, or CNCA). Thus, I ask: why do some TMNs generate more novelties than others? The definition of novelties used here is non-normative. I assert that TMNs generate novelties in global climate governance, by producing instruments to steer local actors in a global governance system towards climate action. TMNs' capacity to generate novelties does not necessarily affect their effectiveness or efficiency. This article does not set out to identify the best TMN governance instruments or to suggest ways to adapt urban climate governance. It contributes to the literature by showing how transnational novel practices might emerge, offering diversified governance approaches to tackling climate change. Many scientists argue that there is no one-fits-all solution to climate change (IPCC, 2018). A variety of actors developing diverse actions are needed. Examining why some TMNs generate more novelties might help better target the conditions under which transnational actors of global climate governance may participate in providing novel governance solutions to climate issues. The TMNs under study here represent 11,781 cities and more than 800 million inhabitants. Considering their actions might affect above 10% of the global population, detailing their practices to steer their member cities towards climate action is also relevant and useful to the literature.

E-mail address: marielle.papin.1@ulaval.ca.

[1] Although TMNs look at a variety of urban issues, this article focuses on those interested in climate action.

https://doi.org/10.1016/j.esg.2020.100064

To answer the question raised, I use network theory, complexity approaches, and some insights from organisational theories. This theoretical framework suggests interactions (TMNs' membership and partnership relationships with other actors, studied through relational variables), with the help of specific actors' attributes (linked to TMNs' characteristics), influence the emergence of novelties. More specifically, it investigates the role of degree centrality (i.e. being connected to the most nodes in a network), and diversity of contacts, structurally (i.e. being connected to the most nodes not shared with other actors), and substantially (i.e. being connected to the most nodes of different types or working on different issues), regarding relational variables; and age, and organisational resources (i.e. the number of staff per city member), regarding actors' attributes. This article's central hypothesis is that *the TMNs that generate the most novelties tend to be the most central and have the most diverse contacts; they have generally been part of the system for the longest and have access to the most organisational resources*. To test this hypothesis, a social network analysis examines the TMNs' ego networks, including all their members and partners, and measures the TMNs' degree centrality, and structural and substantial diversity. A qualitative analysis then examines the significance of age and organisational resources, and reviews two specific examples to further investigate the significance of the presented independent variables. The results suggest TMNs' ability to generate novel governance instruments depends on a combination of centrality, diversity of contacts, and age.

Describing how the literature has reported the relationship between TMNs and novelties, the next section highlights a gap in the analysis of TMNs' capacity to generate novelties in global climate governance. The third section presents the theoretical framework built to account for the emergence of novelties. The fourth section introduces the methods used, i.e. social network analysis and qualitative analysis through documentary observation and interviews. The fifth section presents the results of the empirical analysis. The last section concludes this article by discussing these results. Studying TMNs' interactions leads to envisioning them as hybrid actors of global climate governance. It also highlights the need to focus on the interplay of TMNs' interactions and attributes in order to improve our understanding of their role and influence. While this article represents a first step in this direction, more contributions are needed to further understand how TMNs affect global climate governance.

2. TMNs and novelty

Research on TMNs has focused on how they affect climate governance and whether they have the capacity to make it more effective and efficient. Several scholars underline the role of TMNs in promoting and encouraging new local climate plans (Heikkinen et al., 2020; Hakelberg, 2014). They see cities as 'spaces of innovation' that TMNs could propel onto the global stage (Bouteligier, 2013; see also Bulkeley, 2013). They also use comparative case studies to show how TMNs advance cities' technical and normative innovations (Toly, 2008). TMNs may be perceived as an intermediate variable between global cities and climate action. In a case study of C40, a network dedicated to megacities' climate actions, Lee (2013, 2015) claims that global cities are more likely to join TMNs and develop climate actions because of their global connections and socialisation opportunities.

TMNs could be a source of novelties per se. Comparing the C40 and Metropolis cases, Bouteligier (2013) shows TMNs both follow and depart from conventional environmental governance practices. They diffuse information and knowledge on sustainability, which might facilitate socio-ecological transitions (Labaeye and Sauer, 2013). By sharing information and knowledge, and most importantly, political and financial resources, they appear to mobilise cities (Betsill and Bulkeley, 2004). TMNs have many roles. In a study of German cities involved in climate TMNs, Busch (2015) describes TMNs as platforms of information, consultants for cities' climate action, commitment brokers (who encourage cities to commit to specific climate action targets), and city advocates.

Furthermore, TMNs are examples of new experiments in global climate governance. Their approach to governing climate change differs from that of the multilateral system (Hoffmann, 2011). In a study of C40, Gordon (2013) highlights how, by claiming legitimacy in a state-centric space, TMNs challenge the norms with regard to who governs and how. Thus, they undermine the classic distinction between local, national and international, which strengthens multilevel governance. In cities of the 100 Resilient Cities (100RC) network, mayors work with private actors such as AECOM, meaning the multinational company can participate in cities' resilience strategies design. TMNs ignore traditional borders and present new political geographies, where cities are included on the transnational level (Bouteligier, 2013). In a case study of C40, Román (2010) argues that TMNs generate an unprecedented system of governance from the middle, by combining institutional and market-based elements. TMNs are no more international than they are local, public or private. They appear to govern cities from a space in-between.

Yet, various analyses also question whether TMNs have the capacity to generate change, of which novelties are a form. Acuto and Rayner (2016) examine 170 city networks striving to tackle diverse urban issues. They argue that the emergence of this hybrid form of governance could also create new lock-ins in cities, allowing certain technological innovations to maintain existing path dependencies in decision-making or societal aspects. TMNs lack the resources to facilitate the changes they wish to promote, which makes them dependent on states (Hickmann, 2015). The potential of TMNs to offer new norms is debatable. C40 promotes solutions that are embedded in neoliberal urbanism and do not allow normative changes (Davidson and Gleeson, 2015). Furthermore, some critique TMNs' mitigation effects (Bansard et al., 2017). Being 'networks of pioneers for pioneers', TMNs do little to influence the behaviour of laggards (Kern and Bulkeley, 2009: 311). Although these concerns highlight important issues regarding TMNs' capacity to create certain changes, particularly in climate norms and measurable mitigation effects, they do not question the literature's findings regarding their capacity to develop novel governance practices.

Overall, the literature has considered several ways in which TMNs might generate novelties. However, it is unclear where these novelties come from and why some TMNs generate more than others. Numerous publications on TMNs offer individual or comparative case studies, many of which focus on C40. To better capture TMNs' capacity to generate novelties, it is crucial to broaden the literature's current scope of investigation. In a complex global climate governance (Hermville, 2020; Pattberg and Widerberg, 2019), looking at more TMNs and analysing how they interact among themselves and with other actors might be particularly useful.

This section has underlined an important gap of the literature on TMNs. The next section presents a theoretical framework that provides an explanation for the emergence of novelties, considering TMNs' interactions while not ignoring their attributes. It also includes an analytical framework examining the content of TMNs' novel governance instruments.

3. An explanation for the emergence of novelties

3.1. Where do novelties come from? A theoretical framework

Network theory and complexity approaches help explain why some TMNs generate more novelties than others. Both approaches, which are relevant to the study of change, consider the interactions between actors within a system. For instance, seminal publications using network theory find that actors' capacity to innovate may depend on the strength of their interactions with others or their position in a network (Burt, 1995; Granovetter, 1973). Likewise, complexity approaches, which show that change is the norm not the exception, have revealed some of the trade regime's internal dynamics (Morin et al., 2017). Network theory and complexity approaches appear particularly relevant considering the complexity of global climate governance, which includes numerous interactions between multiple interconnected and interdependent actors at distinct levels. As they belong to this global climate governance system, TMNs also form a system of their own, interacting among themselves and with others to achieve their goals.

