More than planning: Diversity and drivers of institutional adaptation under climate change in 96 major cities

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A B S T R A C T

A key challenge for effective, ongoing urban climate adaptation is to adapt institutions within urban governance. While an extensive foundation of empirical knowledge on urban climate adaptation has accumulated over the last decade, our image of institutional adaptation continues to be dominated by a focus on planning. Whilst understandable, this can obscure a fuller range of areas in which institutional adaptation to climate change is being pursued. Furthermore, methodological path dependency in large-N analysis via a common focus on analyzing formal planning documents risks a skewed perspective as such documents may only offer a partial view. Building on the rich range of work to date assessing climate adaptation in cities, and notwithstanding continued major gaps such as in small-medium cities, we now need to find ways to examine the diversity of institutional adaptation occurring in practice, and to comparatively draw on the situated interpretive knowledge of case experts within individual cities to do so. With this aim in mind, this paper explores institutional adaptation in a specific domain (urban water) in a sample of 96 major cities across six continents through a survey of 319 case experts, examining the diversity of institutional adaptation across contexts and exploratively probing its drivers. Findings show that multiple forms of institutional adaptation are being jointly pursued in cities across all continents, leaning towards 'softer' rather than 'harder' forms, but nonetheless revealing a wide range of activity. Patterns in drivers suggest a political explanation for institutional adaptation (e.g. involving change agents and political pressure) rather than a rational one (e.g. involving response to climate-related risks and/or extreme events). Overall, there is a need to combine parsimony with expanded interpretive sensibility in advancing large-N research on institutional adaptation diversity in comparative perspective.

1. Introduction

A key challenge for effective, ongoing urban climate adaptation is to adapt institutions (i.e. rules and arrangements structuring decision-making) within urban governance (Anguelovski and Carmin, 2011; Aylett, 2015; Birkmann et al., 2010; Carmin et al., 2012a; Hughes and Sarzynski, 2015; Patterson and Huitema, 2019). While an extensive foundation of empirical knowledge on urban climate adaptation has accumulated over the last decade spanning technical, economic, and institutional dimensions, our image of institutional adaptation typically centers on (formal) planning. This is reflected by an often almost synonymous conflation of urban adaptation *with* planning, and thereby an implicit downplaying of the diverse ways in which institutions may be adapted over time within multi-actor urban governance settings. Furthermore, climate change adaptation does not occur on a blank slate but, rather, within complex governance arenas (Ajibade et al., 2016;

Anguelovski et al., 2014; Aylett, 2015; Bhardwaj and Khosla, 2020; Chu, 2016; Khosla and Bhardwaj, 2019; Patterson et al., 2019; Roberts et al., 2020; Taylor, 2016) that tend to be structured around existing issue areas. The common focus in the literature on adaptation planning is understandable since planning is a key mechanism available to municipalities act on climate change, but the range of institutional adaptation being pursued is likely to be much wider.

Three key challenges arise in apprehending institutional adaptation in cities. First, there is an empirical challenge in looking beyond planning in a systematic way. Institutions are complex, and institutional adaptation may occur in multiple areas (e.g. legal frameworks, policies, implementation instruments, organizational setups, coordination arrangements) (Anguelovski and Carmin, 2011; Burch, 2010; Carmin et al., 2012a; Hughes and Sarzynski, 2015; Noble et al., 2014; Patterson and Huitema, 2019), but these are typically either approached separately or not clearly distinguished. We need a comprehensive frame to

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systematically examine multiple forms of institutional adaptation, whilst also recognizing the potential for causal differences between them. At the same time, sharpening the study of institutional adaptation arguably requires focusing on particular issue areas (e.g. water, health, mobility, urban form) rather than maintaining a broad view of all areas of urban climate adaptation simultaneously (building on the pioneering first wave of exploratory research on this topic, such as Aylett, 2014; Carmin et al., 2012b; Tompkins et al., 2010). While cities may create specific bodies for adaptation (e.g. dedicated departments), urban adaptation is also deeply enmeshed with existing issue areas (or policy domains) where much of the adaptation work is likely to occur.

Second, there is a methodological challenge in looking beyond formal planning documents in large-N analysis to make better use of the situated interpretive knowledge of case experts. A large body of formative work has been conducted in recent years through analyzing secondary documents, especially climate-related plans (e.g. Aguiar et al., 2018; Araos et al., 2016; Heidrich et al., 2016; Olazabal et al., 2019; Reckien et al., 2018), which is an invaluable first step for understanding urban climate adaptation activity and progress. However, we are now at the point where such an approach risks become path dependent, because formal documents can only offer a partial (and even sanitized) perspective on urban adaptation, especially concerning institutional and political changes which are often not fully documented. There are limits on the extent to which such deeper insights can be gained based solely on corpuses of secondary documents. We therefore need to find ways to comparatively draw on the primary knowledge of case experts about complex variable constructs leveraging situated judgments about adaptation activities. This remains an under-utilized source of data in large-N urban climate adaptation scholarship.

Third, there is a theoretical challenge in explaining the diversity and drivers of institutional adaptation across varying contexts, given that urban adaptation theory as a whole is still relatively nascent and often (necessarily) draws on a broad range of social and political theories (e.g. Dilling et al., 2017; Knieling, 2016; Lesnikowski et al., 2020; Patterson et al., 2019; Penning-Rowsell et al., 2017). More broadly, in a recent review of adaptation effectiveness in general, Owen (2020) identified the topic of strengthening institutions as relatively under-addressed. While much work to date on institutions in climate adaptation emphasises capacity (e.g. Engle and Lemos, 2010; Gupta et al., 2010), this is often limited to treating institutions as an independent rather than dependent variable, and often views institutions in a relatively undifferentiated way. This suggests a key need for exploratory analysis of institutional adaptation diversity. But such analysis should also bring to bear existing conceptual and empirical insights (e.g. to probe the relations between contexts, drivers, and outcomes) in order to lay groundwork for generating hypotheses for future work.

This paper explores the diversity and drivers of institutional adaptation occurring in response to climate change in a global sample of 96 major cities, addressing the empirical, methodological, and theoretical challenges outlined above. It addresses several key questions: 1) In which areas is institutional adaptation occurring within urban governance in the sampled cities, and with what patterns of commonality and variation?, 2) To what extent are there patterns in drivers of institutional adaptation, and what might be the reasons for this?, and 3) What does this imply for (i) our understanding and expectations about how institutional adaptation is realized?, and (ii) the implications for advancing the study of urban climate adaptation through large-N methods? A cross-national survey of 319 case experts across six continents is conducted to build an original primary dataset for the analysis. The survey focuses empirically on the domain of urban water which is a particularly important but also difficult arena for adaptation given the often complex systems and arrangements involved in urban water governance, and the role of multiple actors and arrangements extending beyond municipalities. It thus provides an empirically salient and theoretically demanding domain for developing and testing primary approaches to studying institutional adaptation.

2. Institutional adaptation and its drivers

An analytical framework comprising forms of institutional adaptation (dependent variable), possible drivers (independent variables), and context is first established. This synthesises insights from existing literature to focus exploratory analysis and identify empirical indicators. It supports the goal of the study to explore a new phenomenon and its variation across contexts, but to also do so in a way that probes patterns and relations in the data, in order to bring empirical findings into close dialogue with theory.

2.1. Forms of institutional adaptation

Institutional adaptation is defined in this study as action taken to adjust urban governance to new (experienced or expected) climate conditions, in order to moderate adverse impacts on humans (e.g. safety, equity, wellbeing), infrastructure, and ecosystems (building on Aylett, 2015; Hughes and Sarzynski, 2015; IPCC, 2014; Sunley et al., 2017). Institutions refer to "rights, rules, and decision-making procedures" that shape and channel social practices and behaviour (Young et al., 2008, xxii). This can include both formal aspects (e.g. laws, policies, procedures), and also informal aspects such (e.g. routines, beliefs, and norms) (Hodgson, 2006; March and Olsen, 2008). Institutions are a key variable in climate adaptation because they structure and channel political decision-making, providing incentives and sanctions that shape practices and behaviors, and reflecting norms of how societies make decisions (Dovers and Hezri, 2010; Hughes and Sarzynski, 2015; Patterson and Huitema, 2019; Penning-Rowsell et al., 2017). Moreover, scholars have convincingly argued that adaptation failures are centrally an issue of governance rather than technical matters (Huitema et al., 2016; Javeline et al., 2019; Pahl-Wostl, 2009), within which institutions occupy a central position.

This study concentrates on formal aspects of institutions, as these are most readily observable and comparable empirically across a large number of cases. On the other hand, informal institutional aspects such as shadow networks are also likely to be crucial in the formation of adaptation approaches (Leck and Roberts, 2015). This can lead to questions about 'institutionalization' (e.g. Anguelovski and Carmin, 2011; Aylett, 2015; Pasquini and Shearing, 2014), which refers to processes by which previously informal or experimental practices and norms come to be formalized. In this paper, the focus on formal aspects of institutions reflects an assumption that institutional changes which are formalized are more likely to convey a durable commitment that is meaningful to capture and compare. Moreover, the city-scale unit of analysis (Section 3) also implicitly brings attention to formal institutions by which urban adaptation is broadly orchestrated.

