Local Climate Change Plans in Brazil: The Role of Risk Management Capacity and Transnational Municipal Networks

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Resumo

As more scientific evidence emerge, governments have developed responses to climate change. Local governments have a strategic role in this new reality, recognizing their vulnerabilities and reducing risks. Understanding the factors that determine the commitment of local governments to act, however, remains a challenge for scholars. This article assesses those factors, by studying Risk Management Capacity (RMC) and the role of Transnational Municipal Networks (TMN) to promote climate adaptation policy in Brazilian municipalities. We examined information on RMC and participation in Local Governments for Sustainability (ICLEI), as well as the existence of climate change plans. Statistical analyzes showed that municipalities with larger populations are more likely to develop climate change plans. In addition, not only the presence of TMNs is important, but the period a municipality has a partnership with the TMN also presented a significant result in the proposed model. Surprisingly stronger RMC does not imply more likelihood to develop climate change plans. In a textual analysis, we also argue that the plans to combat climate change in Brazilian cities are still insufficient, in addition to not always discussing adaptation.

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Abstract

As more scientific evidence emerge, governments have developed responses to climate change. Local governments have a strategic role in this new reality, recognizing their vulnerabilities and reducing risks. Understanding the factors that determine the commitment of local governments to act, however, remains a challenge for scholars. This article assesses those factors, by studying Risk Management Capacity (RMC) and the role of Transnational Municipal Networks (TMN) to promote climate adaptation policy in Brazilian municipalities. We examined information on RMC and participation in Local Governments for Sustainability (ICLEI), as well as the existence of climate change plans. Statistical analyzes showed that municipalities with larger populations are more likely to develop climate change plans. In addition, not only the presence of TMNs is important, but the period a municipality has a partnership with the TMN also presented a significant result in the proposed model. Surprisingly stronger RMC does not imply more likelihood to develop climate change plans. In a textual analysis, we also argue that the plans to combat climate change in Brazilian cities are still insufficient, in addition to not always discussing adaptation.

Keywords: Local Governments, Risk Management Capacity, Transnational Municipal Networks, Adaptation, Climate Change, ICLEI.

1. Introduction

Global warming and its risks to life on Earth are already on the world's political agenda. According to the Intergovernmental Panel on Climate Change (IPCC), the Earth's temperature is likely to reach 1.5ºC between 2030 and 2052 if it continues to increase at the current rate (IPCC, 2022). This scenario emphasizes the strategic role of urban centers, which must recognize their vulnerabilities, reduce risks and create resilient infrastructure (UN-HABITAT III, 2016). In the Brazilian context, the impacts of climate change directly afflict the urban population, especially because much urban development is built in at risk areas (Castello, 2011)

In this new scenario of synergy between climate change and cities' vulnerabilities, there is ample literature to investigate the management of such problems using different approaches, such as planning resilient cities (Folke et al., 2002; Heinzlef et al., 2020; Iturriza et al., 2020; Zhang & Li, 2018), disaster risk reduction (Forino et al., 2017; Hardoy et al., 2011; Ribeiro et al., 2022; Sanderson, 2000), the role of partnerships (Heikkinen et al., 2020; Zahran et al., 2008)

and adaptation policies (Birchall & Bonnett, 2021a; Forino et al., 2017; Nicolletti et al., 2020; Pasquini et al., 2015; Wise et al., 2014). The driving discussion of this working paper refers to the Risk Management Capacity (RMC) and the role of Transnational Municipal Networks (TMN) in the development of adaptation, which are now widely recognized as evidence of its impact on social and natural system while greenhouse gas emissions continue unabated (Wise et al. , 2014).

The Risk Management Capacity (RMC) of a municipality is intrinsically connected to their autonomy to plan and implement public policies focused on aspects to avoid and mitigate disasters, such as land use and urban planning. We argue that not only is local governance seen as particularly important component to develop robust responses, but also the advancement of partnerships with TMNs, which can bring knowledge and resources to tackle climate change. RMC and TMNs are essential concepts for this work and which will be discussed further ahead. Thus, this working paper intends to contribute with the urgent global debate about climate change and local governance with the following research question: *how local Risk Management Capacity and the presence of Transnational Municipal Networks foster awareness of climate change risks in Brazilian municipalities?*

The importance of the study is underlined by three areas of contribution. First, most adaptation studies are composed of case studies. Considering the diversity of the Brazilian space, more comprehensive quantitative studies are essential to better understand adaptation in Brazil (Di Giulio et al., 2018). Second, this will be the first study that will combine statistics and text analysis techniques to analyze a full range of available reports, whether they are prepared by municipalities themselves or with partnerships. Finally, the study is part of interconnected global agendas, which are important for practice, namely: the Paris Agreement, which aims to limit the global temperature below 1.5ºC (UNFCCC, 2015), and the 17 UN Sustainable Development Goals (SDGs).