This article focuses on two important network theory concepts, i.e. centrality and diversity. Centrality generally refers to the extent to which a focal node is connected to the other nodes of a network. Bonding ties between actors of a network might participate in explaining the rise and diffusion of novelties in a network (Rogers, 2003; Coleman, 1988). Centrality also gives actors greater access to and control over resources such as information (Brass, 1984). Considering the centrality of actors is a way of assessing the amount of information that these actors might attract. Diversity here refers to a focal node's diversity of contacts. It is a way of considering the different information to which a focal node might have access. Network theory has studied diversity in distinct ways. Structural holes theory has a structural understanding of diversity, focusing on the position of nodes in a network. It states that novelties often come from bridging ties (Burt, 1995). These connect nodes which are otherwise not directly connected. Burt's theory focuses on how actors, located between two different communities or networks, use bridging ties to combine ideas from the two communities or networks to generate novel arrangements. This article also considers a substantial understanding of diversity, positing that connections to actors of many different types (e.g. governmental agencies, companies) or working on many different issues (e.g. sustainability, resilience) may help generate novelties.

This article focuses on complex adaptive systems (CAS) theories to analyse systems comprising interdependent entities, which continuously interact together and with their environment, 'giv [ing] rise to complex collective behaviour, sophisticated information processing and adaptation via learning or evolution' (Mitchell, 2009: 13; see also Bousquet and Curtis, 2011). CAS develop through exploration and exploitation (Morin et al., 2017). Exploration refers to intents to generate new capabilities through processes involving search and experimentation, e.g. a company seeking to design a new product. Exploitation refers to using existing capabilities through diverse activities such as reproduction or refinement, which progressively produces known strategies, and order, e.g. a company seeking to intensify the production of its most popular good. The openness of CAS suggests that their environment influences them. Generating novelties, CAS entities evolve, which allows the system to adapt to changes in the environment. The dynamics involved may be nonlinear: minor activities or features of actors within the system could have a major impact. In CAS, both structure and agents matter. The impact of certain attributes, actions or behaviours is hard to predict.

Complexity approaches and network theory are complementary. Some networks are CAS; all CAS can be considered networks (McGee and Jones, 2019; Morçöl, 2012). Network theory can be applied to the study of change, but it focuses mainly on the stability of structures of interactions (Morçöl and Wachhaus, 2009). By contrast, complexity approaches explain change by examining the nature of interactions between CAS entities. Network theory looks at the backbone of a system. Complexity theory considers a system in a wider perspective in order to observe and model change (Kim, 2019; Morçöl and Wachhaus, 2009). According to Barabási, network theory is crucial to the development of complexity approaches: 'Should a theory of complexity ever be completed, it must incorporate the newly discovered fundamental laws governing the architecture of complex systems' Barabási (2007: 41).

Yet, interactions might not be the only enabling conditions for the emergence of novelties. To consider the role of actors' attributes, a few insights from organisational theories are particularly valuable. Their use is relevant since TMNs can be seen as organisations, as well as networks. Despite their ambiguous nature, this article looks at TMNs' age and organisational resources as possible variables that influence the emergence of novelties. Some research on organisational theory has suggested there is a positive relationship between organisational resources and the emergence of novelties (Laosirihongthong et al., 2014; Crossan and Apaydin, 2010). It sees organisations with more money, staff or technical resources as more likely to generate novelties. Several studies have identified a negative relationship between the two, however. Indeed, some scholars argue that resource scarcity stimulates creativity and, therefore, helps generate novelties (Löfqvist, 2017). Other scholars suggest that the younger the organisation, the greater the drive to generate novelties by creating tools to match its goals. Younger organisations also tend to be more flexible and have fewer bureaucratic rules (Le Mens et al., 2015). Age is seldom positively correlated with the emergence of novelties in organisational theories. Yet, it is possible that being in the TMNs complex system for longer means that TMNs have more time to generate novel instruments.

Building on the above, this article posits the following. The complex system of climate-related TMNs must adapt constantly to its changing and uncertain environment. TMNs share and receive data through interactions. They process it through exploration and exploitation, in order to identify and respond to the system's needs, and facilitate its adaptation. Having many contacts, and diverse ones, helps TMNs attract important amounts of different information, which they use to generate novel ideas and practices. Their attributes may influence their capacity to generate novelties, given the system's nonlinearity and the interplay between structure and agents. By producing novelties, TMNs might be able to evolve in a world of finite resources and make themselves indispensable. In other words, this article's central hypothesis is that *the TMNs that generate the most novelties tend to be the most central and have the most diverse contacts; they have generally been part of the system for the longest and have access to the most organisational resources*. The significance of relational variables compared to attribute variables depends on the evolving context.

This theoretical framework provides an explanation for change, including novelties. An analytical framework is also necessary to identify and examine the content of the novelties generated by TMNs, and test this article's central hypothesis.

3.2. Where do novelties lie? An analytical framework

This article observes novelties in the instruments of governance generated by TMNs to steer their members towards climate action. Governance instruments are understood as combinations of governance functions and characteristics that an authority uses to steer its population towards achieving, developing or managing

one or several public goods. The literature review suggests that TMNs' novelties are linked to their governance practices, rather than their norms, or attempts to mitigate emissions or adapt. TMNs use a variety of techniques combining distinct governance functions and characteristics to orient the behaviour of their city members. Examples of TMN climate governance instruments include: political declarations setting mitigation targets; grants for cities willing to implement electric public transport plans; new standards to assess cities' resilience. Building on previous work (Papin, 2019), this article uses the following analytical framework to examine TMN governance tools.

This analytical framework draws on previous studies on global climate governance practices, which highlight the functions of numerous transnational governance mechanisms (Bulkeley et al., 2012; Andonova et al., 2009). The framework includes six functions observed in TMNs governance practices, of which it clarifies the meaning for this article. Rule setting is the elaboration of 'rules intended to guide or constrain constituents' towards climate action (Andonova et al., 2009: 65). Building on Bulkeley et al. (2012), funding is the provision of funds to TMN members for implementing climate initiatives; and direct action refers to TMNs' actions, e.g. planting trees rather than encouraging cities to plant trees. Norm setting is here defined as the development of norms, standards and best practices for implementing climate action, encompassing several functions previously highlighted (i.e. monitoring and certification and target setting) (see Bulkeley et al., 2012). Although Andonova and colleagues' definition Andonova et al. (2009) encompasses various resources networks might provide cities, it is more narrowly defined here as technically empowering cities to implement measures for climate action. Lastly, information sharing is the diffusion of information and knowledge on climate action to city members and others (Bulkeley et al., 2012). The analytical framework also includes three implementation characteristics. Obligation indicates whether the use of an instrument is compulsory to members. Commitment indicates whether the instrument creates a commitment that members should respect. Lastly, directness indicates whether the TMN uses its instrument directly in cities or generates it for cities to use. Integrating nine characteristics and functions, this framework enables a more precise analysis of TMN governance practices than what the literature on TMNs has achieved so far. Because it also looks at more TMNs, it should better capture TMNs' techniques to orient cities' climate action as well as allow the identification of novel practices.