Adaptation in formal urban governance institutions may occur in a variety of forms, including adaptation in legal frameworks, policy, implementation instruments, organizations, and coordination arrangements (Table 1). Each form of adaptation (dependent variable) is comprised of several indicators to support empirical measurement as outlined in Table 1 and further elaborated in Annex 1. Together, this provides a multi-dimensional view of institutional adaptation, which allows for variation in different forms in different cases. Importantly, it also disaggregates the dependent variable (Howlett and Cashore, 2009), which has been observed as a common weakness in climate adaptation literature (Dupuis and Biesbroek, 2013).

2.2. Possible drivers

Six possible drivers of institutional adaptation are synthesized from the literature: opportunity structures, change agent activity, political pressure, knowledge, risk concern, and experience of extreme events (Table 2). The rationale for these drivers is twofold. First, they reflect different lines of thinking (e.g. empirical observations, conceptual models) and potentially competing explanations about drivers in climate

Table 1
Multi-dimensional view of institutional adaptation[*],[#].

Form (i.e. dependent variable – DV)	Dimension	Indicators (presence/absence)
Legal frameworks(DV$_1$)	Binding obligations carrying legal force	• New law or regulation • Change to existing law or regulation
Policy(DV$_2$)	Government objectives/goals	• New policy • Change to existing policy
Implementation instruments(DV$_3$)	Means of policy enactment	• Planning • Mainstreaming • Incentives • Communication
Organizations(DV$_4$)	Intra-organizational setups	• New organization/s created • Changes to existing organizations
Coordination arrangements(DV$_5$)	Inter-organizational relations	• Collaboration • Policy coordination • Clarification of roles

[*]Compiled from sources: Næss et al. (2005), Roberts (2008), Burch (2010), Craig (2010), Anguelovski and Carmin (2011), Rosenzweig et al. (2011), Carmin et al. (2012b), Carmin et al. (2012a), Solecki (2012), Dupuis and Biesbroek (2013), Anguelovski et al. (2014), Aylett (2014), Bauer and Steurer (2014), Biagini et al. (2014), Mimura et al. (2014), Noble et al (2014), Aylett (2015), Carter et al. (2015), Hughes and Sarzynski (2015), Vogel and Henstra (2015), Araos et al. (2016), Lopez-Cantu and Samaras (2018), Patterson and Huitema (2019), Roberts et al. (2020), Owen (2020).

[#] See Annex 1 for further detail on operationalization of dependent variables.

Table 2
Possible drivers of institutional adaptation in urban governance[*].

Driver	Indicators
Opportunity structure	• City level authority • Institutional imperative for adaptation • Multilevel alignment
Change agent activity	• Importance of key individuals • Demonstration strategies • Framing strategies • Relational strategies
Political pressure	• Problem recognition • Community pressure • Political disruption
Knowledge	• Internal knowledge availability • Use of knowledge from elsewhere
Risk concern	• Perception of water shortage risks • Perception of flooding risks • Perception of infrastructural risks • Perception of coastal risks[#] • Perception of environmental risks
Extreme events	• Experience of water shortages • Experience of flooding • Experience of coastal impacts[#]

#Coastal risks and events are included only for coastal cities.

[*] See Annex 1 for further detail on operationalisation of drivers.

adaptation literature. Second, they reflect different underlying conceptual categories in the social world (i.e. structure, agency, contestation, knowledge, risk, and events, respectively), which thereby supports comprehensive coverage in exploratory analysis. Each driver is comprised of several indicators for empirical measurement in Table 2 (also see Annex 1). Importantly, this approach reflects a synthetic view of possible drivers of adaptation in *institutions*, which differs to most prior explanatory work focusing on climate adaptation action or overall performance. While scholars are beginning to systematically test rival explanations for climate adaptation outcomes in single countries (e.g. Dilling et al., 2017; Valdivieso et al., 2017), applying this logic in an international comparative perspective, especially using primary interpretive data, is a frontier. Moreover, the specific focus on institutional

adaptation is itself vastly under-studied in large-N perspective.

'Opportunity structure' refers to structural factors conducive to institutional adaptation, including city-level authority (power, support), imperatives (requirements, guidance), and multilevel alignment (vertical and horizontal alignment). Existing institutional structures may spontaneously propel institutional adaptation. For example, Keskitalo (2010, 15) suggests that states "with an established strong focus on environmental policy may act earlier on adaptation", albeit in combination with other drivers such as political pressure and risk exposure. Support from higher levels of government can affect the capability of cities to pursue climate adaptation, although cities may sometimes possess authority to act despite lack of broader support (Anguelovski and Carmin, 2011; Burch, 2010; Dilling et al., 2017). National policy frameworks can support municipalities in climate adaptation, such as by providing imperatives for adaptation planning (Heidrich et al., 2016), but the lack of such "agendas and incentives may burden local governments differently" depending on their capacity (Mimura et al., 2014, 15). This indicates the importance of alignment across levels and between actors (Anguelovski and Carmin, 2011; Corfee-Morlot et al., 2011; Mimura et al., 2014).

'Change agent activity' refers to actors promoting institutional adaptation, including key individuals and the use of various strategies of influence. Such agents may be crucial for stimulating institutional adaptation. For example, Mimura et al. (2014, 15) observe that key individuals can be "decisive for initiating, mainstreaming, and sustaining momentum for climate adaptation planning and implementation in different national settings". The role of change agents is widely recognized in urban climate governance (Bassett and Shandas, 2010; Carmin et al., 2012a; Pasquini and Shearing, 2014), and in broader climate adaptation governance (Huitema et al., 2016). This may include bureaucratic and political actors, or combinations thereof (Anguelovski et al., 2014; Roberts, 2008; Roberts et al., 2020; Ziervogel et al., 2010). Agents may emerge not only due to internal motivation (Carmin et al., 2012a; Keskitalo, 2010), but also in response to conditions of resource scarcity and/or lack of existing guidelines about climate adaptation (Anguelovski and Carmin, 2011). Strategies taken by such change agents may include demonstration of problems and solutions, framing and issue linking, and relational strategies in networks, among others (Brouwer and Huitema, 2017).

'Political pressure' refers to socio-political forces pushing towards institutional adaptation, including problem recognition by various actors (i.e. government, industry, citizens), and political disruption (e.g. economic, political, public health). Political pressure could be necessary since institutions can be inert and resistant to change. For example, the role of politics in climate adaptation is increasingly emphasized (Dolšak and Prakash, 2018; Javeline, 2014; Keskitalo, 2010; Mimura et al., 2014), suggesting that political pressures may influence climate adaptation responses. Howlett (2014) argues that governments are risk-averse on climate action due to a fear of blame for things going wrong, although nowadays with rapidly growing attention to climate impacts, they may equally be blamed for not taking action. Problem recognition is also commonly included in policy change theories (e.g. Kingdon, 2014; Sabatier, 1988). On the other hand, Javeline et al. (2019, 2) argue that climate adaptation can sometimes be pursued under different terms to sidestep charged political debates, suggesting that political pressure might have unexpected effects.

'Knowledge' is commonly thought to play a key role in climate adaptation. This includes both knowledge generated within a city (e.g. Campbell, 2009) and that drawn from elsewhere (e.g. city networks) (e.g. Einstein et al., 2019; Hakelberg, 2014). Knowledge may stimulate proactive preparation. For example, through awareness of climatic impacts and vulnerability, as well as strategies and ideas. Scientists commonly assume that knowledge availability is a key factor in city level decision-making (Bai et al., 2018; McPhearson et al., 2016). But the relation between knowledge and action may not be straightforward (White et al., 2001). For example, Javeline et al. (2019) criticize an

informational deficit explanation of adaptation failure as too simplistic. Hence, the role of knowledge may be somewhat indirect for institutional adaptation.

'Risk concern' refers to perceived climate-related risks (e.g. hydrological, infrastructural, planning, economic, environmental) related to institutional adaptation. The perception of climate risks, especially a combination of multiple risks, could stimulate institutional adaptation. Risk has traditionally occupied a central role in climate adaptation thinking, both in cities (Leichenko, 2011) and more broadly (Noble et al., 2014). For example, Dilling et al. (2017) finds risk perception to be an important driver (among others) of climate adaptation action in a sample of US cities, and Lee and Hughes (2017) find that perception of climate hazards is relatively strongly correlated with city adaptation agendas in a set of 58 cities. But institutional theory cautions that institutions are often inert and 'sticky' which calls into question rational responses to perceived risk. Furthermore, various barriers (e.g. financial, political, cultural) may hold back proactive responses to risks. Risk concern is to some extent related to Knowledge as greater knowledge can reveal risks. Although, the emphasis here is on the frequency of core water-related risks assuming that these are already known to some extent within cities.

'Extreme events' refers to the experience of climate-related crises. This could bring issues of climate adaptation to the attention of a broad public (e.g. water shortages, floods, coastal impacts), and thereby drive institutional adaptation. The role of extreme events is prominent in climate adaptation thinking (Aguiar et al., 2018; Hall et al., 2015; Novalia and Malekpour, 2020; Penning-Rowsell et al., 2006; Wiering et al., 2018), often linked to notions of 'focusing events' (Birkland, 1998; Keskitalo, 347, 2010) and 'windows of opportunity' (Vogel and Henstra, 2015). Although, the role of extreme events in actually spurring climate adaptation remains unclear. In a study of 60 local governments in the US, Dilling et al. (2017) find that the presence of *multiple* types of extreme events was a better predictor of climate adaptation action than singular events. In a case study of water systems in the Western United States, Page and Dilling (2020) find mixed evidence of the role of extreme events in triggering responses among decision-makers. Comparing experiences across cities in this regard is therefore important.

