

Climate change adaptation policy formulation among local governments:
A policy instruments approach

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July 2019

A thesis submitted to McGill University
in partial fulfillment of the requirements of the degree of PhD in Geography

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ACKNOWLEDGEMENTS

This thesis would never have come into being were it not for the support and mentorship of James Ford and Lea Berrang Ford, who hired me fresh out of my undergraduate degree as a research assistant and then continued to support my intellectual and professional development over the past nine years. Their thoughtful feedback and confidence in my ability to lead research such as this has opened up so many opportunities to develop my skills as an independent researcher and for that I will always be thankful. Sarah Moser's willingness to step in and keep an eye on me after James and Lea departed for the University of Leeds was deeply appreciated, as was David Wachsmuth's agreement to join my committee in the reshuffle. Robbert Biesbroek was very generous with his time and professional support, and bears much of the responsibility for recalling me to my roots in comparative politics and introducing me to world of public policy theory.

The development of this thesis has benefitted from discussions and feedback received at a number of conferences and workshops, specifically the 2016 Adaptation Futures conference in Rotterdam, the 2017 European Climate Change Adaptation Conference in Glasgow, 2016 and 2017 workshops of the Adaptation Tracking Collaborative, the 2017 Adaptation Tracking Collaborative workshop on big data approaches to adaptation research held in at Yale-NUS in Singapore, the 2018 Workshop of the International Public Policy Association held at the University of Pittsburgh, and the 2019 International Conference on Public Policy held at Concordia University. This research was made possible by funding from the Social Science and Humanities Research Council of Canada, McGill University, and a Google Cloud Platform Education Grant. Many thanks to Mathijs Veenkant, Geneva List, Florian Dorner, and Malcolm Araos Egan for your assistance with data collection.

I first joined the Ford lab in 2010, never expecting that a one-year contract would blossom into nearly ten years of ongoing collaborations and enduring friendships. The Ford ‘army,’ as we came to be known in the department, was always full of energy, new ideas, and passion, and I hope this legacy continues in its new home at the University of Leeds. Michelle Maillet, Anna Bunce, Malcolm Araos Egan, Dylan Clark, Stephanie Austin, Jolène Labbé, Carolyn Poutianen, Toni Sohns, Drew Tanabe, Camila Florez Bossio, Eranga Galappaththi, and Nathan Debortoli, our conversations both in the lab and over many a *cinq à sept* made everything about this journey fun and rewarding. Thank you for your friendship, wisdom, and support.

To dear friends made during my time at the University of British Columbia, Jim Beaudreau, Greg Deans, and Megan Ahearn, your friendship has sustained me during the most difficult times. I look forward to a lifetime of reunions and laughter.

My parents (Wojciech and Julie) and sister (Natalie) have always encouraged and supported me, including my decision in 2006 to leave the United States and move to Montréal for university, and eventually to make Canada my home. My father passed away in 2014 and this thesis is dedicated to him.

Finally, my life would be much emptier without my partner Brian Vermeire. Thank you for your encouragement and perspective over the past eight years. You have always been a source of support and stability during times of transition, and I look forward to what is to come in this next stage of our life together.

ABSTRACT

The consequences of rising greenhouse gas emissions (GHG) are already being experienced around the world in the form of increasingly frequent and intense extreme weather events, fluctuating precipitation levels and prolonged droughts, changing patterns of vector-borne diseases, and growing pressures on species and natural habitats. Our ability to successfully adapt to the changing environment is one of the most significant challenges facing communities and governments in this century. Scientific interest in climate change adaptation has grown dramatically over the past two decades, and a distinct literature has emerged around adaptation policy that aims to understand why and how governments are engaging with adaptation. The growth of empirical adaptation research, however, has largely outpaced conceptual and theoretical development in our understanding of what defines adaptation as a policy issue. This is resulting in a fragmented literature that makes knowledge accumulation across studies challenging.

The aim of this thesis is to advance the conceptual foundations of adaptation policy research by proposing an approach that is rooted in public policy theories on policy instrument choice. This research is guided by three overarching objectives:

1. To overcome the ‘dependent variable problem’ in adaptation research, which is reflected in ambiguity over exactly what it is that adaptation policy scholars seek to understand and explain;
2. To apply theory on policy instrument choice to explain emerging adaptation policy approaches at the local government level; and
3. To continue developing comparative perspectives on adaptation policy research.