A novel instrument is a combination of governance functions and characteristics that appears in a system for the first time (Hollway et al., 2020). The TMNs with the greatest capacity to generate novelties are the ones that generate the most novel governance instruments to steer their member cities.[2] Following previous understandings of innovation in CAS (Morin et al., 2017), novelties are here considered to be novel combinations of existing elements, rather than completely new objects. The analytical framework presented above makes this article's identification of novelties much more precise than that of other studies of TMN practices.

This section has built an explanation for the emergence of novelties in TMNs, including a central hypothesis. It has also presented the analytical framework necessary to identify novelties. The next section introduces the methods used in the study to test the theory presented.

4. Material and methods

This research is based on a study of 15 TMNs. I conducted a documentary observation and interviews to collect data, and then analysed them using social network analysis and qualitative analysis.

Initially, data collection involved the selection of all the formal TMNs active in 2018 that saw climate action as crucial and included at least one European Union member. I identified a TMNs system comprising 15 TMNs, i.e CNCA, Milan Food Urban Policy Pact (MUFPP), 100RC, CoM, C40, CIVITAS, Global Compact Cities Programme (GCCP), Alliance in the Alps (AllAlps), ICLEI, Union of Baltic Cities (UBC), Energy Cities (EnCit), Climate Alliance (ClimA), Polis, Eurocities (EuCit), and Metropolis. I then identified the other actors in the system via the 15 TMNs' websites, i.e. the 2018 TMN lists of members and partners. The TMNs system is composed of 12,703 nodes and 14,057 edges. It links TMNs to their members and partners. TMN members and partners are not directly linked.

The 15 selected TMNs' current and former websites were scanned using the Internet Archive Wayback Machine (Internet Archive, 2019). I listed all the governance instruments generated by the TMNs since their launch and until 2018. Using the analytical framework presented above, I identified 535 tools, including 62 novelties. I calculated the TMNs' novelty ranking according to the number of novel instruments, i.e. first-time combinations of governance characteristics generated by each TMN. Where necessary, I considered the number of novelty points granted for each tool according to its originality.

Using the original datasets on TMNs' interactions and governance instruments, I conducted a social network analysis to determine how central the TMNs are and how diverse their contacts are. I focused on the degree centrality of the 15 TMNs for the entire network and two subgraphs to account for the amount of information TMNs attract.[3] Degree centrality is based on the number of nodes to which an actor is connected (Hafner-Burton et al., 2009). Central actors are the nodes connected to the most actors in a network. They are likely to attract more information than others. Degree centrality contains an assumption of homogeneity of a focal node's contacts (i.e. all contacts might bring the same kind of information). Other centrality measurements start questioning this assumption. For example, betweenness centrality considers the number of shortest paths that go through a node. A node is more central if it is located on a higher number of shortest paths. The number of contacts does not matter as much as their position in the network. Betweenness centrality assesses the control or the dependence of a node over the other nodes of the network, or frequent brokerage (Brandes, 2016). Thus, it facilitates the identification of nodes that appear between two communities. Betweenness centrality starts considering a focal node's diversity of contacts. Yet, in order to properly assess the significance of centrality on the one hand, and diversity on the other hand, having independent measurements of the two variables is crucial. It thus appeared best to use degree centrality to assess the amount of information to which TMNs might have access, and not their contacts' influence on their behaviour, or the kind of information these contacts might bring to TMNs. To consider the distinctiveness of the information to which TMNs might have access, I examined structural diversity (computing the number of non-redundant contacts for each TMN in the entire network) and substantial diversity (measuring the different types of contacts TMNs have and the diverse issues on which these contacts work). I compared these

[2] An analysis of the potential differences in the degree of novelty of governance instruments is beyond the scope of this article.

[3] Studying two subgraphs allowed for a closer investigation of the connections between TMNs and their members, and TMNs and their partners.

Table 1
The 15 selected TMNs[41].

TMN	Launch date	Founders	Geographical scope	Thematic scope	Number of novel instruments	Novelty ranking
CNCA	2015	Cities	Global	Carbon neutrality	0	14
MUFPP	2015	Cities	Global	Urban food policy	1	12
100RC	2013	Rockefeller Foundation	Global	Resilience	2	10
CoM	2008	European Commission (EC)	Europe	Climate change	4	9
C40	2005	Cities	Global	Climate change	6	2
GCCP	2003	City of Melbourne + UN	Global	Sustainability	2	11
CIVITAS	2002	EC	Europe	Transportation	6	3
AllAlps	1997	NGO	Alps (Europe)	Sustainability	5	6
UBC	1991	Cities	Baltic region (Europe)	Urban issues	5	5
ICLEI	1991	Cities	Global	Sustainability	17	1
EnCit	1990	Cities	Europe	Energy	4	7
ClimA	1990	City of Frankfurt	Europe	Climate change	6	4
Polis	1989	Cities	Europe	Transportation	0	15
EuCit	1986	Cities	Europe	Urban issues	0	13
Metropolis	1985	Cities	Global	Urban issues	4	8

results to the TMNs' novelty ranking.

The social network analysis was conducted on only 15 TMNs. Consequently, the results were primarily used to run correlation tests and identify specific cases that might reveal the significance of relational variables. The results were then compared to qualitative data derived from a documentary observation of TMN publications (annual activity reports, manifestos, blog posts on TMN websites, posts on Twitter) and a survey of academic literature. I conducted 18 interviews with TMN staff members, representatives of city members and partners of TMNs from 2017 to 2019.

The next section presents and discusses the results of the data analysis.

5. Results: the significance of combined relational and attribute variables in the emergence of novel governance instruments

5.1. Presentation of the 15 TMNs' governance practices

Table 1 presents the creation, scope and novelty ranking of the 15 TMNs. It shows some variation across these parameters, particularly TMNs' capacity to generate novelties. ICLEI generated the most novel instruments; Polis, a small TMN working on transportation, generated the least. Confirming other studies (e.g. Bouteligier, 2013; Román, 2010), the investigation's results identify C40 as having a high capacity to generate novelties.

Almost all TMN governance instruments tools (97%) enable information sharing; 75% of those are also designed to establish norms. 25% of the governance tools listed are designed to facilitate capacity building. This echoes previous findings on TMN governance functions (Hickmann, 2015; Andonova et al., 2009). Climate finance is often discussed in TMNs, although few tools actually offer cities funding. Similarly, direct action is a virtually non-existant feature. Fig. 1 shows that TMNs generate predominantly voluntary tools. However, rule-setting and compulsory instruments are present, 8% and 7%, respectively. Several TMNs use the same compulsory tools (statutes and manifestos), which means many adopt the novel instruments devised by others. The TMNs that adopt obligatory measures most often tend to be the youngest (GCCP, C40, CoM and 100RC). The use of constraining mechanisms is noteworthy, since the literature often shows TMNs as necessarily voluntary arrangements (Hickmann, 2015; Kern and Bulkeley, 2009).

The nine governance functions and characteristics of this article's analytical framework make the potential number of distinct combinations, and thus novelties, high. Fig. 1 displays a bipartite network representation of the 62 novelties identified and the TMNs which first generated or later adopted these novelties. It reveals that TMNs may have similar governance practices, including the use of voluntary and compulsory governance instruments. The TMNs that are close together in the graph use similar instruments. TMNs that are further apart tend to use different instruments. The instruments identified as small nodes on the outskirts of the network are tools that only a few TMNs have adopted.