2.3. Context

Context (social, economic, political) is particularly important in cross-national comparison. Context is not simply a background attribute, but can condition causal relations (Falleti and Lynch, 2009; Newig and Rose, 2020), such as by influencing forms of institutional adaptation, and/or the role of different drivers. Extensive evidence from small-N analysis of urban climate adaptation highlights the complex role of context in shaping adaptation (e.g. Anguelovski et al., 2014; Dilling et al., 2017; Keskitalo, 2010; Patterson et al., 2019; Roberts, 2008; Taylor, 2016). Hence, we might expect that institutional adaptation is related to context, possibly leading to highly variegated patterns of institutional adaptation. On the other hand, cities across the world (especially large cities) are increasingly embedded in a globalized scientific and policy discourse about urban climate governance. For example, through participation in transnational city networks (Heikkinen et al., 2020; Lee and Hughes, 2017), cities may share ideas and develop common norms and strategies. This could lead to similarities in patterns of institutional adaptation across contexts.

Context includes both remote and proximate aspects. Remote aspects include population size (e.g. are there differences between smaller or larger cities?), development status (e.g. are there differences across more-developed and less-developed contexts, as measured through a national proxy?), and government effectiveness (e.g. does government effectiveness, measured using a national proxy, influence patterns of institutional adaptation?) (see Annex 1). This is not about exploring causality between national context and city-level variables, but rather,

about examining the potential conditioning role of context given the global study frame. The contextual variables employed here are in line with the recommendation of Koch (2020) who suggests taking account of geographical location, city size and political regime when studying cities of the global south. Further proximate aspects of context are also considered, relating to multilevel influence and sources of leadership, which condition an urban governance arena.

3. Methodology

3.1. Research design

The study takes an exploratory approach building and analyzing a primary dataset comprising a global sample of 96 major cities across six continents. This involves an original primary survey of 319 case experts across the sampled cities, administered May-July 2017 (single cohort). The survey focused on identifying forms of institutional adaptation, indicators of drivers, and contextual factors, with definitional guidance to ensure consistent interpretations of questions. The focal period concerned the preceding decade.

A sizeable body of large-N output-based assessments of urban adaptation planning utilizing secondary data has accrued in recent years in specific countries such as the United Kingdom (Heidrich et al., 2013), the United States (Bassett and Shandas, 2010; Hughes, 2015; Tang et al., 2010), India (Singh et al., 2021), and Chile (Valdivieso et al., 2017); regions such as the European Union (Aguiar et al., 2018; Reckien et al., 2018); and globally (Araos et al., 2016; Klein et al., 2018; Olazabal et al., 2019). This work tends to focus on planning progress and/or stated adaptation commitments. However, important information that is not recorded in public documents (e.g. concerning social and political processes) cannot always be captured. Some scholars have utilized primary data in large-N studies of cities to investigate adaptation planning progress and factors behind it, globally (Aylett, 2015, 2014; Carmin et al., 2012b) and in the United States (Dilling et al., 2017; Shi et al., 2015). Inspired by both of these bodies of work, this study examines global patterns of institutional adaptation, disaggregating multiple dependent variables and operationalizing complex theoretical constructs, deepening analysis in a specific domain (i.e. urban water).

Arguably, we need to move beyond the formative but broad exploration of many issue areas of adaptation (e.g. Aylett, 2014; Carmin et al., 2012b; Ford et al., 2011; Tompkins et al., 2010), to focus on specific adaptation domains within urban governance (e.g. water). For example, Aylett (2015) raises critical questions about the articulation between dedicated adaptation planning and established sectors such as water, Araos (2016) explores health as a specific domain of adaptation planning, and Javeline et al. (2019) uncover a range of complex issues relating to urban water hazards. Such an approach contrasts against the typical focus on treating climate adaptation as a self-standing policy domain, which is common in urban adaptation literature, and sometimes also in studies at broader levels (Massey and Huitema, 2013). Such approaches risk underplaying the practical reality that climate adaptation is enmeshed within existing structures and approaches to the provision of public goods and services. Thus, existing issue areas, or policy domains, should be a primary entry point for empirical analysis if we are to gain deeper insight into exactly how and why adaptation is or is not realised in practice. The focus here on urban water is emblematic as a core domain of public good/service provision confronted with climate adaptation needs.

The study employs a comparative approach that draws on the situated interpretive knowledge of case experts through a structured questionnaire to balance the need for contextual insight with comparability across cases. This is labelled an 'interpretive-comparative' approach because it 1) seeks to operationalize complex theoretical constructs rather than standard objective measures (e.g. public opinion, financial metrics) and thereby to combine elements of qualitative thinking with large-N analysis, and 2) draws on the rich knowledge of case experts

who can make informed judgments that distill complex experiences into common measures. Case experts (unit of observation) are heterogeneously-distributed and their roles may vary across cases (e.g. policymakers, academics, consultants, utilities) and therefore the survey allowed for this (Section 3.3). This moves beyond targeting a single type of respondent (e.g. sustainability officers in municipalities) which is the usual approach in primary large-N urban climate governance studies. Multiple respondents per city were sought as far as possible to assess institutional adaptation and its drivers per city (unit of analysis), thereby aiming to obtain aggregate scores of each variable on a city (case) basis.

3.2. Sampling

Cities were sampled systematically and stratified by continent. The aim was to identify major cities that are potential leaders in climate adaptation relative to their continent. Sampling applied sequential criteria: 1) presence in leading global city networks (i.e. C40, 100 Resilient Cities, ICLEI), 2) screen for self-identified concern on urban water issues under climate change, 3) apply population thresholds (i.e. city population > 400,000 and country population > 5 million; maximum 2 cities per country unless very large country with population > 100 million), and 4) check geographical distribution within and across continents and add capital cities of countries in under-represented regions guided by steps 1–3. This produced a shortlist (i.e. population) of 122 cities, for which survey response data was ultimately received for 96 cities (79% coverage). The final sample (Fig. 1) achieves a relatively even global geographical distribution (notwithstanding some over-representation of Europe) (Table 3). This spread is unusual for large-N city studies which often skew substantially towards more developed regions.

3.3. Implementation

The survey was conducted online (using commercial software with a plain text version if requested) which allowed for global distribution and self-completion. Potential respondents were contacted 3 times: an initial invitation, and 2 reminders (approximately 1 month and 1 week before closing). Standardized invitations were used containing an overview of

the study and ethical procedures, and respondents could freely opt-out at any time. The survey was made available in 7 languages: English, Spanish, Chinese, French, Arabic, Russian, and Portuguese (i.e. UN languages + 1) to enable equitable global participation as far as possible. Survey translations were produced by contracted individuals fluent in both English and the second language, and familiar with study concepts (e.g. climate change, sustainability, policy) to ensure accurate translation. The survey used plain language terms, supported by basic definitions of key terms, and standard question formats (i.e. 4-point Likert scales with consistent answer categories, and dichotomous categories). These scales provide an appropriate level of precision for this exploratory study and allow plain language presentation to respondents (e.g. 'strongly agree, agree, disagree, strongly disagree') to support measurement consistency and allow ease of completion. An even number of Likert scale categories was chosen to avoid 'middling' by pushing respondents to make a clear determination since a middle option is not available. The full survey was piloted with 6 experts from 4 countries with both research and policy backgrounds to test clarity of questions and answer categories resulting in small editorial refinements.

Respondents within each city were recruited through a combination of purposive and snowball sampling. An initial contact list of potential experts in urban water and/or climate adaptation in the target cities was developed through existing organizational networks and reviewing publicly available literature (e.g. websites, policy documents, academic literature), resulting in an initial contact list of 2,001 experts (average 16.4 per city). Contactees were invited to provide the survey to a more suitable colleague if appropriate to ensure both effective (i.e. reaching relevant experts) and equitable (i.e. opportunity to participate) distribution. Despite trying to balance these objectives, there could nevertheless be some risk of bias from snowballing. Targeting of different types of respondents (i.e. including academics as well as policy actors) and seeking multiple responses per city sought to counter this risk by balancing out responses as far as possible.

Multiple respondents were sought in each city (target 2–5 per city) to strengthen measurement of each case. To minimize potential self-reporting bias, respondents were anonymous by default to encourage honest and critical responses, and respondents from multiple sectoral roles were sought. A total of 319 complete responses were obtained (approximately 17% response rate), comprised of: research (42%),

Fig. 1. Cities sampled in the survey. Open circle indicates cities with 1 respondent; Closed circle indicates cities with 2 + respondents; Dashed lines show continent groupings.

Table 3
Contextual attributes of the sampled cities.