Findings from this work indicate that emerging local adaptation policy approaches are highly complex in nature, with policy goals and instruments spanning a number of climate change impacts and administrative units. Policy instrument choices are influenced both by local and country-level contextual circumstances, underlining the influence of inter-governmental institutional arrangements on local policy development. Furthermore, differences in adaptation policy framing by local governments are observable across country contexts, which suggests that distinct adaptation policy approaches may be emerging across countries.

Chapter 3 situates the analytical focus of this research on local governments within the emerging multilevel governance landscape of climate change adaptation that is being formalized through international climate change agreements. Chapter 4 of the thesis develops a conceptualization of adaptation policy that is grounded in the idea of policy mixes and demonstrates this approach by characterizing the nature of adaptation policy portfolios across 125 local governments in Canada, France, Germany, Netherlands, and the United Kingdom. Chapter 5 seeks to explain policy instrument choices among these local governments using a model of policy implementation styles proposed in the policy instruments literature. Chapter 6 of the thesis turns to consider the current state of comparative research methods in adaptation governance research and proposes that the introduction of computational text analysis techniques, specifically topic modelling, can contribute new perspectives in adaptation policy research. Chapter 7 of the thesis uses topic modelling to identify adaptation policy frames from the local policy documents analyzed in Chapters 4 and 5. Chapter 8 concludes the thesis with a reflection on key findings and contributions, policy implications, and needs for future research.

RÉSUMÉ

Les conséquences de l'augmentation des émissions de gaz à effet de serre (GES) se font déjà ressentir dans le monde entier, sous forme d'événements météorologiques extrêmes de plus en plus fréquents et intenses, de fluctuations au niveau des précipitations et des sécheresses prolongées, de changements à l'étendue des maladies à vecteur et de pressions croissantes sur des habitats naturels. Notre capacité à nous adapter avec succès à un environnement en mutation est l'un des défis les plus importants auxquels les communautés et les gouvernements doivent faire face au cours de ce siècle. L'intérêt scientifique pour l'adaptation aux changements climatiques a considérablement augmenté au cours des deux dernières décennies, et une littérature distincte est apparue autour des politiques d'adaptation qui visent à comprendre pourquoi et comment les gouvernements s'intéressent à l'adaptation. La croissance de la recherche empirique sur les politiques d'adaptation a toutefois largement dépassé les progrès conceptuels et théoriques de notre compréhension de la nature de la politique d'adaptation. Il en résulte une littérature fragmentée qui rend difficile l'accumulation de connaissances d'une étude à l'autre.

Le but de cette thèse est de faire progresser les fondements conceptuels de la recherche sur les politiques d'adaptation en proposant une approche enracinée dans les théories des politiques publiques sur le choix des instruments politiques. Cette recherche est guidée par trois objectifs généraux:

1. Surmonter le problème de «variable dépendante» dans la recherche sur l'adaptation, ce qui se traduit par une ambiguïté quant à ce que les spécialistes de la politique de l'adaptation cherchent à comprendre et à expliquer;

2. Appliquer la théorie sur le choix des instruments de politique pour expliquer les nouvelles approches en matière de politique d'adaptation au niveau des administrations locales; et
3. Continuer à développer des perspectives comparatives en matière de recherche sur les politiques d'adaptation.

Les résultats de ces travaux indiquent que les approches politiques émergentes en matière d'adaptation locale sont de nature très complexe, avec des objectifs et des instruments politiques couvrant un certain nombre d'impacts des changements climatiques et d'entités administratives. Les choix d'instruments politiques sont influencés à la fois par les circonstances contextuelles locales et nationales, soulignant l'influence des arrangements institutionnels intergouvernementaux sur l'élaboration des politiques locales. En outre, les différences de formulation des politiques d'adaptation par les gouvernements locaux sont observables d'un contexte national à l'autre, ce qui suggère que des approches distinctes en matière de politique d'adaptation pourraient émerger d'un pays à l'autre.