This work will be organized as follows. Firstly, it discusses the concepts necessary to carry out the research, namely: Risk Management Capacity (RMC), Transnational Municipal Networks (TMN), and adaptation to climate change. Second, the study collects official climate change plans or projects of all Brazilian municipalities, explains the methodology and the required variables for analysis to understand why some municipalities act to tackle climate change and others not. Then, statistical results will be presented, in addition to a supplementary content analysis, which will help to understand the space that ‘adaptation’ occupies in climate change plans. Finally, we present the preliminary discussions, as well as limitations and future directions.

2. Conceptual Overview

2.1. Risk Management Capacity (RMC)

Climate change is a multidisciplinary debate, which needs to involve not only the environmental and sustainability dimensions, but also other aspects such as urban development and risk reduction. For example, the results of a study on Brazil (Regina Alvalá et al., 2019) show that disasters materialize at the local level, resulting in loss of lives, houses and infrastructure. It also affects other areas such as health and education in municipalities (Hardoy et al., 2011). In this sense, actions that lead to risk reduction need to be taken at the management and policy level of the city (Sanderson, 2000) since, according to Hardoy et al. (2011, p. 401), "most issues of land use management, regulation and provision of services and infrastructure fall on local governments".

Risk Management Capacity (RMC) at the local level also depends on the coordinated action of different sectors. Studying urban spaces in Latin America, Hardoy et al. (2011) concluded that there is a growing tendency to integrate disaster risk reduction as a cross-cutting issue in many different government policies. However, according to the author, a key factor contributing to the improvement of RMC is the occurrence of several major disasters in the region. Along the same lines, Ribeiro et al. (2022) argues that the capacity of a municipality is also related to local laws, the main economic sectors and the size of the municipality.

Considering that each city's adaptation efforts will be affected by how urgent the threats of climate change are (Araos et al., 2016), we argue that not only the understanding of disaster risk and all its dimensions – e.g. exposure to danger, vulnerability and responsiveness – is essential for disaster risk management (UNISDR, 2015), but urban spaces that improve in terms of RMC are likely to be the best prepared to face the challenges of climate change and the necessary adaptation actions (Hardoy et al., 2011).

2.2. Interactions with local government: the role of Transnational Municipal Networks

''Partnerships'' according to Lasker et al. (2000, p.180) ''enable different people and organizations to support each other by leveraging, combining and capitalizing on their complementary strengths and capabilities''. The role of coordinated partnerships with local governments is extensively studied in the literature (e.g., Andrews & Entwistle, 2010; Beisheim et al., 2014; Williamson et al., 2000). Andrews and Entwistle (2010) explored the advantages of partnerships with local governments and, according to the authors, the private sector is widely considered to enjoy a range of resources that can benefit the provision of public services, such as accessing funds for capital investment, reaping economies of scale, gaining

managerial, technical or professional experience, provide more flexible services, share risks and benefit from less "red tape". Partnering with non-profit or voluntary organizations, in turn, is seen as a way to lead to more equitable public service outcomes. The main idea is that partnerships with local organizations generate better policies that meet local needs and increase opportunities for social inclusion, especially if they are able to build empirical legitimacy at the local level and if its institutional design ensures adequate monitoring (Beisheim et al., 2014; Williamson et al., 2000).

Regarding climate change, there are several TMNs to help cities around the world deal with this challenge. The oldest one, Local Government for Sustainability (ICLEI), founded in 1990, presents a more diverse climate agenda, is open to smaller urban areas and works on general sustainability themes (Heikkinen et al., 2020). Since TMNs focus on learning, informing members about best practice methods, and representing municipalities at national, continental and international levels and at climate forums (Bulkeley, 2010) it is expected that Brazilian municipalities working with a TMN show more commitment and awareness of climate change risks. This has a potential impact on increasing the RMC, as cities learn from each other (Zambrano-Guitierrez and Puppim de Oliveira, 2022).