5.2. The importance of centrality

Several subgraphs in the TMNs' system facilitate the detailed analysis of centrality. They highlight the relationship between centrality and the emergence of novelties, depending on the type of interactions (membership or partnership). This article focuses on the network as a whole, i.e. the connections between TMNs and their members and partners (including other TMNs). It also examines the members' subgraph, i.e. the links between TMNs and their members, and the partners' subgraph, i.e. the links between TMNs and their partners. Measuring centrality reveals several noteworthy cases (see Table 2). ICLEI, the TMN that has generated the most novelties, is the third most central node in the members' subgraph (with a score of 0.069) and the second most central in the partners' subgraph (0.186). It is the third most central overall (0.079). CIVITAS comes third for novelty ranking, fourth in the members' subgraph (0.025) and third in the partners' subgraph (0.15). It ranks fourth overall (0.035). ClimA, the fourth in the novelty ranking, is the second most central TMN in the whole network and the members' subgraph. These results suggest that there might be a positive relationship between centrality and the emergence of novelties for TMNs with a high capacity to generate novelties. The same tendency appears among TMNs lower down in the novelty ranking. EnCit, Metropolis and 100RC rank seventh, eighth and tenth, respectively, and have average centrality. The lowest ranking TMNs, CNCA and GCCP, also have low centralities in the distinct networks. However, some TMNs show centrality values that contrast with their novelty ranks. C40 ranks second in the novelty ranking, ninth in centrality in the entire network (0.011), eleventh in the members' subgraph (0.008), and tenth in the partners' subgraph (0.039). CoM ranks first in terms of centrality in all the graphs, but ninth in the novelty ranking.

Although correlation tests may only serve as plausibility probes, they are useful for analysing the relationship between the degree centrality of each TMN and their novelty rank.[5] The analysis shows correlation coefficients of 0.45 for the whole network, 0.11 for the

[5] The tests used Spearman's method, which is relevant in the analysis of rank correlations.

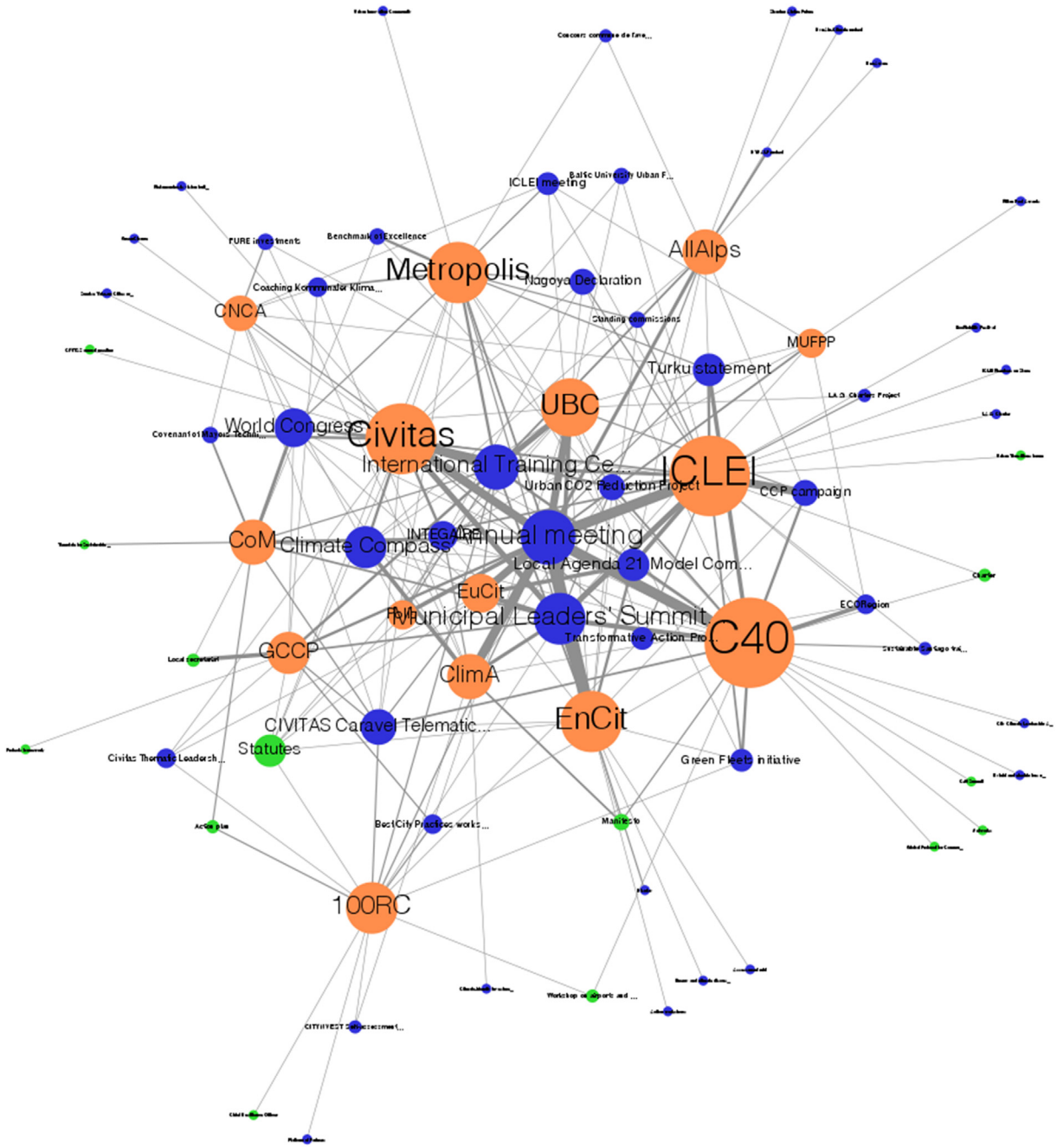

Fig. 1. Compulsory and voluntary TMN governance instruments – The orange nodes correspond to the 15 TMNs, the blue and green nodes are the voluntary and compulsory governance instruments, respectively. The size of nodes and labels is proportional to the degree of the nodes. The labels show the names of the novelties generated by TMNs. The biggest TMN nodes represent TMNs that have generated the most tools. The biggest instrument nodes are the combinations most used by TMNs. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

partners' subgraph and 0.53 for the members' subgraph. There is a much higher (strong to moderate) correlation between novelty rank and TMN centrality in the whole network and members' subgraph than between TMN centrality and novelty rank in the partners' subgraph (no significant correlation). Partners may have a less important role than members when it comes to diffusing important amounts of information and ideas for the emergence of novelties.

5.3. The significance of diverse TMN contacts

Diversity is here measured both structurally and substantially. One noteworthy structural feature is TMNs' number of exclusive contacts (i.e. that TMNs do not share with others). This is similar to Burt's understanding of non-redundancy Burt (1995). Regarding substance, I looked at the types of contacts TMNs have (i.e. cities, companies, countries, governmental agencies, global partnerships, IGOs, local governments, local government associations, NGOs, private foundations, research institutions, subnational governments, TMNs that are not part of the studied system, TMNs from the

[4] The launch date indicated in Table 1 corresponds to the year that selected TMNs began operations and potentially started to generate governance tools. It might differ from their date of creation.

Table 2
Analysis of relational and attribute variables and the emergence of novelties.