Le chapitre 3 place l'accent analytique de cette recherche sur les gouvernements locaux dans le paysage émergent de la gouvernance à plusieurs niveaux de l'adaptation aux changements climatiques, en cours de formalisation dans le cadre des accords internationaux sur les changements climatiques. Le chapitre 4 de la thèse développe une conceptualisation de la politique d'adaptation fondée sur l'idée de mélanges de politiques et démontre cette approche en caractérisant la nature des portfolios de politiques d'adaptation de 125 administrations locales au Canada, en Allemagne, aux Pays-Bas, au Royaume-Uni et en France. Le chapitre 5 cherche à expliquer les choix d'instruments politiques de ces administrations locales en utilisant un modèle de styles de mise en œuvre des politiques proposé dans la littérature sur les instruments politiques. Le chapitre 6 de la thèse aborde l'état actuel des méthodes de recherche comparatives

en recherche sur la gouvernance de l'adaptation et propose que l'introduction de techniques d'analyse de texte computationnelles, en particulier la modélisation de thèmes, puisse apporter de nouvelles perspectives à la recherche sur les politiques d'adaptation. Le chapitre 7 de la thèse utilise la modélisation par sujet pour identifier les cadres de politique d'adaptation à partir des documents de politique locale analysés aux chapitres 4 et 5. Le chapitre 8 conclut la thèse par une réflexion sur les principaux résultats et contributions, les implications politiques et les besoins en matière de recherche future.

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AUTHOR CONTRIBUTIONS

This thesis includes five manuscripts that are either published, in review, or being prepared for submission to peer-reviewed journals. These manuscripts were written with co-authors, whose contributions are as follows.

Chapter 3: *“What does the Paris Agreement mean for adaptation?”* by Alexandra Lesnikowski (primary author), James Ford, Robbert Biesbroek, Lea Berrang-Ford, Michelle Maillet, Malcolm Araos and Stephanie E. Austin. Alexandra Lesnikowski led the conceptual development of the manuscript, wrote the manuscript, and coordinated feedback among co-authors. James Ford, Robbert Biesbroek, Lea Berrang-Ford, Michelle Maillet, Malcolm Araos, and Stephanie Austin contributed to the conceptual development of the manuscript, and provided comments, feedback, and suggestions on the manuscript.

Chapter 4: *“Characterizing local climate change adaptation policy mixes”* by Alexandra Lesnikowski (primary author), James Ford, Robbert Biesbroek and Lea Berrang-Ford. Alexandra Lesnikowski led the conceptual development of the manuscript, data collection, data analysis, and manuscript preparation. James Ford, Robbert Biesbroek, and Lea Berrang-Ford contributed feedback throughout the research development stage and provided comments on the preparation of the manuscript.

Chapter 5: *“Policy implementation styles and local governments: The case of climate change adaptation”* by Alexandra Lesnikowski (primary author), James Ford, Lea Berrang-Ford, and Robbert Biesbroek. Alexandra Lesnikowski led the conceptual development of the manuscript, data collection, data analysis, and manuscript preparation. James Ford, Lea Berrang-Ford, and Robbert Biesbroek contributed feedback throughout the research development stage and during data analysis and provided comments on the preparation of the manuscript.

Chapter 6: *“Frontiers in data analytics for adaptation research: Topic modelling”* by Alexandra Lesnikowski (primary author), Ella Belfer, Emma Rodman, Julie Smith, Robbert Biesbroek, John D. Wilkerson, James D. Ford, and Lea Berrang-Ford. Alexandra Lesnikowski led conceptual development of the manuscript to situate it within the adaptation governance scholarship, provided data for the second case, interpreted model results with Ella Belfer, wrote the final manuscript, and handled revisions following review. Ella Belfer also contributed to development of the literature review and early drafts of the manuscript. Ella Belfer, Emma Rodman and Julie Smith ran the models and provided the tables and figures for the cases. James Ford, Robbert Biesbroek, John Wilkerson, and Lea Berrang-Ford provided guidance and feedback during the development of the article and reviewed and commented on the manuscript.

Chapter 7: *“Climate change adaptation policy framing among local governments”* by Alexandra Lesnikowski (primary author), James Ford, Robbert Biesbroek, and Lea Berrang-Ford. Alexandra Lesnikowski led the conceptual development of the manuscript, data collection, data analysis, and manuscript preparation. James Ford, Lea Berrang-Ford, and Robbert Biesbroek contributed feedback throughout the research development stage and provided comments on the preparation of the manuscript.