Attribute	Average [min, max]					
	Africa	Asia	Europe	Central and South America	North America	Oceania
Number of cities:	18	21	26	13	12	6
Population per city (million) (2017)*	4.22[0.39, 13.09]	12.6[0.85, 37.31]	2.68[0.43, 10.85]	9.03[0.89, 21.52]	6.01[1.44, 18.71]	2.59[0.41, 4.70]
Human Development Index (HDI: 0–1) [national] (2017)[#]	0.57[0.44, 0.70]	0.73[0.56, 0.94]	0.89[0.81, 0.94]	0.77[0.76, 0.84]	0.92[0.92, 0.92]	0.93[0.92, 0.94]
Government effectiveness (approx. range −2.5 to 2.5) [national] (2017)[±]	−0.43[-1.43, 0.29]	0.19[-1.11, 1,90]	1.16[-0.17, 2.06]	−0.06[-0.32, 0.84]	1.65[1.55, 1.85]	1.62[1.54, 1.77]

Sources: *World Urbanization Prospects (United Nations, 2018); [#]Human Development Report (UNDP, 2019); [±]Worldwide Governance Indicators (Kaufmann and Kraay, 2020).

government (38%), community/NGOs (17%), and private sector (3%) actors. Respondents were relatively evenly distributed across continents: Africa (17%; average 3.1 per city), Asia (27%; average 4.0 per city), Europe (23%; average 2.8 per city), Central and South America (16%; average 4.0 per city), North America (10%; average 2.7 per city), Oceania (7%; average 3.7 per city). Respondents had a median professional experience with urban water issues of 8.0 (3.5, 13.0) years giving confidence in their expert status.

3.4. Data processing and analysis

Data collected was converted to numerical form (ordinal or dichotomous) for individual responses based on the underlying equidistant structure of answer categories. Mean scores of each measure were computed from individual responses to obtain values at the city (case) level, and combined to produce composite indicators, and ultimately, the main variables (Annex 1). This produces continuous scale variables for those measured on a Likert scale reflecting a common assumption in survey research of linearity to a first approximation, and dichotomous values averaged by all respondents for those measured on a dichotomous scale. Reliability of data (all indicators at case level) was examined using Cronbach's alpha which was computed to be 0.79 suggesting acceptable-good internal consistency. Internal triangulation checks of responses for dichotomous variables were done to verify inverse selection of "no changes" cf. positive selection for dependent variable measures. Single responses were taken as the best available estimate of measures for singly-observed cases. Checks of difference in presence for dependent variables between single- and multi-observed cases were made (Annex 2), showing no significant difference for 89% of indicators. In situations suggesting group difference, presence in multi-observer cases was higher, which is essentially conservative as it is the singly-observer cases that we do not want to over-estimate. Thus, this is

deemed acceptable. Final measurements of dependent variables remain dichotomous (presence/absence). A combined count of the presence of the five dependent variables was computed.

Data for socio-economic-political context was drawn from secondary sources on population of urban agglomerations (World Urbanization Prospects) (United Nations, 2018), development (Human Development Index - HDI) (UNDP, (United Nations Development Programme), 2019), and government effectiveness (Worldwide Governance Indicators) (Kaufmann and Kraay, 2020). Population is at the city level, whereas HDI and government effectiveness are national proxies due to lack of data available at the city level. As noted in Section 2.3, the key purpose here was simply to situate cities within cross-national context rather than investigate causality per se.

4. Results

4.1. Proximate urban governance contexts

The proximate urban governance context provides initial insight on the arenas where institutional adaptation is pursued. One aspect is the multilevel setting, which is starting to be systematically explored empirically in large-N analysis (Heidrich et al., 2016; Lesnikowski et al., 2020; Olazabal et al., 2019; Reckien et al., 2018). The reported importance of different levels of governance varies, showing municipal and metropolitan levels as most important, with decreasing importance towards broader levels, but with notable variation between continents (Fig. 2). The importance of the international level is highest for South and Central American cities and lowest for cities in North American and Oceania, suggesting that cities in the latter regions may view urban water adaptation as a domestic (local) issue moreso than cities in other regions. Furthermore, cities in Africa, Asia, and Central and South America tended to identify a more prominent role for national
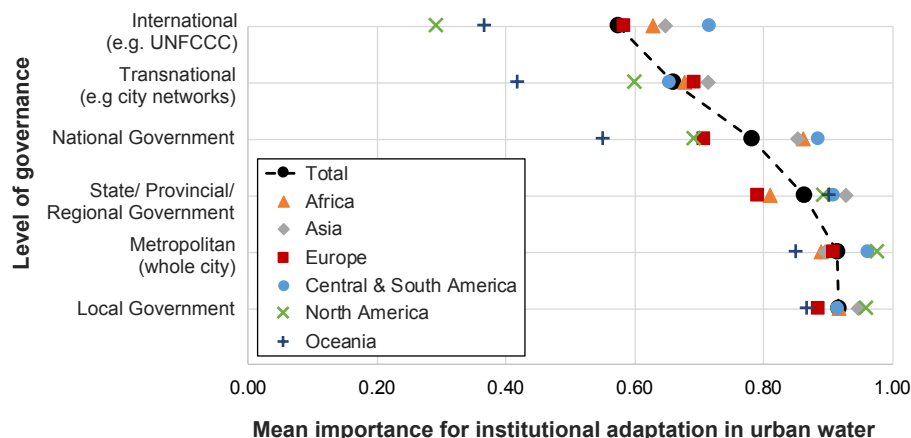

Fig. 2. Reported importance of different governance levels for institutional adaptation in urban water.

Table 4
Leadership on urban water adaptation (presence as % of cities per group using non-exclusive categories; top 3 per group highlighted).

Actor categories	Total	Africa	Asia	Europe	Central & South America	North America	Oceania
Government:							
Local Government	**52%**	**33%**	**57%**	**62%**	**31%**	**75%**	**50%**
State/ Provincial Government	29%	28%	29%	31%	**31%**	33%	17%
National Government	**36%**	28%	**52%**	27%	**31%**	**42%**	**50%**
Other formal bodies:							
Metropolitan authority	25%	28%	14%	27%	23%	33%	33%
Water utility/company/provider	**36%**	**33%**	29%	**62%**	15%	33%	17%
River basin/watershed organization	13%	11%	14%	12%	0%	17%	33%
Civil society:							
Domestic non-governmental organizations (NGO's)	21%	22%	10%	23%	15%	33%	33%
International non-governmental organizations (NGO's)	16%	28%	14%	19%	8%	8%	0%
Citizens and/or communities	13%	6%	19%	15%	8%	8%	17%
Other:							
Research/academia	**42%**	**44%**	**48%**	38%	23%	**50%**	**50%**
Business/industry	4%	0%	10%	4%	0%	8%	0%
Global development organizations	14%	11%	19%	23%	8%	0%	0%

government than cities in Europe, North America, and Oceania. The importance of the transnational level was relatively low for cities in Oceania, and appears somewhat underwhelming overall, despite its prominence in urban climate change discourse and the fact that nearly all sampled cities are members of transnational city networks. This resonates with Bhardwaj and Khosla's (2020, p.6) caution about over-emphasizing the role of transnational actors in regard to global south cities. The overall patterns in Fig. 2 may reflect differing tendencies in the relative distribution of formal authority within or beyond cities in regions of the world with different traditions and discourses of governance, and/or different capacity needs.

Identifying sources and configurations of key actors is important in a complex domain such as urban water. In this light, patterns of reported leadership on adaptation (Table 4) varied across continents but tended to show a strong focus on governmental (local and national) and other formal public bodies, along with academia[1]. Local government is prominent in cities in Asia, Europe, North America, and somewhat also Oceania, but notably less in cities in Africa and Central and South America. The reasons for these relative differences are not clear; for example, whether they are due to capacity shortfalls, structural disempowerment of local government, or simply pessimism among respondents. Overall, the findings suggest that actor configurations vary across contexts. Moreover, contrary to prominent emphasis on actors beyond government in urban climate governance literature, for the domain of urban water, governmental and public sector bodies seem to remain central. This is understandable as urban water involves complex public good/service provision and existing institutionalized accountabilities that may be difficult for new actors to enter into.

Together, Fig. 2 and Table 4 suggest a need to nuance dominant narratives about city-level assertiveness and shifts away from the state for the domain of urban water. Relative roles of actors and arrangements at different levels are likely to vary substantially across different settings. Findings also support previous arguments that both endogenous and exogenous institutions and actors are important in urban adaptation (Carmin et al., 2012a; Hughes and Sarzynski, 2015; Patterson et al., 2019; Romero-Lankao et al., 2013).