2.3. Adaptation to Climate Change

Brazil adopted Law No. 12,187/2009 for the National Policy on Climate Change (PNMC) seeking to ensure that economic and social development contribute to the protection of the global climate system. In its Article 5, the law determines as a guideline "the adaptation measures to reduce the adverse effects of climate change and the vulnerability of the environmental, social and economic systems" (Brasil, 2009). Adaptation, in turn, is defined by the law as "initiatives and measures to reduce the vulnerability of natural and human systems in view of the current and expected effects of climate change". In 2016, Brazil instituted the National Plan for Adaptation to Climate Change (PNA), which aims to promote coordination and cooperation between public bodies to manage the risk associated with climate change through participatory processes with society, and to identify and propose measures to promote adaptation and the reduction of the risk associated with climate change (Brasil, 2016).

The existing literature on urban vulnerability and climate change adaptation generally focuses on individual cases and highlights different mechanisms and stakeholders that are important in this challenge (e.g. Birchall & Bonnett, 2021; Cloutier et al., 2018; Nalau et al., 2015). Regarding Brazil's climate change adaptation scenario, studies usually conclude that the country's progress in this regard was insufficient in the face of risk. For example, the profile of

six Brazilian subnational government policy responses to climate change – Belo Horizonte (MG), Feira de Santana (BA), Palmas (TO), Recife (PE), Rio de Janeiro (RJ) e São Paulo (SP) – showed that, of the places with climate policies, not all included the two main aspects, i.e. mitigation and adaptation. (Barbi & da Costa Ferreira, 2017). Di Giulio et al. (2019), considering six cities – Natal (RN), Manaus (AM), Porto Alegre (RS), Vitória (BA), Curitiba (PR) and São Paulo (SP) – analyzed a set of dimensions that affect the capacity of local governments to advance adaptation and assesses constraints on adaptation across the municipal level. The authors concluded that factors such as the disconnection between sectoral policies – e.g. risk mapping – , the lack of definition of responsibilities and priorities, and the bureaucratic perspective hinder the capacity of these cities to employ resources and promote the integration of adaptation as a central theme in development planning.

3. Methodology and Variables

The research aims at understanding the role of TMNs and RMC in determining the likelihood of a municipality to act to combat climate change through specific climate-related plans and projects. Brazil is an interesting country to research climate change adaptation at the local level, as it has 5,570 municipalities with significant policy autonomy.

The first phase of analysis corresponds to a binary logistic regression model in order to estimate the odds of a municipality to have a climate change plan or a general plan that discusses in depth the adaptation aspect according to the following equation:

$$Y_i = \alpha + \beta_1 RMC_i + \beta_2 TMN_i + \beta_3 Disasters_i + X_i + \varepsilon_i$$
$$(\beta_2 TMN\_time_i)$$

where Y_i indicates a dichotomous variable for the presence of a climate change plan or project[1] in municipality i; α denotes the constant; $\beta_1 RMC_i$ is a quantitative variable that indicates the RMC of a municipality i; $\beta_2 TMN_i$ is a dichotomous variable that receives the value of 1 if the municipality i participates in a TMN and zero otherwise; $\beta_3 Disasters_i$ is a quantitative variable that receives the total of disasters faced by municipality i, if any; X_i is a set of municipality characteristics; and ε_i is the random error term for a municipality i. We also conducted the same logistic regression considering the quantitative variable TMN_time_i, representing the time that municipality i participates in a TMN. Given the extent of the Brazilian territory with more than 5,000 municipalities, only municipalities with more than 100,000

[1] Previous literature has already shown that climate change plans - specifically, adaptation plans - are scarce in Brazil (Barbi & Da Costa Ferreira; Di Giulio et al). In this scenario, we chose to increase the scope of the survey, so that municipalities that developed other plans, such as Vulnerability Analysis, Risk Mapping, Ecosystem-based Adaptation Projects, among others (See Table 2), received value 1 for the dependent variable.

inhabitants were selected – a total of 326 municipalities, as this will comprise of a homogeneous group of municipalities. Table 1 summarizes all variables and their sources, and Table 2 presents the plans separated by type, adapted from Unnikrishnan & Nagendra, (2021).