PUBLICATION DETAILS

Chapter 3: “*What does the Paris Agreement mean for adaptation?*” is published in *Climate Policy*. It can be found at:

Lesnikowski A, Ford J, Biesbroek R, Berrang-Ford L, Maillet M, Araos M, et al. What does the Paris Agreement mean for adaptation? *Clim Policy*. 2017;17:825–31.

Chapter 4: “*Characterizing local climate change adaptation policy mixes*” has been resubmitted with revisions following review to *Climatic Change* (March 2019).

Chapter 5: “*Policy implementation styles and local governments: The case of climate change adaptation*” is in review at *Environmental Politics* (April 2019).

Chapter 6: “*Frontiers in data analytics for adaptation research: Topic modelling*” is published in *Wiley Interdisciplinary Reviews: Climate Change*. It can be found at:

Lesnikowski A, Belfer E, Rodman E, Smith J, Biesbroek R, Wilkerson J, et al. Frontiers in data analytics for adaptation research: Topic modeling. *WIREs Clim Chang*. 2019;1–15.

Chapter 7: “*Climate change adaptation policy framing among local governments*” is being prepared for submission to *Nature Climate Change*.

Chapter 1: Introduction

1.1 Background and context

Rising levels of greenhouse gas emissions (GHGs) have put the Earth on track to hit an increase in global average temperatures that is well above 2°C by 2100, with profound implications for average land and ocean temperatures and variability of extreme temperatures and precipitation (IPCC 2018). Despite repeated warnings from scientists about the risks associated with rising emissions, global GHGs continue to climb unabated and more ambitious action is necessary if climate targets are to be met (Millar et al. 2017). Furthermore, even if progress were to be made on mitigating the worst of climate change, impacts on environmental and human systems are already being felt in the increasing strength and frequency of extreme events, rising sea levels, accelerating desertification, ecosystem stress, and changing patterns of vector-borne diseases (IPCC 2012). A consensus now exists within the climate change policy community that some degree of adaptation to these changes is necessary in order to minimize negative impacts of climate change and respond to emerging opportunities (IPCC 2014).

Over the last fifteen years, a large body of literature has emerged that focuses on understanding the nature of climate change vulnerability across places, scales, and over time, and identifying solutions for adapting to climate change impacts (Ford et al. 2018; Bisaro, Swart, and Hinkel 2016). Despite agreement on the importance of adaptation, however, our understanding of how different adaptation policy approaches are emerging across countries and levels of government is still in its infancy (Bednar and Henstra 2018). What is more, the focus in the adaptation literature on diagnosing institutional, political, and economic barriers to policy progress has developed largely independently from theories in the political and policy sciences on policy change and policy design (Biesbroek et al. 2015).

This thesis contributes to the adaptation policy literature by examining policy formulation among local governments from the perspective of emerging adaptation policy mixes and linking policy choices to the normative and institutional environments in which they are made. The aim of this research is to develop a robust conceptualization of adaptation policy that enhances our understanding of how governments govern climate change adaptation and supports theorizing about the relationship between policy ideas and discourses, institutional environments, and actor networks that shape policy decisions. My research design draws on systematic content analysis, statistical analysis, and computational text analysis (topic modelling) to characterize adaptation policy approaches emerging across 125 local governments in five countries with diverse constitutional arrangements and political cultures (Canada, France, Germany, Netherlands, and the United Kingdom).

This introductory chapter describes the context for this research with regards to the growing importance of adaptation in the climate change policy agenda, and the role of local governments in managing climate change impacts. It describes current research gaps, the key aims and objectives of the thesis, and the epistemological and methodological decisions that guide the research design. Finally, it provides an overview of the remaining chapters in the thesis and their relationship to the research questions that guide this work.

1.1.1 The growing importance of adaptation in global climate change policy

In the early years of global climate change policy, adaptation was regarded as a ‘poor cousin’ to mitigation. The two were frequently positioned antagonistically (Biesbroek, Swart, and van der Knaap 2009), with many climate change scientists and activists concerned that adaptation represented a ‘defeatist’ alternative to GHG reduction that would detract attention and political will away from solving the true problem of climate change, that of emissions reduction (Schipper 2006; Gupta 2010). Indeed, the 1992 United Nations Framework Convention on

Climate Change (UNFCCC) was principally concerned with mitigation, framing adaptation as an issue primarily for developing countries and making few concrete provisions for action beyond supporting adaptation planning and financing in low-income regions (UNFCCC 1992).