TMN	Centrality			Diversity		Attribute variables			Nov. rank
	Degree in the whole network	Degree in members' subgraph	Degree in partners' subgraph	Struct. Diversity	Subst. diversity	Age[a]	Novelties/ year	Org. resources	
CNCA	0.002	0.002	0.002	0.001	0.365	3	0	0.25	14
MUFPP	0.014	0.014	0.021	0.003	0.565	3	0.33	NA	12
100RC	0.016	0.008	0.096	0.01	0.8	5	0.4	1.01	10
CoM	1	1	1	0.722	0.815	10	0.4	0.003	9
C40	0.011	0.008	0.039	0.002	0.75	13	0.46	1.58	2
GCCP	0.008	0.008	0.01	0.006	0.385	15	0.13	0.06	11
CIVITAS	0.035	0.025	0.15	0.017	0.75	16	0.38	NA	3
AllAlps	0.021	0.022	0.003	0.016	0.4	21	0.24	0.02	6
ICLEI	0.079	0.069	0.186	0.064	1	27	0.6	0.32	1
UBC	0.008	0.007	0.018	0.004	0.535	27	0.18	NA	5
EnCit	0.016	0.015	0.054	0.005	0.7	28	0.14	0.15	7
ClimA	0.136	0.146	0.007	0.128	0.5	28	0.21	0.02	4
Polis	0.009	0.006	0.046	0.004	0.665	29	0	0.22	15
EuCit	0.02	0.011	0.123	0.007	0.915	32	0	0.39	13
Metropolis	0.015	0.012	0.06	0.008	0.785	33	0.12	0.06	8

[a] I consider TMNs' organisational age at the end of 2018, the last year for data collection relating to TMN governance instruments.

studied system or other actors that do not belong to any of these categories). I also looked at the issues on which these contacts work (i.e. climate change, energy, food security, health, resilience, sustainability, technology, transportation, urban or other issues). A substantial measurement of diversity helps determine the diversity of backgrounds, interests and views, which appears crucial to the emergence of novelties (Burch et al., 2018). These distinct indicators of diversity help determine a TMN's capacity to receive different information, which in turn facilitates the production of novelties.

Structural diversity appears to be biased against TMNs with low centrality (see Table 2). CoM has the highest centrality overall and the highest structural diversity score. CNCA has the lowest centrality score and the lowest structural diversity score. ICLEI, CIVITAS and ClimA come top for novelty ranking and also have the highest structural diversity values. Average TMNs, such as EnCit, Metropolis or 100RC, have average structural diversity scores. CNCA has the lowest centrality score and the lowest structural diversity score. A correlation test reveals a moderate correlation coefficient of 0.39 between structural diversity scores and novelty ranks. The results of the substantial diversity analysis are statistically less significant. A correlation test between substantial diversity scores and novelty ranking shows a weak correlation coefficient of 0.22. Nonetheless, ICLEI also has the highest substantial diversity score. CIVITAS and C40 score relatively high in terms of substantial diversity, yet appear below TMNs with a lower novelty rank (EuCit, CoM, 100RC and Metropolis). The diversity analysis points to cases that may confirm this article's theory.

Overall, for six of the 15 TMNs (ICLEI, EnCit, MUFPP and CNCA), the diversity measures correspond to their novelty rank. ICLEI generated the most novelties and has one of the highest diversity scores, much higher than the two TMNs that follow in the novelty ranking (C40 and CIVITAS). ICLEI appears to have contacts of the 15 types listed above, who deal with the 10 issues identified. Therefore, ICLEI has the greatest diversity of contacts in terms of substance. Structurally, it ranks third in terms of exclusive contacts (not shared with peers). At the other end of the spectrum, CNCA ranks 14th in the novelty ranking and last for its two diversity indicators. It is connected to five out of 15 distinct types of actors, which deal with four out of 10 of the issues identified.

This social network analysis points to noteworthy trends and cases regarding the relationship between centrality and diversity of contacts on the one hand, and the emergence of novelties on the other hand. To test this article's central hypothesis, an analysis of the role that actors' attributes might play is also necessary.

5.4. Time and money as additional independent variables?

This article posits that centrality and diversity might not lead to the emergence of novelties on their own. While access to more information and more diverse information may facilitate the emergence of novelties, it does not suffice per se. Specific TMN attributes should also be considered.

Organisational theories tend to see a negative relationship between age and the emergence of novelties (Le Mens et al., 2015). These conclusions do not apply to the TMNs system. Although results are mixed, Table 2 indicates that the youngest TMNs do not generate the most novelties. The highest TMN in novelty ranking, ICLEI, is one of the oldest in the system. C40, the second highest, was launched far more recently. C40 is not the youngest. Indeed, no less than four TMNs (CoM, 100RC, MUFPP and CNCA) were created after C40.

This finding is closely linked to the method for measuring novelties, which focuses on the quantity of novel tools. The most recent TMNs have had less time to produce tools, which means they are less likely to generate the most novelties. The age bias can be mitigated by looking at the average number of novelties created per year per TMN (see Table 2, novelties per year ranking). This reveals that ICLEI still has the highest capacity to generate novelties, with 0.6 tools per year since its creation. C40 also maintains its rank, with 0.46 tools per year. CoM and 100RC rank third, with 0.4 tools per year, compared to ninth and tenth in the novelty ranking, respectively. Age bias might help explain why CoM only has an average novelty rank,[6] despite having the highest centrality and diversity scores.

Another reason why older TMNs might generate more novelties is linked to the scarcity of novelties. As time goes by, it becomes harder for the system to generate novel governance characteristic and function combinations, or instruments. Novelties, as evidence of change, are hard to develop. This gives older TMNs an advantage because they started producing instruments when very few instruments had been developed, i.e. it was easier to generate new instruments. The most recent TMNs (MUFPP and CNCA) rank 12th and 14th out of 15.

With regard to organisational resources, I used the proportion of

[6] To a lesser extent, the same applies to 100RC.

staff per city member as a proxy for the TMNs' organisational resources, assuming that the cost of human resources represents a major part of their budget. While organisational theories provide ambiguous results (Löfqvist, 2017; Laosirihongthong et al., 2014; Crossan and Apaydin, 2010), organisational resources might here positively affect the emergence of novelties. Indeed, more staff may mean more resources are available for generating tools. It may also mean that more consideration is given to city members' needs, which might lead to the development of more diverse tools. More staff could mean more resources are available for exploring and exploiting the information that is received and transformed into novel tools. Given this article's method to measure novelties (the number of novel instruments weighs more than the quality of the novelty of each tool), it is probable that a TMN with more staff can generate more novel tools than one with less staff.

C40 ranks second in the novelty ranking and has the most organisational resources, with 1.58 staff per member (see Table 2). ICLEI generated the most novelties and ranks fourth in terms of organisational resources. CoM appears to have few organisational resources, which corresponds to its low novelty rank. This is noteworthy because most of CoM's relational variable scores are quite high and fail to account for its novelty rank. A few TMNs show the opposite trend. Eurocities, CNCA and Polis have a low capacity to generate novelties despite their relatively high organisational resources score. These mixed findings do not lead to the identification of a positive relationship between organisational resources and the emergence of novelties.

Attribute variables might help explain why some TMNs generate more novelties than others. However, so far the results are difficult to interpret. Besides, the results of the social network analysis, conducted only on 15 TMNs, cannot confirm the existence of a causal relationship between interactions and the emergence of novelties. To deepen the investigation of the significance of relational and attribute variables in the emergence of novelties, it is necessary to look more closely at specific TMNs. The next subsection focuses on two examples: ICLEI, a TMN with a high capacity to generate novelties; and CoM, a TMN with an average capacity.

5.5. The interplay of relational and attribute variables: examples of ICLEI and Covenant of Mayors

A deeper qualitative analysis sheds light on how relational and attribute variables influence the TMNs' capacity to generate novelties. Two examples are particularly valuable, i.e. ICLEI and CoM.