4.2. Forms of institutional adaptation

Institutional adaptation may vary in composition as well as geographically. Patterns of institutional adaption show both

commonality and variation across continents (Table 5). The most common forms of institutional adaptation are in coordination arrangements (92%), implementation instruments (88%), and organizations (81%); patterns which tend to hold relatively within each continent group (Fig. 3). Adaptation in policy (72%) and especially in legal frameworks (54%) were reported less frequently, and are somewhat less consistent relatively within each continent group (Fig. 3). Overall, this shows that while multiple forms of institutional adaptation are being jointly pursued in cities across all continents, the tendency is towards 'softer' rather than 'harder' forms.
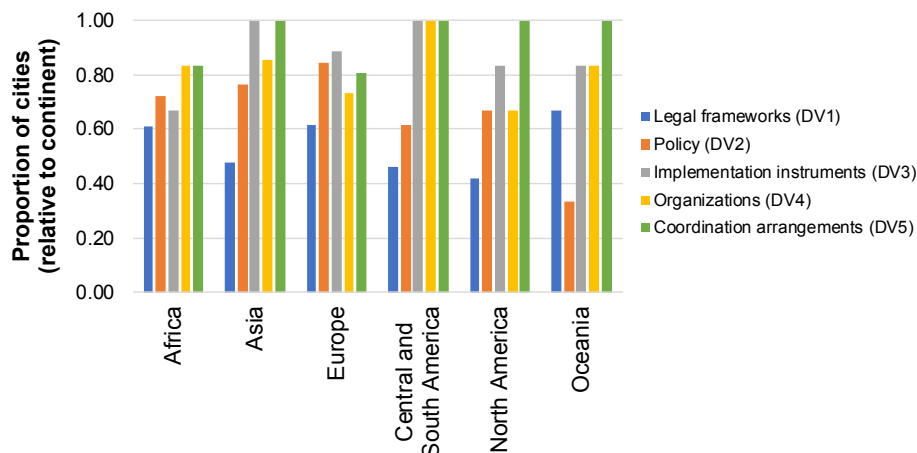
For each area of institutional adaptation, contributing indicators were lower than the total, suggesting variation in configurations of institutional adaptation. For both adaptation in policy (DV_2) and adaptation in legal frameworks (DV_1) there is a quite even balance between contributing indicators. For adaptation in implementation instruments (DV_3) planning is prominent, mainstreaming and communication are moderately prominent, but incentives is substantially lower. For adaptation in organizations (DV_4) there is most emphasis on changing existing organizations rather than creating new ones, which may reflect the need to work within existing setups rather than treat adaptation as a new domain. For adaptation in coordination arrangements (DV_5) collaboration was by far the highest contributor, with policy coordination and especially clarification of roles much lower. This suggests a strong emphasis on voluntary arrangements but perhaps little change in more concrete inter-organizational relations, and uncertainty about who is responsible for what. Overall, despite some high total measures of institutional adaptation (as a consequence of aggregation), individual indicators suggest helpful discernment of different aspects.

The distribution of forms of institutional adaptation shows some variation against contextual variables (Fig. 4). The total reported presence of adaptation in legal frameworks (DV_1) was relatively lower in low government effectiveness contexts, suggesting that this may be an relevant scope condition. The total reported presence of adaptation in policy (DV_2) shows a dip for middle categories of HDI and government effectiveness context, suggesting challenges for cities in this mid-range (e.g. perhaps competing demands with increasing development). The total reported presence of adaptation in implementation instruments (DV_3) increases with city size, but more complex patterns underlie this. For the smallest cities (<1m), planning is the main focus, and a greater variety of indicators come into play with increasing city size. Most indicators show an increase with HDI and government effectiveness suggesting the importance of capacity. Mainstreaming is relatively low in medium government effectiveness contexts, but increases notably in high government effectiveness contexts. Incentives were low across all contexts but patterns observed may reflect use in certain moderately-

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[1] This finding could carry some bias from respondents (who were ~40% academic, and ~60% non-academic) (Section 3), although the signal appears strong enough to have merit regardless.

Table 5

Contingency table of forms of institutional adaptation across continents.

Form of institutional adaptation	Indicators	Total		Continent* (N)					
		N	%	Afr.	Asia	Eur.	C/S Am.	N Am.	Ocea.
Legal frameworks (DV_{LEGAL})	New law or regulation	37	39%	9	8	11	4	3	2
	Change to law or regulation	35	36%	8	7	9	4	4	3
	Total presence	**52**	**54%**	**11**	**10**	**16**	**6**	**5**	**4**
Policy (DV_{POLICY})	New policy	43	45%	7	8	16	7	5	0
	Change to existing policy	48	50%	9	11	13	5	8	2
	Total presence	**69**	**72%**	**13**	**16**	**22**	**8**	**8**	**2**
Implementation instruments ($DV_{IMPLEMENTATION}$)	Planning	73	76%	9	18	20	13	9	4
	Mainstreaming	53	55%	8	12	16	7	7	3
	Incentives	27	28%	5	7	9	1	4	1
	Communication	56	58%	10	11	19	6	5	5
	Total presence	**84**	**88%**	**12**	**21**	**23**	**13**	**10**	**5**
Organizations ($DV_{ORGANIZATIONS}$)	New organization/s created	32	33%	7	6	8	5	4	2
	Changes to organizations	65	68%	11	15	17	10	8	4
	Total presence	**78**	**81%**	**15**	**18**	**19**	**13**	**8**	**5**
Coordination arrangements ($DV_{COORDINATION}$)	Collaboration	84	88%	15	20	19	12	12	6
	Policy coordination	39	41%	7	11	11	5	4	1
	Clarification of roles	15	16%	2	5	4	1	3	0
	Total presence	**88**	**92%**	**15**	**21**	**26**	**13**	**12**	**6**
Total number of cities:		**96**		**18**	**21**	**26**	**13**	**12**	**6**

* NB: Afr. = Africa; Eur. = Europe; C/S Am. = Central and South America; N Am. = North America; Ocea. = Oceania.

Fig. 3. Reported forms of institutional adaptation within cities of each continent group.

sized developed contexts (e.g. Europe). The total reported presence of adaptation in organizations (DV_4) increases with city size, but for the largest cities (>10 m) there is a clear pattern towards changing organizations rather than creating new ones. This same tendency was clear across all HDI and government effectiveness contexts. The total reported presence of adaptation in coordination arrangements (DV_5) increases with city size but varies little with other contextual variables. Collaboration is almost always co-present. Conversely, policy coordination and clarification of roles is relatively low across all contextual variables, and is particularly so for the smallest cities (<1m). This may suggest widespread difficulties in improving coordination and the allocation of responsibilities.

Although useful for disaggregating cities across global contexts, a reliance on national level indicators leaves open questions about variation across cities within particular countries. For example, of the 8 cities sampled within the United States, 50% reported adaptation in legal frameworks (DV_1), 75% reported adaptation in policy (DV_2) and

organizations (DV_4), and 100% reported adaptation in coordination arrangements (DV_5). Of the 4 cities sampled in India, 75% reported adaptation in legal frameworks (DV_1), 50% reported adaptation in policy (DV_2), and 100% reported adaptation in implementation instruments (DV_3) and coordination arrangements (DV_5). This suggests a need for more precise measures of context that can also account for intra-country variability in future work.

4.3. Drivers

Possible drivers of institutional adaptation vary across continents and against contextual variables. Variation in median scores and dispersion for drivers across continent groups is shown in Fig. 5. Median scores for Opportunity structures (IV_1) are somewhat consistent across continent groups, although dispersion is greatest for cities in Africa and North America. Median scores for Change agent activity (IV_2) are somewhat variable across continent groups, being highest for cities in
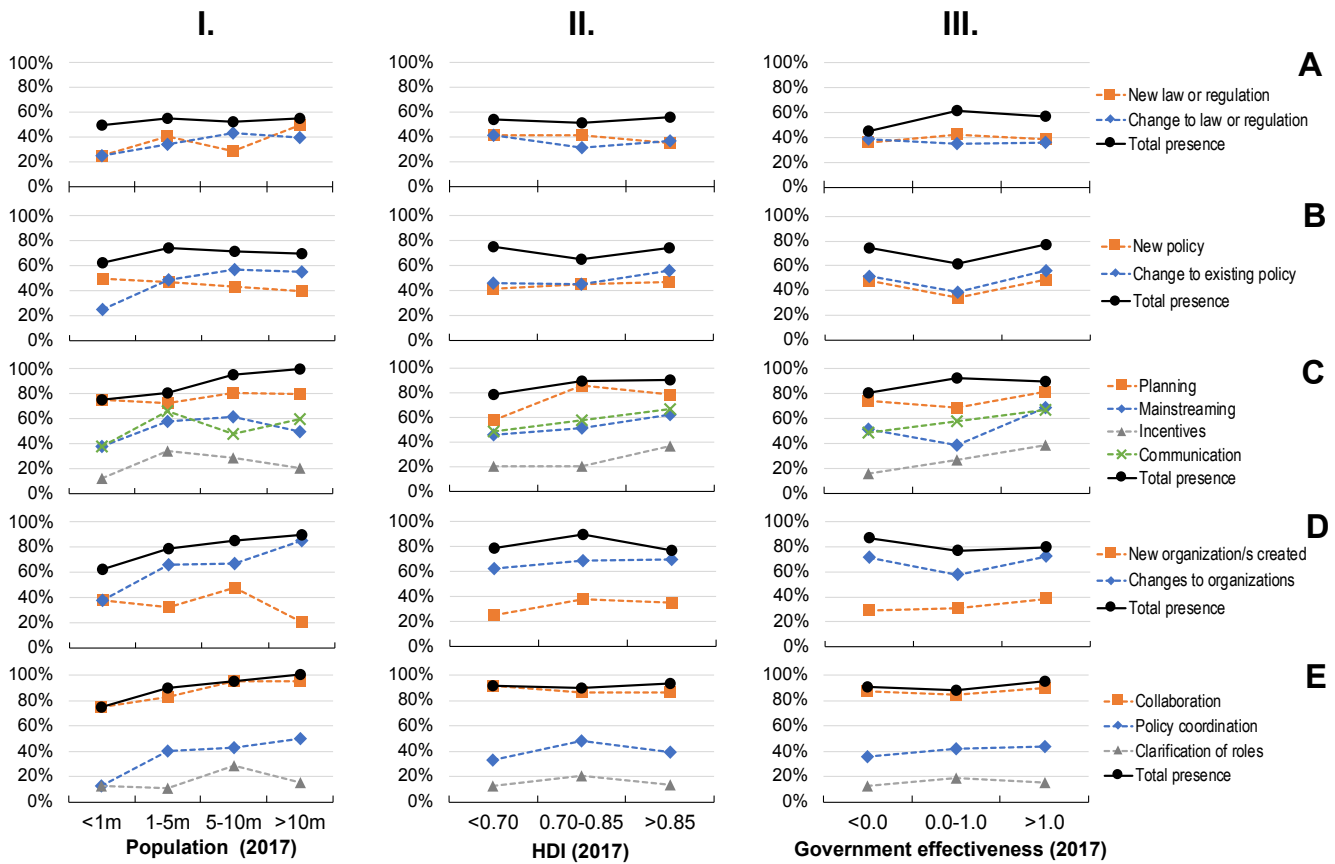
Fig. 4. Forms of institutional adaptation against I. Population (2017), II. Human Development Index (HDI) (2017), and III. Government effectiveness (2017): A-Legal frameworks (DV_1); B-Policy (DV_2); C-Implementation instruments (DV_3); D-Organizations (DV_4); and E-Coordination arrangements (DV_5).