The second step of the analysis concerns the use of corpus analysis techniques of the plans publicly available. Qualitative corpus analysis is a methodology to pursue in-depth investigations of linguistic phenomena, allowing researchers to access, highlight and explore linguistic phenomena that become easily discernible over thousands of words (Hasko, 2012). According to the author, the benefit of mixing quantitative analysis with the interpretive power of qualitative methodology is uncontestable. The use of corpus analysis techniques will focus on the identification of important points in the documents, especially related to the theme of adaptation[2] to climate change. It is important to mention that the intended textual analysis involves pre-processing techniques known as tokenization and removal of stop words[3]. A preliminary visualization of this step will be presented ahead.

Table 1

Variables and data sources.

Variable name	Explanation	Source
Climate Change Municipal Plan	Measured dichotomously. A municipality receives a score of 1 if it has a municipal climate change plan and zero otherwise. It is difficult to identify adaptation since there is no specific metric (Dupuis & Biesbroek, 2013; Ford et al., 2013; Ford & Berrang-ford, 2016). Thus, while the availability of reports is an imperfect proxy, it can be used to identify trends in adaptation action and planning (Araos et al., 2016; Berrang-ford et al., 2014; Ford et al., 2013; Reckien et al., 2014; Gagnon-Lebrun and Agrawala, 2007).	Documents were searched city by city using the Google search engine in two steps: i) through the municipal website and their environmental secretariats; and ii) Google search using the name of the city and the terms 'climate change' (see Table 2).
RMC - Risk Management Capacity	Total of the municipality's positive responses to questions focusing on the following areas: planning instrument and legislation, management of disasters resulting from floods, management of disasters resulting from landslides, institutional bodies, information from the Municipal Civil	2020 Municipal Basic Information Survey developed by the Brazilian Institute of Geography and Statistics (MUNIC - IBGE).

[2] As mentioned previously, Brazilian law number 12,187/2009 defines adaptation as "Initiatives and measures to reduce the vulnerability of natural and human systems in view of the current and expected effects of climate change." (Brazil, 2009). Thus, different related terms will be investigated in addition to 'adaptation', such as 'vulnerability', 'risks' and 'resilience'.

[3] First, *tokenization* consists of splitting the document into sentences and then into words. The *'stop words'* can be added as much as possible so that the words that are not of any value such as "the" or "a" are filtered and removed before the data processing. This ensure that we get useful words as output.

	Defense and Protection Coordination (COMPDEC) and educational practices. In all, there were 48 questions to the municipalities, so the RMC of a municipality ranges from 0 to 48.	
Number of disasters	The total number of disasters faced by municipalities from 2013 to 2016, since they are a key factor in the prioritization for better urban management and adaptation (Hardoy et al., 2011)	Integrated Disaster Information System (S2ID).
TMN - Transnational Municipal Networks	Measured dichotomously. A municipality receives the value of 1 if the municipality is part of the ICLEI network and zero otherwise. ICLEI network was chosen because it is open to small urban areas and is present in several Brazilian municipalities. 44 of the 326 municipalities participate in ICLEI.	ICLEI website.
Time of partnership with TMN	Total time that the municipality has been a partner of the ICLEI network. Measured through the difference between 2021 and the year of accession between the parties.	ICLEI Website.
GDP per capita	Total GDP divided by the total population in a municipality.	Municipal Basic Information Survey developed by IBGE – 2019.
Population	Total population of a municipality.	Municipal Basic Information Survey developed by IBGE – 2019.

4. Results

Table 3 presents descriptive statistics and independent sample t-test results in order to understand the differences between municipalities that have plans or projects related to climate change and those that do not. It is possible to observe that municipalities that have plans are quantitatively different from those that do not in relation to population (t = -2.85, p<0.05) and the time of partnership with the ICLEI network (t = -3.83, p<0.05). A previous chi-square test also showed that the presence of climate change plans is not independent of network membership (χ^2 = 44.17, p<0.05). Surprisingly, number of disasters and RMC do not have significantly different averages between municipalities that have plans and those that do not.