Since the mid-2000s, however, adaptation has emerged as a core pillar of the UNFCCC framework, culminating in the 2010 Cancun Agreement which states that “adaptation must be addressed with the same priority as mitigation and requires appropriate institutional arrangements to enhance adaptation action and support” (UNFCCC 2011). The 2015 Paris Agreement achieved an important milestone for adaptation, delivering a global goal on adaptation that focuses on “enhancing adaptive capacity, strengthening resilience and reducing vulnerability to climate change, with a view to contributing to sustainable development and ensuring an adequate adaptation response in the context of the temperature goal” (UNFCCC 2015). The Paris Agreement calls for stronger political and financial commitments from Member States and new transparency mechanisms for monitoring progress on meeting these commitments. It also articulates a flexible governance framework that emphasizes bottom-up initiatives and the role of non-state actors, particularly local governments, in adaptation implementation (Lesnikowski et al. 2017).

The last eight years thus represent a broadening of the political agenda around adaptation, from a problem primarily concerning the Global South to one requiring international mobilization of resources and cooperation across regions and scales of government. Concern about increasing vulnerability to climate change is also reflected in other major international agreements such as the Sustainable Development Goals, with Goal 13 committed to taking “urgent action to combat climate change and its impacts,” and the Sendai Framework for Disaster Risk Reduction, which calls for coherent action between the Sendai Framework and UNFCCC to promote cooperation in implementing and monitoring the Sendai goals.

1.1.2 Climate change and local governments

The post-Paris climate governance landscape is frequently described as multi-centric in nature, meaning that it is characterized by diverse networks, ideas, and institutions that form complex modes of governance and challenge traditional assumptions of hierarchical, state-centric governing authority (Jordan et al. 2015; Hsu, Weinfurter, and Xu 2017; Hughes, Chu, and Mason 2018). Much of the foundational research on urban climate change governance emerged in the context of mitigation policy (Bulkeley and Betsill 2005; Bulkeley and Betsill 2013; Hughes 2017; Burch and Robinson 2007), but a distinct literature focusing specifically on local adaptation policy processes has coalesced over the past ten years (Nalau, Preston, and Maloney 2015). Climate change is expected to have wide-ranging effects in urban areas (Revi et al. 2014); more than half the global population lives in urban centres, and cities are commonly regarded as critical sites for implementing adaptation due to the place-based nature of environmental risk dynamics and the authority of local governments over key mechanisms for adaptation delivery, including land use planning decisions, building permitting, and service delivery (de Coninck et al. 2018). Local governments are highly visible within the global climate change policy community, with urban climate networks such as C40, Resilient Cities, and the Global Covenant of Mayors acting as venues for organizing local leaders and representing their priorities and needs in international climate change negotiations (Aylett 2015; Rosenzweig et al. 2018).

The empirical literature on urban adaptation policy centres primarily around three intersecting questions. First, what strategies are local governments adopting (or not adopting) to adapt to climate change impacts (Amundsen, Berglund, and Westskogh 2010; Carmin, Nadkarni, and Rhie 2012; Araos et al. 2016; Castán Broto and Bulkeley 2013; Rauken, Mydske, and Winsvold 2014; Aguiar et al. 2018; Reckien et al. 2018)? Second, what drives local governments to engage with adaptation (Angelovski and Carmin 2011; Burch 2010; Fünfgeld 2015;

Hakelberg 2014; Heidrich et al. 2016; Hjerpe, Storbjörk, and Alberth 2014; Homsy and Warner 2015; Hughes 2015; Kern and Bulkeley 2009; Koski and Siulagi 2016; Reckien et al. 2015; Shi, Chu, and Debats 2015; Wang 2013; Wood, Hultquist, and Romsdahl 2014)? And third, how do political, institutional, economic, or social factors act as barriers or facilitators of local adaptation policy adoption (Corfee-Morlot et al. 2011; Jones 2012; Dannevig, Rauken, and Hovelsrud 2012; Macintosh, Foerster, and McDonald 2014; Measham et al. 2011; Mukheibir et al. 2013; Picketts, Déry, and Curry 2013)?