North America and Oceania, and lowest for cities in Asia, but with high dispersion in Asia and Europe. Median scores for Political pressure (IV_3) are somewhat consistent across continent groups, with dispersion greatest for cities in Africa, Asia, Europe, and Central and South America. Median scores for Knowledge (IV_4) are highest for cities in Europe and North America, and only slightly lower for cities in Central and South America and Oceania, with dispersion greatest for cities in Africa and Europe. Median scores for Risk concern (IV_5) are consistent across all continent groups except for Europe where this score is notably lower, with dispersion greatest for cities in Asia and Central and South America. Median scores for Extreme events (IV_6) are consistent across continent groups, with dispersion greatest in Europe. Overall patterns across continent-based groups of cities are not easy to discern. Importantly, the composite measures of each driver are each relative measures so scores are not directly comparable between drivers.

Drivers show some notable patterns of variation against contextual variables, which is useful for considering the scope conditions under which they are produced. Bivariate (Pearson) correlations are calculated (Table 6). A moderate positive correlation ($r_p = 0.32$, p = <0.01) is observed between Population and Risk concern (IV_5), suggesting that perceptions of risk are greater in cities that are more populous. A low-moderate positive correlation ($r_p = 0.23$, p = <0.05) is observed between HDI and Change agent activity (IV_2), suggesting that more developed cities confer greater opportunities for agency. A low-moderate negative correlation ($r_p = -0.27$, p = <0.01) is observed between HDI and Political pressure (IV_3), suggesting that more developed cities experience lower political pressure on climate adaptation. A moderate-substantial positive correlation ($r_p = 0.41$, p = <0.01) is observed between HDI and Knowledge (IV_4), suggesting that more developed cities have greater knowledge capacity. A low-moderate positive correlation ($r_p = 0.28$, p = <0.01) is observed between

Government effectiveness and Change agent activity (IV_2), suggesting that more developed cities permit greater opportunity for agency. A substantial positive correlation ($r_p = 0.48$, p = <0.01) is observed between Government effectiveness and Knowledge (IV_4), suggesting that Government effectiveness is an important condition for knowledge-related activity. A low-moderate negative correlation ($r_p = -0.26$, p = <0.05) is observed between Government effectiveness and Risk concern (IV_5), suggesting that cities in contexts with greater government effectiveness have lower risk perceptions about climate impacts. Altogether, these patterns are logical, and imply important scope conditions for some drivers.

4.4. Bivariate associations between institutional adaptation and drivers

Associations between drivers and forms of institutional adaptation are examined to further probe how institutional adaptation arises. Bivariate correlations are computed using a point-biseral coefficient for association between continuous and dichotomous variables (Table A6, Annex 5). Normality of the continuous independent variables (drivers and indicators) is examined for each value of the dichotomous dependent variable using QQ plots, which suggests that the assumption of normality is likely to be appropriate as a first approximation. Conditions for the assumption of homogeneity of variance of continuous variables were met 96% of the time. Conventional significance levels (i.e. p = 0.05, 0.01) are used, along with a more generous level (p = 0.10) given the exploratory nature of study (e.g. sufficient for hypothesis generation).

Significant correlations are not found between the forms of institutional adaptation (dependent variables) and the six drivers. This may because the drivers are composite variables comprised of multiple indicators which lose data resolution in the process of aggregation. If so, it
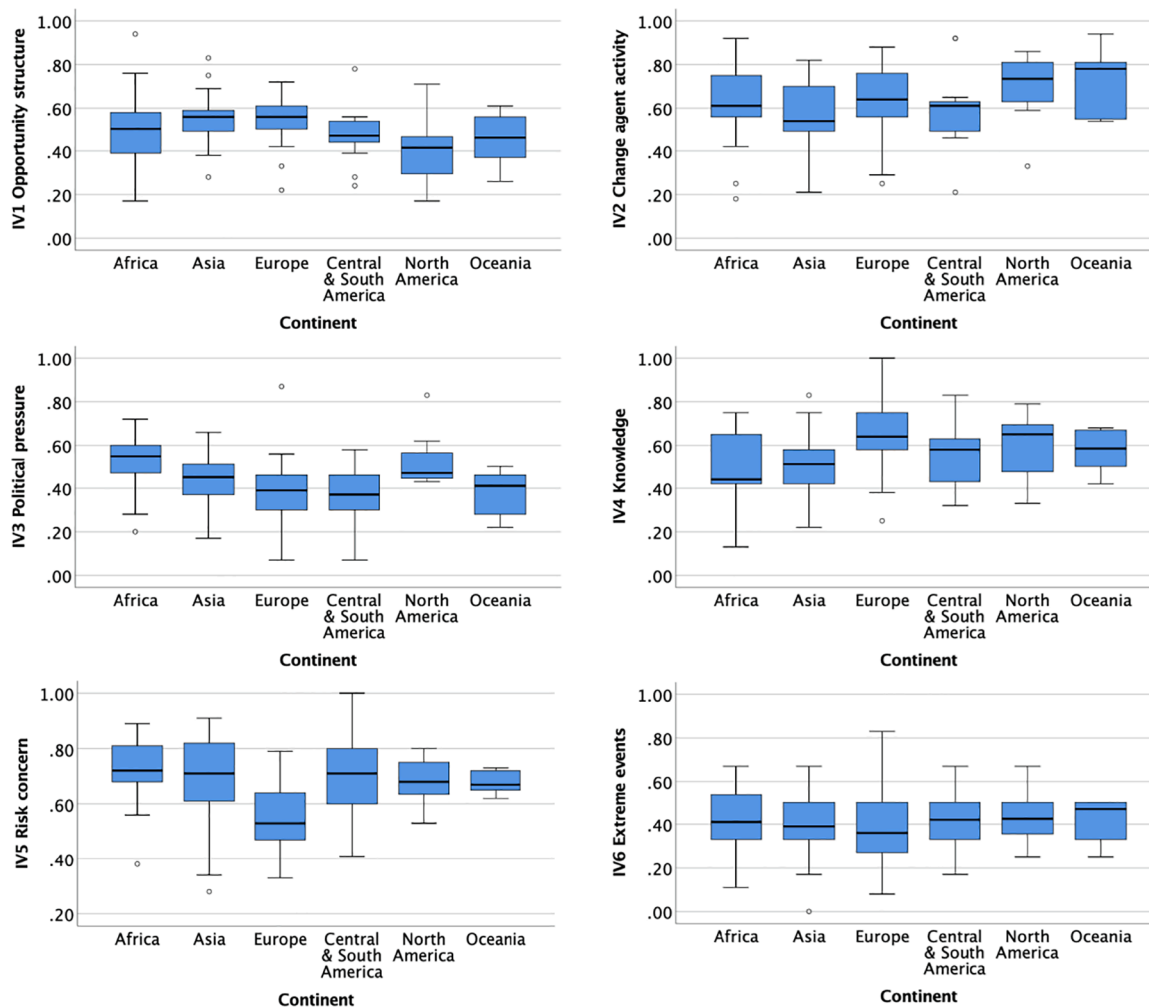
Fig. 5. Boxplots of the six drivers (i.e. IVs-independent variables) in the sampled cities per continent, showing medians and dispersion. Also see Table A3 (Annex 3) for summary data.

Table 6
Bivariate correlations (Pearson) between drivers and contextual variables*.

Drivers	Context variables (remote)					
	Population		Development (HDI)		Government effectiveness	
	Corr. coeff.	2-tail sig.	Corr. coeff.	2-tail sig.	Corr. coeff.	2-tail sig.
Opportunity structure (IV$_1$)	−0.13	0.20	−0.10	0.35	−0.05	0.60
Change agent activity (IV$_2$)	−0.18	0.08	0.23*	0.02	0.28**	0.006
Political pressure (IV$_3$)	−0.63	0.55	−0.27**	0.008	−0.08	0.46
Knowledge (IV$_4$)	−0.13	0.21	0.41**	0.000	0.48**	0.000
Risk concern (IV$_5$)	0.32**	0.001	−0.33	0.001	−0.26*	0.011
Extreme events (IV$_6$)	0.05	0.61	0.01	0.91	0.04	0.74

* Also see Figure A4 (Annex 4) for scatter plots.

would imply that the use of composite measures, despite their conceptual rationale, could pose difficulties in statistical analysis involving weak signals. One possibility is to refine these measures (e.g. weighting), which would require further careful reasoning and sensitivity analysis.