First, data confirms that ICLEI has high centrality and diversity of contacts within the TMN system. It constitutes a focal point for the Local Governments and Municipal Authorities constituency of the United Nations Framework Convention on Climate Change (UNFCCC). ICLEI collaborates with different types of non-state actors, who directly or indirectly tackle climate issues following the UNFCCC process (interviews with an ICLEI staff member and an ICLEI partner representative, December 2017 and January 2019). Like many networks, ICLEI is inclusive rather than exclusive, i.e. it is open to many kinds of members and partners. However, actors whose interests are too divergent may be avoided, since they might seek to have access to cities for purposes other than climate action (interview with ICLEI staff member, November 2017).

ICLEI staff underline that interactions in general have manifold functions. First, interactions reveal overlaps in terms of goals and membership (interviews with ICLEI staff members, November and December 2017). This is inevitable, given the increasing number of TMNs and the growing interest in working with cities at the global level (interview with ICLEI staff member, December 2017). Overlaps reveal TMNs' data exploitation processes. They can generate competition or collaboration. For instance, since TMNs often examine the same funding sources, they either compete to get the entire funding, or collaborate to share it. Competition is thus part of TMNs' interactions.

Second, as a network, ICLEI sees itself as a facilitator. It aims to bring the right actors together to tackle urban issues, according to its own norms. Given its limited internal resources, it does not present itself as an expert on every issue it tackles. Instead, it strives to partner with actors that have the expertise:

'Rather than us now trying to work as climate finance experts, we would rather look to organisations that we can partner with, to then bring in their expertise to either help the assessment of urban projects and say "how can we make this more bankable?", or try to fundraise or to bring in people who can speak the language of the financial institutions to help [cities] better understand what needs to be done.' (Interview with ICLEI staff member, December 2017).

This kind of interactions helps ICLEI gather different information, which it is likely to explore to generate novel instruments, as highlighted below.

Third, and as underlined above, there is competition for limited funding, on which TMNs depend for their work. Both exploration and exploitation appear crucial in the face of competition. Collaborating with new partners might help attract funding. Yet, TMNs need to use existing resources to dedicate time and energy to develop and manage partnerships (interview with ICLEI staff member, December 2017). Table 2 indicates that the most central TMNs have considerable organisational resources (with the notable exception of CoM). A staff member from a partner organisation that belongs to ICLEI and CoM stated that some partners 'just don't have the financial resources to spend the time to be part of an initiative' (interview with ICLEI partner representative, December 2017).

Fourth, partnerships lead ICLEI to work differently. Interactions with partners from distinct areas allow ICLEI to explore new information, which may influence its project management: 'different sectors bring different strengths, in different adventures to the table, so their having us working together, it's also affected the way the projects are being executed to the best of ability.' (Interview with ICLEI staff member, December 2017). Since funding often depends on certain rules, interactions with funding partners might influence TMNs' governance practices.

Lastly, like other TMNs, ICLEI considers that partnerships enhance its effectiveness and impact (interviews with ICLEI staff member and partner representative, November and December 2017). It sees partnerships as 'the new normal for achieving integrated, effective #climateaction.'[7]

The scores for ICLEI's attribute variables appear to correspond to its novelty rank. ICLEI started generating tools in 1990 (before its official launch in 1991), at a time when there were still few TMN climate governance instruments. It was not the first TMN in the system, although it is probably the first, along with ClimA, to have prioritised climate change, notably through its novel 1993 Cities for Climate Protection campaign (Kern and Bulkeley, 2009). TMNs evolve over time (Bouteligier, 2013). The governance tools of older TMNs, such as Metropolis and EuCit (which prioritise urban issues), and Polis and EnCit (transportation and energy), suggest they did not focus on climate change from the outset. ICLEI's age affects its interactions: 'we've been working with the cities for a long time, so we get approached a lot as well from people.'(Interview with ICLEI staff member, December 2017). Therefore, ICLEI might have developed many novelties simply because it has been in the system for longer and was operating when few governance instruments existed. Yet, when considering the number of novelties created per

[7] See ICLEI's Twitter profile page. URL:https://twitter.com/ICLEI/status/1179737880861777923 (last accessed October 3, 2019).

year (thus, eliminating the age bias), ICLEI still ranks top, with 0.6 novelties per year. While age has probably facilitated the emergence of novelties in ICLEI, it is not the most significant variable at play in ICLEI's capacity to generate novelties. ICLEI scores fourth highest for its organisational resources. It is one of the wealthiest TMNs, despite having far fewer staff per member than C40 or 100RC. The role played by organisational resources in ICLEI's capacity to generate novelties is unclear. While resources may facilitate the emergence of novelties, they appear to be less relevant than the other variables identified.

CoM is another valuable example. It stands out in the social network analysis. It has the greatest centrality, with more than 8800 members and 350 partners. It has quite a high diversity of contacts, including the highest number of exclusive contacts (to which no other TMNs are connected). This gives it high structural diversity. Its substantial diversity score is slightly lower than expected, but remains in the top third. Interviews also highlight that CoM's interactions with other actors are fundamental: 'this whole cooperation of different actors with the cities is key to the Covenant of Mayors' governance, and it's key also to enable cities to go further in doing climate action and energy transition'. (Interview with CoM staff member, November 2017). Some scholars consider that CoM is 'an institutional innovation' (Kemmerzell, 2018: 54-55) or has innovative climate governance architecture (Domorenok, 2019). In contrast to other TMNs, CoM, created by the European Commission, requires its members to strengthen their commitments to climate action. It has the capacity to aggregate its members' interests towards the European level (Kemmerzell, 2018).

Yet, CoM's novelty rank is only average, which contradicts the theory put forward. Attribute variables, especially age, shed light on CoM's poor scores in terms of relational variables. Indeed, CoM was launched in 2008, which makes it one of the youngest TMNs in the system. It has created four novelties in 10 years. In contrast, it took Metropolis 33 years to do the same. Ranking novelties per year shows that, when the age bias is eliminated, CoM ranks third, just below ICLEI and C40. If CoM had been in the system longer, it might have generated more novelties and adopted more of the novelties created by the other TMNs. A TMN that ranks low for relational variables might have a higher novelty rank than a TMN that scores high for relational variables because it is older (e.g. EnCit).

In terms of organisational resources, CoM ranks last with only 0.003 staff members per city.[8] Its limited organisational resources could also help explain why it only has an average novelty rank. Yet, this variable might be insignificant. A CoM staff member explained that CoM had a loose relationship with its cities. In contrast, other TMNs (interview, CoM staff member, November 2017) have strong relationships with their members (C40 or 100RC: interviews with Mexico City staff member and CoM city representative, July and December 2018). The documentary observation indicates that CoM uses coordinators to work with its members, i.e. numerous European public actors that provide strategic and financial support to members. Other TMNs appear to lack this type of support. Thus, if CoM coordinators provide local support to cities, they could give their staff the resources to focus on developing governance instruments for cities. In other words, the strength of some of CoM's links could allow it to concentrate its relatively few resources on generating governance tools. If this is the case, organisational resources may not matter very much.

On the one hand, the case of CoM suggests that it has the potential to generate more novelties in the future. Its recent character overrides its high relational variable scores. The weight of its interactions and its original approach suggest that it could continue to generate novelties at a fast rate. The changing context might give non-state actors more agency in global climate governance. On the other hand, some interviewees do not actually see CoM as a network, but as an initiative (interview with CoM staff member, November 2017). This might explain why it has a looser relationship with its members and why it has not generated many governance tools overall. CoM was created by the European Commission to enhance cities' climate action. It requires member cities to meet specific climate action targets. A city staff member, whose city belongs to CoM and three other TMNs of the system, stated 'The Covenant of Mayors does nothing for you. It only wants to show your data'. (Interview with CoM city representative, December 2018). Yet, other studies see CoM as a TMN (e.g. Kern, 2019). Besides, CoM fits the selection criteria presented in the methods section. It is thus considered a TMN here. CoM nonetheless appears to be a special type of network, which interacts with its city members less than most TMNs. Therefore, it may not need more governance tools. CoM's case will be worth investigating in the years to come to further test the interplay of interactions and actors' attributes in the emergence of novelties.