Despite clear interest in understanding the role of local governments for achieving effective adaptation, however, political research on emerging adaptation policy approaches remains underdeveloped (Hughes 2017; Javeline et al. 2014). The empirical scholarship on adaptation that has developed around the questions described above examines issues such as capacity, intergovernmental relationships, issue salience, and political leadership, but knowledge accumulation about how these elements dynamically intersect to influence policy choices across governance contexts is limited. Public policy critiques of adaptation research argue that a better understanding is needed of the rationales for policy choice, and attention should be focused on how adaptation is being shaped the wider governing traditions of states and subnational governments (Biesbroek et al. 2015; Wellstead, Howlett, and Rayner 2016; Wellstead, Howlett, and Rayner 2013; Rayner, McNutt, and Wellstead 2013; Wellstead and Stedman 2014; Craft and Howlett 2013; Howlett 2014).

1.2 Aim and research questions

The aim of this thesis is to advance the conceptual foundations of adaptation policy research and contribute to a growing interest in explaining adaptation policy choices across decision-making contexts. I address two fundamental challenges for adaptation policy research. First is how to define government action on adaptation in order to overcome the ‘dependent

variable problem' in adaptation governance research, meaning how we conceptualize adaptation as an empirical phenomenon and identify coherent variables to study it (Dupuis and Biesbroek 2013). Second is how to understand adaptation policy approaches given the diversity of policy approaches taken by governments to address different aspects of adaptation, and differences in the political and institutional contexts in which policy-makers make these decisions. I approach this aim from a comparative perspective, with the goal of developing a conceptual approach that can be applied across spatial and scalar diverse contexts.

This thesis develops a conceptual approach to the study of local adaptation policy formulation that is informed by the policy sciences. The overarching questions guiding this research are:

1. What policy approaches are local governments taking to deal with climate change adaptation?
2. How do local and national policy environments influence the adaptation policy choices of local decision-makers?
3. How is adaptation being framed as a policy issue by local governments and what does this indicate about emerging policy approaches?

To accomplish these aims and examine the research questions stated above, I draw on and advance in an adaptation context the conceptual model of policy change developed by Hall (1993) and Howlett and Cashore (2009).

1.3 Epistemological and methodological considerations

This thesis characterizes local adaptation policy approaches based on the systematic analysis of policy goals and policy instruments adopted by local governments, and analyzes how the institutional and normative contexts of local decision-making explain these policy choices.

Given the large-n research design, I adopt a correlational approach to drawing inferences about these relationships (Humphreys and Jacobs 2015), and integrate qualitative and quantitative techniques in the research design.

1.3.1 Comparative approach

Comparative methods are a cornerstone of social science research, and are used to test hypotheses, refine concepts and theoretical models, and discover new relationships (Laitin 2002). Individual case studies are key for theory development and illustrating the causal influence of conditions that are unique to individual cases, but progress on scientific explanation also requires comparative examination of how relationships change under different conditions (Tilly 1984). A fundamental challenge for comparative urban research is how to balance trade-offs between the simplification of concepts and variables necessary for generalizability, and the great diversity of governance contexts that characterize urban policy environments. Kantor and Savitch, for example, observe that theories of urban politics have often emerged from scholarship conducted in single country contexts and can struggle to explain policy outcomes in different institutional settings (Kantor and Savitch 2005). This observation is particularly relevant here because it mirrors Howlett's early critique of competing theories of national-level policy choice in the 1970s and 1980s, which he argued tended to reflect distinct national approaches to policy-making rather than generalizable theories of policy choice (Howlett 1991).