Another possibility could be to discard composite measures entirely, although this could close off important opportunities for synthetic conceptual reasoning. A third possibility is to disaggregate composite measures (of the dependent variables) into contributing indicators and explore correlations between these indicators and drivers to make fuller use of available data resolution. Taking this approach reveals several intriguing associations.

Across the 13 indicators of the five dependent variables, the most frequent drivers showing significant correlations are Change agent activity (IV$_2$), Political pressure (IV$_3$), and Knowledge (IV$_4$). Change agent activity (IV$_2$) shows low-moderate positive correlations with all indicators of Implementation instruments (DV$_3$) (planning: $r_{pb} = 0.20$, $p = 0.05$; mainstreaming: $r_{pb} = 0.27$, $p = 0.01$; incentives: $r_{pb} = 0.25$, $p = 0.02$; communication: $r_{pb} = 0.28$, $p = 0.01$), and low-moderate positive correlations with some indicators of Coordination arrangements (DV$_5$) (Collaboration: $r_{pb} = 0.19$, $p = 0.07$; Clarification of roles: $r_{pb} = 0.30$, $p < 0.01$). This suggests that Change agent activity (IV$_2$) is particularly important for operational and coordinative forms of institutional adaptation, and therefore that these are not automatic processes but require sustained agency to accomplish. Political pressure (IV$_3$) shows low-moderate positive correlations with certain indicators of Legal frameworks (DV$_1$) (New law or regulation: $r_{pb} = 0.20$, $p = 0.05$), Policy (DV$_2$) (Change to existing policy: $r_{pb} = 0.21$, $p = 0.04$), Organizations (DV$_4$) (New organization/s created: $r_{pb} = 0.26$, $p = 0.01$), and Coordination arrangements (DV$_5$) (Collaboration: $r_{pb} = 0.22$, $p = 0.03$; Clarification of roles: $r_{pb} = 0.22$, $p < 0.03$). This suggests that Political

pressure (IV_3) may create an important imperative for strategic intervention (e.g. new law/regulation, changes to policy, creation of new organizations, and actions to improve coordination), and therefore that forms of political pressure should be a key area for future work on urban adaptation.

Knowledge (IV_4) shows low correlations with certain indicators of Policy (DV_2) (New policy: $r_{pb} = 0.17$, $p = 0.09$), Implementation instruments (DV_3) (planning: $r_{pb} = 0.16$, $p = 0.12$; mainstreaming: $r_{pb} = 0.17$, $p = 0.1$; incentives: $r_{pb} = 0.17$, $p = 0.1$), and Coordination arrangements (DV_5) (Clarification of roles: $r_{pb} = 0.19$, $p < 0.07$). This is a weaker signal, but its presence in multiple areas suggests relevance, perhaps in combination with other drivers. Risk concern (IV_5) shows a low-moderate negative correlation with a single indicator of Implementation instruments (DV_3) (communication: $r_{pb} = -0.23$, $p = 0.02$), which may reflect communicative responses in the presence of risk. Extreme events (IV_6) shows a low positive correlation with a single indicator of Legal frameworks (DV_1) (Change to existing law or regulation: $r_{pb} = 0.18$, $p = 0.09$), although this association is weak. This suggests that extreme events may matter for certain 'hard' institutional adaptations, but also suggests that extreme events may not be a key factor across the board.

4.5. Co-occurrence of multiple forms of institutional adaptation

Finally, patterns in the co-occurrence of multiple forms of institutional adaptation are explored. A numerical count of the number of forms of institutional adaptation reported in cities (Fig. 6) shows a strong tendency towards the presence of multiple forms of adaptation across all continent groups. This provides evidence confirming the departure point for this study that institutional adaptation is likely to occur in multiple different areas within complex urban governance settings, implying a need to foreground such a view in future work. Patterns in the simultaneous presence of institutional adaptation in dyads (Table 8) and triads (Table 9) further probe co-occurrence.

Dyadically, frequently co-occurring areas are: adaptation in Implementation instruments (DV_3) with i) Coordination arrangements (DV_5) which may reflect a link between planning (a dominant indicator of DV_3) and collaboration (a dominant indicator of DV_5), ii) with Policy (DV_2) which suggests that policy and its means of implementation are jointly addressed, and iii) with Organizations (DV_4) although an

Table 8
Frequency of dependent variable dyads (highest to lowest).

Simultaneous presence of …	Total
Implementation instruments * Coordination arrangements	83%
Organizations * Coordination arrangements	77%
Implementation instruments * Organizations	75%
Policy * Coordination arrangements	68%
Policy * Implementation instruments	67%
Policy * Organizations	63%
Legal frameworks * Implementation instruments	53%
Legal frameworks * Coordination arrangements	50%
Legal frameworks * Organizations	48%
Legal frameworks * Policy	46%

Table 9
Frequency of dependent variable triads (highest to lowest).

Simultaneous presence of …	Total
Implementation instruments *Organizations * Coordination arrangements	72%
Policy * Implementation instruments * Coordination arrangements	64%
Policy * Implementation instruments * Organizations	58%
Legal frameworks * Implementation * Coordination arrangements	50%
Legal frameworks * Implementation * Organizations	48%
Legal frameworks * Policy * Implementation instruments	46%
Legal frameworks * Organizations * Coordination arrangements	45%
Legal frameworks * Policy * Coordination arrangements	43%
Legal frameworks * Policy * Organizations	41%

explanation here is not immediately clear; and adaptation in Coordination arrangements (DV_5) with i) Organizations (DV_4) which may reflect organizational changes to accommodate inter-organizational shifts, and ii) with Policy (DV_2) which may reflect institutionalization of inter-organizational shifts or vice versa. Triadically, frequently co-occurring areas are: Implementation instruments (DV_3) and Coordination arrangements (DV_5) with i) Organizations (DV_4) which may reflect a focus on operationalizing adaptation action, and ii) with Policy (DV_2) which may suggest a focus on embedding strategic direction for adaptation. Delving further into these relationships is an area for future research. Importantly, these patterns of co-occurrence imply a need to study the combinations of forms of institutional adaptation within and across settings.
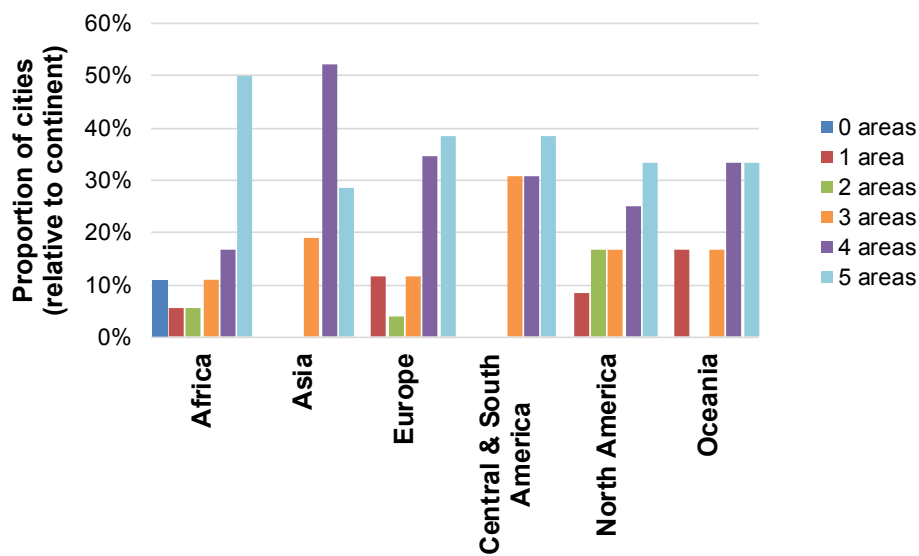

Fig. 6. Co-occurrence of forms of institutional adaptation in cities grouped by continent.

5. Discussion

5.1. Understanding and advancing institutional adaptation

This study probes the diversity and drivers of institutional adaptation occurring in cities. Findings reveal a relatively vibrant although differentiated range of institutional adaptation activity occurring, but also possible interdependence between different forms. Joint patterns in the presence of drivers across the five dependent variables (i.e. Change agent activity-IV_2, Political pressure-IV_3, and Knowledge-IV_4) suggest a political explanation for institutional adaptation rather than a rational one (e.g. response to risk and/or extreme events) or a spontaneous one (e.g. response to opportunity structures). Instead, what seems to matter is a combination of agency and political pressure, possibly also in the presence of knowledge. Although, the heterogeneous presence of drivers across different dependent variable indicators means that differing explanations may apply for specific forms of institutional adaptation.