Overall, this example shows that while centrality and diversity are significant, they are insufficient to generate novelties. However, when combined with age, they appear to represent enabling conditions for the emergence of novelties. The role of organisational resources in this regard remains uncertain and should be the subject of more in-depth analyses.

6. Concluding discussion

In a complex global climate governance, in which more and more distinct actors interact in diverse ways, producing nonlinear effects, paying attention to actors' interactions is fruitful. Studying TMNs' interactions provides a more complete understanding of their effects (Busch, 2015). The empirical investigation presented above revealed the significance of centrality and diversity in the emergence of novel TMN governance instruments. The correlation coefficients between centrality and TMNs' novelty ranking suggested that being connected to many member cities matters more than being connected to many partners. Partners are far from insignificant, however: they account to a large degree for TMNs' diversity of contacts, which participates in explaining the emergence of novelties. A study of TMNs' interactions thus highlights the limits of the literature's traditional depiction of TMNs as public networks made by cities for cities (Pattberg, 2010). Envisioning them as hybrid structures that integrate a variety of public and private actors including IGOs, NGOs, research institutes, companies, or private foundations, might better describe TMNs. It might help better account for how non-city actors influence TMNs and their steering of cities, thus indirectly participating in urban climate governance (Papin, 2019). Here, the study of TMNs' interactions with city and non-city actors reveals how TMNs seek to steer their members and generate novel governance instruments. A deeper investigation might shed light on the source of their demands at the global level and on the politics behind urban climate policies. Identifying the distinct actors connected to TMNs may help explain why TMNs favour certain types of policies or initiatives. Likewise, it might help account for the characteristics of the governance tools they generate and adopt.

The investigation of TMN interactions and attributes does not strictly confirm this article's hypothesis. It reveals that it is the combination of centrality, diversity, and age which explains the emergence of novelties, while it shows no evidence that organisational resources play a role in the emergence of novelties. The

[8] Although the weight of the European Commission has not enabled CoM to have more organisational resources than other TMNs, it might partly explain why the TMN has so many contacts.

analysis highlights the interplay of relational and attribute variables in the rise of novelties. Paying attention to interactions does not mean ignoring actor attributes. Although being central and having the most diverse contacts in a network matters, it affects the emergence of novelties only when it is combined with having been in the network for a long time.

The analysis of TMNs' novel governance instruments helps specify their governance practices and capture their effects at the global level. The constant evolution of these practices might facilitate the system's adaptation to changes in its environment. For instance, while TMNs mostly generate voluntary instruments, recent TMNs increasingly tend to resort to obligation and rule-setting tools, which might reflect the growing demands of global climate governance. Evolving in their practices, thus enabling the system's adaptation, might help TMNs survive in a resource-constrained system in which they must prove their relevance. Well-connected TMNs, that have been in the system for a long time, may offer novel governance instruments that other actors of global climate governance might adopt. Therefore, TMNs might provide diversified governance approaches to climate issues, an important question for students of global climate governance. Overall, studying TMNs helps capture how they might help cities cooperate towards climate mitigation and adaptation. Considering TMNs involve a growing part of the global population, this kind of analysis is crucial.

This article is only a first step in the analysis of TMNs' interactions. More in-depth analyses are needed to confirm the results presented above. Comparative case studies might also help examine the causal process between interactions and the emergence of novelties. They might be applied to other kinds of transnational actors, to test whether the same process is at play in their production of novelties. Qualitative analyses might also explain unresolved cases, such as C40's. Indeed, this TMN has generated many novelties, but has low centrality and diversity scores, and was only created three years before CoM. Other factors might be at play here. Although studies on TMNs have flourished over the last 15 years, several promising avenues of research have yet to be explored. Further contributions are important to determine how TMNs, their architecture and agency affect global climate governance.

CRediT authorship contribution statement

Marielle Papin: Supervision.

Declaration of competing interest

The author declares that she has no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

I am deeply grateful to the Fonds de Recherche du Québec-Société et Culture (Grant number 2019-B2Z-255350) and Institut Hydro-Québec en environnement, développement et société for supporting this project, as well as to the reviewers of the Oran R. Young Prize and the ESG journal, and my colleagues for their valuable comments on this study. I also thank all the interviewees who gave of their time to answer my questions.

References

Acuto, M., Rayner, S., 2016. City networks: breaking gridlocks or forging (new) lock-ins? Int. Aff. 92, 1147–1166. https://doi.org/10.1111/1468-2346.12700.

Andonova, L.B., Betsill, M.M., Bulkeley, H., 2009. Transnational climate governance. Global Environ. Polit. 9, 52–73. https://doi.org/10.1162/glep.2009.9.2.52.

Bansard, J., Widerberg, O., Pattberg, P.H., 2017. Cities to the rescue? Assessing the performance of transnational municipal networks in global climate governance. Int. Environ. Agreements Polit. Law Econ. 17, 229–246. https://doi.org/10.1007/s10784-016-9318-9.

Barabási, A.-L., 2007. The Architecture of Complexity. From Network Structure to Human Dynamics. IEEE Control Systems Magazine 27 (4), 33–42. https://doi.org/10.1109/MCS.2007.384127.

Betsill, M.M., Bulkeley, H., 2004. Transnational networks and global environmental governance: the cities for climate protection program. Int. Stud. Q. 48, 471–493. https://doi.org/10.1111/j.0020-8833.2004.00310.x.

Bousquet, A., Curtis, S., 2011. Beyond models and metaphors: complexity theory, systems thinking and international relations. Camb. Rev. Int. Aff. 24, 43–62. https://doi.org/10.1080/09557571.2011.558054.

Bouteligier, S., 2013. Cities, Networks, and Global Environmental Governance. Spaces of Innovation, Places of Leadership. Routledge, New York.

Brandes, U., 2016. Network positions. Methodol. Innov. 9, 1–19. https://doi.org/10.1177/2059799116630650.

Brass, D.J., 1984. Being in the right place: a structural analysis of individual influence in an organization. Adm. Sci. Q. 29, 518–539. https://doi.org/10.2307/2392937.

Bulkeley, H., 2013. Cities and Climate Change. Routledge, New York.

Bulkeley, H., Andonova, L.B., Bäckstrand, K., Betsill, M.M., Compagnon, D., Duffy, R., Kolk, A., Hoffmann, M., Levy, D., Newell, P., 2012. Governing climate change transnationally: assessing the evidence from a database of sixty initiatives. Environ. Plann. C. 30, 591–612. https://doi.org/10.1068/c11126.

Burch, S., Hughes, S., Romero-Lankao, P., Schroeder, H., 2018. Governing Urban Sustainability Transformations. In: Elmqvist, T., Bai, X., Frantzeskaki, N., Griffith, C., Maddox, D., McPhearson, T., Parnell, S., Romero-Lankao, P., Simon, D., Watkins, M. (Eds.), Urban Planet. Cambridge University Press, Cambridge.

Burt, R.S., 1995. Structural Holes. The Social Structure of Competition. Harvard University Press, Cambridge.