Table 4 reports the results of our logistic regression model, showing the odds ratio estimating the propensity of a municipality to have a climate change adaptation plan or a general plan that discusses adaptation. Most of our explanatory variables, although presenting the expected positive sign in relation to the municipality's propensity to have a climate change plan, did not present significant results[4], with the exception of the control variable *population* (*exp* 1.000, p<0.001) and one of the variables of interest, *TMN_time* (*exp* 1.111, p<0.05). A

[4] It is important to note that, even when dividing the risk management capacity by clusters as shown in Table 1 (planning instrument and legislation, management of disasters resulting from floods, management of disasters resulting from landslides, institutional bodies, information from the Municipal Civil Defense and Protection Coordination (COMPDEC) and educational practices), *RMC* did not present any significant results (p>0.05) for the propensity of the municipality to have a climate change plan or not.

significant result for population suggests that a municipality with a greater population is more likely to have a plan to combat climate change, while, for time with TMN, a unit increase in time significantly boosts the odds of the existence of a climate change plan. Thus, not only the presence of a TMN partnership is sufficient to influence the development of a plan, but also the time of partnership between the parties. Although there are municipalities that have developed a plan or project even with a short time of partnership, most municipalities in the database already have a significant follow-up time, as is the case of Sorocaba/SP (10 years) and Curitiba/PR (29 years).

Table 2

Brazilian municipalities that have municipal climate change plans or a more general plan that discusses the climate change topic.

Type of Plan	Cities	Plan title
Resilience Strategies	Porto Alegre/RS	Porto Alegre Resilience Strategy (2016)
	Curitiba/PR	Actions and Strategies: Climate and Resilience (2016)
	Salvador/BA	Resilient Salvador (2019)
	Americana/SP Embu das Artes/SP Francisco Morato/SP Guaratinguetá/SP Guarulhos/SP Itanhaém/SP Praia Grande/SP São José do Rio Preto/SP São Vicente/SP	Resilient São Paulo Municipalities Project (2020)
	Teresina/PI	Diagnosis of Urban Resilience (2021)
Environmental Reports[5]	Eunápolis/BA	Municipal Plan for the Conservation and Recovery of the Atlantic Forest (2016)
	Paranaguá/PR	Municipal Plan for the Conservation and Recovery of the Atlantic Forest (2020)
	Guarujá/SP	Municipal Plan for the Conservation and Recovery of the Atlantic Forest (2021)
City Development Plans	Palmas/TO	Action Plan - Sustainable Palmas (2015)
	Diadema/SP Mauá/SP Ribeirão Pires/SP Santo André/SP São Bernardo do Campo/SP São Caetano do Sul/SP	ABC Consortium - Action Plan to Combat Climate Change (2017)
	Curitiba/PR	PlanClima - Climate Change Mitigation and Adaptation Plan (2020)
	Fortaleza/CE	Local Climate Action Plan (2020)
	Recife/PE	Local Climate Action Plan (2020)
	Rio Branco/AC	Municipal for Mitigation and Adaptation to Climate Change of Rio Branco (2020)

[5] Due to the specific law for the protection of the Atlantic Forest (Law 11.428/2006, regulated by Decree 6660/2008), which provides for the use and protection of its native vegetation, several municipalities act in the implementation of the Law through the Municipal Conservation and Recovery of the Atlantic Forest – PMMA. However, for the present work, only municipal plans that discuss the topic of Climate Change and Ecosystem-based Adaptation (EBA) were selected.

	Salvador/BA	Climate Action Plan (2020)
	São Paulo/SP	PlanClima SP - São Paulo Climate Action Plan (2020)
	Atibaia/SP	Urban Afforestation Pilot Project (2021)
	Cachoeiro de Itapemirim/ES	Municipal Plan for Drainage and Management of Urban Rainwater (2022)
	Santos/SP	Santos Municipal Climate Change Plan (2022)
	João Pessoa/PB	Climate Action Plan (Ongoing, until 2022)
Disaster Management Plans	Belo Horizonte/MG	Analysis of Vulnerability to Climate Change in the Municipality of Belo Horizonte (2016)
	Rio de Janeiro/RJ	Strategy for Adaptation to Climate Change in the City of Rio de Janeiro (2016)
	Recife/PE	Climate Risk and Vulnerability Analysis and Adaptation Strategy of Recife Municipality (2019)
	Fortaleza/CE	Climate Change Vulnerability Index and Adaptation Plan (2020)
	Curitiba/PR	Climate Risk Assessment of Curitiba city (2020)
	Sorocaba/SP	Sorocaba Climate Risk Analysis (2020)
	Betim/MG	Betim Climate Risk Analysis (2021)
	Brasília/DF	Plan to address the adverse impacts of global climate change to reduce vulnerabilities and expand adaptation in the Federal District, with a special focus on extreme weather events related to water resources and extreme temperatures.
	Manaus/AM	Manaus Metropolitan Region and Climate Change (2022)