The importance of change agents confirms extensive literature highlighting the role of agency and leadership in urban climate governance (Anguelovski et al., 2014; Carmin et al., 2012a; Hughes, 2017; Roberts, 2008). However, the importance of political pressure is less commonly seen in current literature. Climate adaptation is often approached in a managerial way, when it may in fact be critically influenced by political pressure in much the same way as other societal issues are thought to be, such as seen in some policy change frameworks (Kingdon, 2014; Sabatier, 1988). This suggests a need for scholars to better theorise the political forces *driving* adaptation (e.g. pressure on decision-making arenas and/or societal demand) which remain understudied, despite growing recognition of the politics of climate adaptation (e.g. Dolšak and Prakash, 2018; Eakin et al., 2017; Javeline et al., 2019). For example, Konisky et al., (2016) find links between public opinion, extreme events, and ideology in shaping climate change concern, and Page and Dilling (2020) find that political pressure is sufficient to explain adaptation actions by certain resource decision makers under drought. The somewhat ambivalent findings about the importance of knowledge are intriguing given the common emphasis on scientific knowledge for climate action, and the importance of city networks in circulating knowledge (Hakelberg, 2014; Heikkinen et al., 2020). It would be hard to dismiss the role of knowledge, but it could be a necessary rather than a sufficient condition, and/or one that is difficult to independently detect.

The absence of certain drivers is also notable, particularly extreme events since this is often assumed to raise the salience of adaptation needs and thereby provide opportunities for strategic action (Anderson et al., 2018). While criticisms are already being made about the dangers of maladaptation in such cases (Anderson et al., 2018; Conway and Mustelin, 2014), the findings here are striking in their overall lack of signal for this variable at all. This could suggest a danger in functionalist reasoning about the role of extreme events (i.e. that adaptation occurs because extreme events cause systems to fail). On the other hand, responses to extreme events grounded in social-psychological factors (e.g. narratives, motivations) may be more plausible (following Weyland, 2008). Of course, further clarity on this matter could be gained by relating interpretive data (as in this study) to physical and economic records of extreme events to sharpen the discriminatory power of this variable.

Patterns of variation suggest an important but perhaps subtle role for context. While some differences across continents are noticeable in both the dependent and independent variables, there is also much consistency. Differences in drivers are mostly not pronounced, although dispersion within continent groups is sometimes high. Some variation is observed in the co-occurrence patterns across continent groups, but all groups generally tended towards a greater rather than lesser number of simultaneous forms of institutional adaptation. We might expect that institutional adaptation will depend significantly on context, as highlighted in institutional theory (Ostrom, 2005), which could produce diversified patterns of institutional adaptation as cities take unique and varying actions in response to specific circumstances. On the other hand, cities are now part of globalized scientific and policy discourse about climate change and may face common structural challenges (e.g. uncertainty, conflicting interests, resistance), which could lead to similarities in patterns of institutional adaptation (e.g. tendency towards 'softer' rather than 'harder' action). The observed similarity across contexts suggests perhaps more convergence than would be initially expected, although this certainly belies extensive complexity of individual cases. This could be because, despite varying contexts, there may be much common path-finding in how cities seek to adapt urban institutions. Yet, while a focus on 'softer' actions (e.g. implementation instruments, organizations, coordination arrangements) is understandable in the recent past as cities come to terms with adaptation needs, it may not be sufficient looking forward when adaptation needs become more demanding. Current experience may hint towards a reluctance to take difficult steps, particularly given the apparent gaps in current efforts to improve policy coordination and allocation of responsibilities (Section 4.2). At the same time, 'harder' actions (e.g. legal frameworks) may not always be the most appropriate. Examining the relations between forms of institutional adaptation needed to address different climate-related risks across different contexts would be a promising area for future work.

Importantly, while the study seeks to take a global focus in a way that seeks to differentiate important forms of variation across contexts, it is likely that it may nonetheless overlook important differences especially between cities in the global South and North (Nagendra et al., 2018). This is an inherent challenge for large-N comparative analysis seeking to cover a broad range of urban contexts. On the one hand, it can be useful to bring cities across the world into a common dialogue regarding evolving responses to climate change. On the other hand, major differences between contexts (e.g. population growth; social, economic and infrastructural factors; political systems; development needs; post-colonial histories) (Ajibade et al., 2016; Khosla and Bhardwaj, 2019; Koch, 2020; Nagendra et al., 2018; Ziervogel et al., 2010) undoubtedly challenge such comparison. The findings here confirm the importance of paying attention to context as the drivers studied did show some significant variation against certain contextual variables. Although, this only scratches the surface, and a challenge for future work will be to account for context more fully in large-N analysis. A further challenge is to explore interactions with other issues, even while maintaining a focus on a certain domain (such as water in this study). For example, scholars have emphasised the importance of linking climate adaptation with development needs in global south cities (e.g. Ajibade et al., 2016; Bhardwaj and Khosla, 2020; Roberts et al., 2020; Singh et al., 2021). This relates to the broader notion of co-benefits where climate adaptation is linked to other salient issues of human wellbeing (Floater et al., 2016). Co-benefits may be viewed as a driver, mediator, and/or outcome of institutional adaptation, which therefore requires careful conceptualization to enable comparative study. This a limitation of the current study.

The findings overall are most strictly limited to the sample itself, which could arguably be extended to the original targeted population of 122 cities. The findings may also broadly resonate thematically with other major cities concerned with urban water adaptation challenges. Being an exploratory study, the aim is not to make inferences but rather to provide a conceptual and empirical basis for future studies, seeking to identify promising lines of investigation and provide a basis for generating hypotheses that could be tested in future work, thereby opening up an agenda on institutional adaptation diversity in large-N comparative

perspective. The inevitable tension between global comparison and regional (or sub-regional) disaggregation will ideally require larger sample sizes in future work.

5.2. Implications for future comparative analysis

There are several lessons for future work arising from the interpretive-comparative approach to large-N analysis developed here. First, there are inherent difficulties in detecting distinct statistical patterns from weak signals in complex urban adaptation governance data. This problem is likely to be endemic in studying climate governance using statistical methods (e.g. Berrang-Ford et al., 2014; Dilling et al., 2017; Lesnikowski et al., 2020), but is also common in broader social science (De Vaus, 2014 p. 261–262). The approach taken here to focus on a specific domain (urban water) is likely to help obtain greater purchase, but clearly itself remains challenging. Moreover, the pursuit of deliberate institutional change can be complex and political (Roberts et al., 2020), often confronting path-dependency (Bhardwaj and Khosla, 2020; Patterson et al., 2019), which delays the signal between effort and outcomes, thereby adding fuzziness to the data. Snapshot assessments could focus on a time period sufficient to capture cause-effect relations (e.g. 5–10 years), and design variables based on theoretical (structural) models to support causal inference (Wunsch et al., 2010). On the other hand, longitudinal sampling would of course be extremely useful (e.g. changes within single cities or groups of cities over time), but further standardization would be needed to afford both interpretive sensibility as well as comparability over time. Structured expert elicitation methods are particularly promising here (e.g. Dias et al., 2018), but remain untapped.

Second, there is a challenge in systematic sampling to ensure robust but also realistic studies. Despite calls for greater randomised sampling (e.g. Biesbroek et al., 2018), scholars conducting large-N analysis of urban climate governance will inevitably confront heterogeneously distributed experts and cases, and the need to operationalize complex theoretical constructs. Hence, classical random sampling techniques may not always be suitable. While non-random approaches are increasingly recognised (e.g. Baker et al., 2013), what is arguably most important is to make well-founded, systematic, and justified design decisions that sensibly combine elements of random and non-random sampling. This requires plausible judgments that are fit for purpose in real-world settings, seeking incremental advancement on previous approaches, balancing imperatives of multiple validities (e.g. measurement, internal, external, ecological), and being transparent about these choices. In essence, the challenge is to combine interpretive sensibility with parsimonious analysis.

Third, there is a key opportunity to combine primary and secondary data to strengthen interpretations, minimise measurement error through triangulation, and obtain benefits that cannot be gained through any single data source (e.g. experts, policy/ planning documents, social/ political/ economic data). Some examples of studies combining multiple sources of data are emerging (e.g. Dilling et al., 2017; Lesnikowski et al., 2020). Fruitful opportunities are likely to arise through connecting existing datasets and advancing future joint initiatives.

6. Conclusions

A decade ago Dovers and Hezri (2010, 212) observed that "institutions and institutional change are mentioned often but rarely specified in discussions of climate adaptation", with "detailed discussion" particularly lacking at national and subnational scales. While advances have been made in the urban domain since then, particularly through rich and varied case study work, this weakness largely persists at a broader comparative scale. In response, this study contributes to opening up systematic analysis of the institutional dimensions of urban climate adaptation in large-N perspective. Departing from the idea that disaggregating the dependent variable is vital in studying institutional

adaptation, the study provides evidence of possible drivers of different forms of institutional adaptation, notably suggesting a political view as a promising line of future enquiry.

Moreover, the study demonstrates the need for a research agenda on the diversity of institutional adaptation in a comparative perspective. Multiple forms of institutional adaptation appear to often co-occur, implying a need for greater attention to these developments and their possible interactions (e.g. synergy, competition, sequencing) as a promising line of future work. Although, achieving both specificity (i.e. a focus on particular forms of institutional adaptation) while also maintaining an eye to interactions between areas will no doubt be challenging. The point is not to study everything at once, but rather, to openly embrace interactions where they exist rather than foreclose into conceptual silos (e.g. planning, policy change, …). Accounting for context is inherently challenging for comparative analysis, but at the same time, may create opportunities to identify scope conditions that sharpen our understanding of casual relations and outcomes. Advancing this overall agenda requires continuing methodological innovation, building on the impressive foundation to date, to understand institutional adaptation in large-N perspective.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.gloenvcha.2021.102279.

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