Busch, H., 2015. Linked for action? An analysis of transnational municipal climate networks in Germany. Int. J. Urban Sustain. Dev. 7, 1–19. https://doi.org/10.1080/19463138.2015.1057144.

Coleman, J.S., 1988. Social capital in the creation of human capital. Am. J. Sociol. 94, S95–S120. https://doi.org/10.1086/228943.

Crossan, M.M., Apaydin, M., 2010. A multi-dimensional framework of organizational innovation: a systemic review of the literature. J. Manag. Stud. 47, 1154–1191. https://doi.org/10.1111/j.1467-6486.2009.00880.x.

Davidson, K., Gleeson, B., 2015. Interrogating urban climate leadership: toward a political ecology of the C40 network. Global Environ. Polit. 15, 21–38. https://doi.org/10.1162/GLEP_a_00321.

Domorenok, E., 2019. Voluntary instruments for ambitious objectives? The experience of the EU Covenant of Mayors. Environ. Polit. 28, 293–314. https://doi.org/10.1080/09644016.2019.1549777.

Gordon, D.J., 2013. Between local innovation and global impact: cities, networks and the governance of climate change. Can. Foreign Pol. J. 19, 288–307. https://doi.org/10.1080/11926422.2013.844186.

Granovetter, M.S., 1973. The strength of weak ties. Am. J. Sociol. 78, 1360–1380. https://doi.org/10.1086/225469.

Hafner-Burton, E., Kahler, M., Montgomery, A.H., 2009. Network analysis for international relations. Int. Organ. 63, 559–592. https://doi.org/10.1017/S0020818309090195.

Hakelberg, L., 2014. Governance by diffusion: transnational municipal networks and the spread of local climate strategies in europe. Global Environ. Polit. 14, 107–129. https://doi.org/10.1162/GLEP_a_00216.

Heikkinen, M., Karimo, A., Klein, J., Juhola, S., Ylä-Anttila, T., 2020. Transnational municipal networks and climate change adaptation: a study of 377 cities. J. Clean. Prod. 257, 120474 https://doi.org/10.1016/j.jclepro.2020.120474.

Hermville, L., 2020. Hardwired towards transformation? Assessing global climate governance for power sector decarbonization. Earth Sys. Governance, 100054. https://doi.org/10.1016/j.esg.2020.100054.

Hickmann, T., 2015. Rethinking Authority in Global Climate Governance: How Transnational Climate Initiatives Relate to the International Climate Regime. Routledge, New York.

Hoffmann, M.J., 2011. Climate Governance at the Crossroads: Experimenting with a Global Response after Kyoto. Oxford University Press, New York.

Hollway, J., Morin, J.-F., Pauwelyn, J., 2020. Structural Conditions for Novelty: The Introduction of New Environmental Clauses to the Trade Regime Complex. Int. Environ. Agreements Polit. Law Econ. 20 (1), 61–83. https://doi.org/10.1007/s10784-019-09464-5.

Internet Archive, 2019. Wayback machine. Available at: https://archive.org/web/.

IPCC, 2018. Global Warming of 1.5°C: Summary for Policymakers [SR1.5-SPM]. Intergovernmental Panel on Climate Change, Geneva.

Kemmerzell, J., 2018. Innovations in European Climate Governance and Their Impact of Local Climate Policy: An Analysis of German Major Cities. In: Hughes, S., Chu, E.K., Mason, S.G. (Eds.), Climate Change in Cities: Innovations in Multi-Level Governance. Springer, Cham.

Kern, K., 2019. Cities as leaders in EU multilevel climate governance: embedded upscaling of local experiments in Europe. Environ. Polit. 28, 125–145. https://doi.org/10.1080/09644016.2019.1521979.

Kern, K., Bulkeley, H., 2009. Cities, europeanization and multi-level governance: governing climate change through transnational municipal networks.

J. Commun. Media Stud.: J. Common. Mark. Stud. 47, 309–332. https://doi.org/10.1111/j.1468-5965.2009.00806.x.
Kim, R.E., 2019. Is global governance fragmented, polycentric, or complex? The state of the art of the network approach. Int. Stud. Rev. viz052 1–19. https://doi.org/10.1093/isr/viz052.
Labaeye, A., Sauer, T., 2013. City Networks and the Socio-Ecological Transition: A European Inventory. WWWforEurope Working Paper No. 27. WIFO Studies, WIFO, 46888.
Laosirihongthong, T., Prajogo, D.I., Adebanjo, D., 2014. The relationships between firm's strategy, resources and innovation performance: resources-based view perspective. Prod. Plann. Contr. 24, 1231–1246. https://doi.org/10.1080/09537287.2013.819593.
Le Mens, G., Hannan, M.T., Pólos, L., 2015. Age-related structural inertia: a distance-based approach. Organ. Sci. 26, 756–773. https://doi.org/10.1287/orsc.2015.0966.
Lee, T., 2013. Global cities and transnational climate change networks. Global Environ. Polit. 13, 108–128. https://doi.org/10.1162/GLEP_a_00156.
Lee, T., 2015. Global Cities and Climate Change. The Translocal Relations of Environmental Governance. Routledge, New York.
Löfqvist, L., 2017. Product innovation in small companies: managing resource scarcity through financial bootstrapping. Int. J. Innovat. Manag. 21, 1750020 https://doi.org/10.1142/S1363919617500207.
McGee, Z.A., Jones, B.D., 2019. Reconceptualizing the policy subsystem: integration with complexity theory and social network analysis. Pol. Stud. J. 47, S138–S158. https://doi.org/10.1111/psj.12319.
Mitchell, M., 2009. Complexity: A Guided Tour. Oxford University Press, New York.
Morçöl, G., 2012. A Complexity Theory for Public Policy. Routledge, New York.
Morçöl, G., Wachhaus, A., 2009. Network and complexity theories: a comparison and prospects for a synthesis. Adm. Theor. Prax. 31, 44–58. https://doi.org/10.2753/ATP1084-1806310103.
Morin, J.-F., Pauwelyn, J., Hollway, J., 2017. The trade regime as a complex adaptive system: exploration and exploitation of environmental norms in trade agreements. J. Int. Econ. Law 20, 365–390. https://doi.org/10.1093/jiel/jgx013.
Papin, M., 2019. Transnational Municipal Networks: Harbingers of Innovation for Global Adaptation Governance? Int. Environ. Agreements Polit. Law Econ. 19 (4–5), 467–483. https://doi.org/10.1007/s10784-019-09446-7.
Pattberg, P., 2010. The role and relevance of networked climate governance. In: Biermann, F., Pattberg, P., Zelli, F. (Eds.), Global Climate Governance beyond 2012: Architecture, Agency and Adaptation. Cambridge University Press, Cambridge, pp. 146–164.
Pattberg, P., Widerberg, O., 2019. Smart mixes and the challenge of complexity: lessons from global climate governance. In: van Erp, J., Faure, M., Nollkaemper, A., Philipsen, N. (Eds.), Smart Mixes for Transboundary Environmental Harm. Cambridge University Press, Cambridge, pp. 49–68.
Rogers, E.M., 2003. Diffusion of Innovations. Free Press, New York; Toronto.
Román, M., 2010. Governing from the Middle: the C40 Cities Leadership Group, vol. 10. Corp. Gov., pp. 73–84. https://doi.org/10.1108/14720701011021120
Toly, N.J., 2008. Transnational municipal networks in climate politics: from global governance to global politics. Globe 5, 341–356. https://doi.org/10.1080/14747730802252479.