Table 3

Descriptive statistics and average comparisons for municipalities that have plans or projects related to climate change

Variables	*Presence of Climate Change Plan or Project*	*N*	*Mean*	*Std. deviation*	*Std. error*	*Mean difference*	*t*	*p-value*
Population	1	37	1,315,850	2,268,899	373,004.80	-1,062,242	-2.85	*p<0.05*
	0	289	253,608	216,976	12,763.31			
lnPIB per capita	1	37	9.92	0.78	0.13	-0.14	-1.04	p>0.05
	0	289	9.78	0.61	0.04			
Number of Disasters	1	37	2.19	2.16	0.35	-0.02	-0.04	p>0.05
	0	289	2.17	3.70	0.22			
Total RMC	1	37	8.70	7.27	1.20	0.33	0.26	p>0.05
	0	289	9.04	7.67	0.45			
Time with TMN	1	37	6.21	9.00	1.48	-5.70	-3.83	*p<0.05*
	0	289	0.52	2.25	1.13			

Note: Unequal variances are assumed for all variables.

Table 4

Binary logistic regression coefficients estimating the chances of municipalities having a climate change plan.

	Model 1 **Odds Ratio**	Model 2 **Odds Ratio**	Model 3 **Odds Ratio**	Model 4 **Odds Ratio**	Model 5 **Odds Ratio**
Presence of Plans or Projects					
Population	1.0000***	1.0000***	1.0000***	1.0000***	1.0000***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
lnPIB per capita	1.6727	1.7371	1.7238	1.5622	1.5576
	(0.4996)	(0.5202)	(0.5183)	(0.4879)	(0.4829)
Total RMC		0.9736	0.9728	0.9744	0.9750
		(0.0279)	(0.0279)	(0.0282)	(0.0284)
Number of disasters between 2013-2016			0.9629	0.9585	0.9722
			(0.0737)	(0.0767)	(0.0733)
TMN				2.5845	

membership				(1.3569)	
Time with TMN					1.1114* (0.0564)
N	326	326	326	326	326
r2	0.237	0.241	0.243	0.256	0.261

Exponentiated coefficients; Standard errors in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Next, in order to visualize the content analysis of the plans, we plotted a Word Cloud that provides an overview of the words that appear most frequently in the municipalities' plans. Figure 1 presents the word distribution after pre-processing techniques. It is possible to observe that, although there is an emergency in the topic, adaptation (adaptação, in Portuguese, in the center of the figure) is not a word that is strongly present in climate change reports. As an example, the Porto Alegre Resilience Strategy plan, after pre-processing, has a total of 15,529 words, and words referring to 'adaptation' and 'vulnerability' appear only 7 and 12 times, respectively. The word emissions (emissões, in Portuguese, on the left side of the figure), in turn, appears more frequently, corroborating previous studies that showed that plans in Brazil are incomplete in terms of the two necessary dimensions (Barbi & da Costa Ferreira, 2017). However, it is important to note that, although also infrequently, words related to adaptation also appear in the documents, such as "risk" (risco), "vulnerability" (vulnerabilidade) and "drainage" (drenagem). Future steps of the present work will qualitatively study some specific plans in order to present a more robust discussion.

Figure 1

Word Cloud of all municipal climate change plans

4. Discussion and Future Directions

The strategic role of cities in combating climate change is increasingly highlighted in the literature and in international reports. Considering the extension and diversity of the Brazilian territory, it is important to assess how cities are dealing with this challenge, especially in the face of more frequent climate risks. To assess this situation is the main focus of this working paper. We have three main points of analysis, which are discussed below.

Size of the Local Government Matters

Our statistical results showed that there is a significant relationship between the population of the municipality and their propensity to have plans or projects regarding climate change. The role of the size of municipalities is not only coherent because climate impacts are more visible in large urban spaces, but it has also been discussed in the literature (Schneider et al., 2021; van den Berg & Coenen, 2012). Schneider et al. (2021), for example, found that, in 85 German cities, the set of planning instruments related to adaptation increases with the size of the city. A possible explanation for this occurrence, according to the authors, is the better administrative structure and financial resources of larger cities. Added to this result are the results of Birchall & Bonnett (2021b), which claim that the implementation of planning policies in small towns can be limited by several factors, such as: financial, technical resources and legal mechanisms.

Surprisingly, the occurrence of disasters did not present a significant result in our model, contrary to previous studies (Hardoy et al., 2011; van den Berg & Coenen, 2012). However, it is important to highlight a finding by van den Berg & Coenen (2012) in which, in the municipality of Rijssen-Holten, in the eastern Netherlands, shortly after being hit by severe storm floods, there was a complete review of the urban drainage system. However, in the process, climate change itself was not considered, suggesting that, in terms of adaptation, proactive behavior is less likely than post-event measures (p. 456). This possibility opens a window for future research in Brazilian municipalities.

The Role of Transnational Municipal Networks

Our results showed that the time of partnership with a TMN matters for the presence of climate change plans or projects in the municipalities. The importance of partnerships corroborates the findings of other scholars, who show that network members are more likely to initiate actions to combat climate change, mainly due to the exchange of knowledge that such partnerships provide (Frantzeskaki et al., 2019; Heikkinen et al., 2020).

More specifically in relation to the role of ICLEI, Frantzeskaki et al. (2019) identified three role patterns that ICLEI fulfills: knowledge role, through translation, education and integration of municipalities with sustainability debates; relational role, through connection and mediation between cities and important events; and game-changing roles, co-creating with municipalities. Furthermore, the main outcomes of such roles are seen in building the municipality's capacity to integrate scientific concepts into city planning policies. In summary, networks have the potential to support urban adaptation but, according to Heikkinen et al., (2020), there is still room for improvement, since TMNs need to encourage adaptation even more, especially in developing countries.

The Links with Risk Management Capacity

The role of RMC was also not significant in our model. The result is surprising because, according to the literature, local governments are currently considering climate change as part of a comprehensive risk management framework (Gagnon-Lebrun & Agrawala, 2007). However, especially when we talk about adaptation, scholars point out that there is a problem of policy integration (van den Berg & Coenen, 2012). Through interviews, van den Berg & Coenen (2012) noted that water, spatial planning and environment sectors were familiar with climate change and its impacts, but few saw direct links between such impacts and adaptation (p. 453).

Finally, considering that the ability of local governments to adapt to climate change is influenced by the availability of personnel, knowledge and financial resources (Birchall & Bonnett, 2021b), we argue that a possible avenue for future research is to analyze specific sectors that compose the RMC of municipalities in order to understand their relevance in the development of adaptation policies.

5. Limitations

We believe the work will have theoretical and practical implications and may serve as an aid to policymakers in this urgent debate, especially in developing countries. Nevertheless, like all research, this has some limitations. First and most importantly is that there is still no specific measure to analyze adaptation to climate change in municipalities since it involves several important sectors for local development. Thus, it was decided to start an analysis based on what is found publicly – the municipal reports. Although such analysis is an advance in the academic literature, we can say little about the implementation of such adaptation guides.

The second limitation that we have is that we only work with one TMN. As ICLEI is the largest network and is present in many municipalities in the national territory – whether

large or small municipalities – we chose to work with their presence as a partnership. However, authors have already argued that being a member of several networks is associated with higher levels of adaptation planning (Heikkinen et al., 2020). Finally, the last biggest limitation is the amount of information we have, since it is little discussed at the local level. As a result, few municipalities produce climate change reports, which makes analysis difficult for a country as large as Brazil. Future research may investigate the adaptation debate and its mechanisms in Brazilian cities involving other sectors of urban development – e.g. water, sanitation, urban planning, vulnerable population, among others – and search for adaptation measures in the planning of other areas of development. Future research should continue studying the role of these variables in Brazilian municipalities and bring more robust results in future analyses.

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