While comparative research is a growing focus within the local adaptation literature, to date most comparative studies have focused either on cities within just one country (Aall 2012; Dannevig, Hovelsrud, and Husabø 2013; Dannevig, Rauken, and Hovelsrud 2012; Heinrichs, Beck, and Kuhlicke 2009; Hughes 2015; Macintosh, Foerster, and McDonald 2014; Measham et al. 2011; Mukheibir et al. 2013; Rauken, Mydske, and Winsvold 2014; Shi, Chu, and Debats 2015; Swart et al. 2014; Wamsler and Brink 2014; Bierbaum et al. 2012; Gurran, Norman, and

Hamin 2013), or on a small number of cities in different countries (Jones 2012; Picketts, Déry, and Curry 2013; Rosenzweig and Solecki 2014; Rosenzweig et al. 2011). Increasingly, however, larger cross-country studies are being conducted to study progress on local adaptation policy adoption using data such as policy documents, surveys, web searches, interviews, and literature reviews (Carmin, Nadkarni, and Rhie 2012; Castán Broto and Bulkeley 2013; Reckien et al. 2014; Araos et al. 2017; Aguiar et al. 2018). While these studies have contributed valuable empirical insights into the emergence of adaptation within local climate change policy agendas, they do not explicitly address or resolve the issue of how we conceptualize the diverse types of policies that constitute local adaptation policy responses and understand their relationship with one another. This has significant implications for research designs; in the absence of more robust metrics, large-n explanatory research on local adaptation policy adoption tends to rely on the presence of a strategic adaptation plan as a binary outcome condition representing local adaptation policy (Reckien et al. 2015; Wang 2013), without capturing the diverse policy approaches that local governments are taking on adaptation that can occur even in the absence of strategic adaptation planning.

By addressing the dependent variable problem from a large-n comparative perspective, the logic of this thesis primarily consists of “establishing a principle of variation in the character or intensity of a phenomenon having more than one form by examining systematic differences among instances” (Tilly 1984, pg. 116). This is implemented by specifying a clear standard for measuring variation in the nature adaptation policies across local governments, namely the mixes of policy goals and instruments that local governments adopt through formal decision-making processes (Howlett 2004). These policy mixes accumulate over time and contain combinations of individual policies such as land use regulations, infrastructure standards, or public outreach campaigns. A variation-finding approach is useful for establishing the generalizability of

concepts and validity of measurements because it stresses clarity of assumptions and definitions and the avoidance of overly-specified metrics (Adcock and Collier 2001). A large-n comparative research design in particular provides a testing-ground for determining the consistency, comparability, comprehensiveness, and coherence of proposed approaches to characterizing adaptation (Ford and Berrang-Ford 2016). The empirical scope of the thesis demonstrates how the concept of policy mixes can be applied across diverse contexts to systematically examine differences in the policy approaches being taken by governments to address climate change impacts and vulnerability.

1.3.2 Sample selection

In light of my focus on formal decision-making processes around climate change adaptation, the thesis takes as its starting point the assumption that local governments are discrete political units with institutional arrangements that influence and shape how decision-making takes place on policy issues. While the geographical tradition has a rich history of debate about the nature of the urban and key thinkers have deconstructed the idea of the city as a bounded spatial unit (Harvey 1996; Sassen 2001), given the research questions stated above I argue that it is appropriate to consider local governments as constitutionally-created entities that are given shape by formal institutional structures and have certain powers and responsibilities granted to them, for example to conduct elections, adopt policy measures, and collect taxes. To make this assumption explicit, I therefore refer to the unit of analysis in this thesis as ‘local governments’ rather than cities or urban areas and identify the study sample based on the nature of local authority over land use planning, building permitting, and service delivery, which can vary across countries.

Implicit in this assumption is that the relationship between local government and higher levels of government is critical for understanding local policy processes and outcomes. Local

governments are embedded within particular national (and regional) contexts that have distinct state structures and policy traditions wherefrom their authorities and jurisdiction are derived. I therefore set out to identify a sampling frame of local governments from countries that represent different degrees of decentralization corresponding of Lijphart's distinction between federal/decentralized democracies and unitary/centralized democracies (Lijphart 1999). This distinction captures how power is divided between central and subnational governments, with federal/decentralized democracies such as Canada, the United States, or Germany characterized by a spatial division of power and unitary/centralized democracies such as France or the United Kingdom characterized by the concentration of power at the national level. Lijphart's conceptualization recognizes that these distinctions exist on a spectrum, with some states for example being federal and centralized and others unitary and decentralized. The countries selected here reflect this spectrum, with Canada and Germany being federal and decentralized, the Netherlands being semi-federal, the United Kingdom being increasingly unitary and decentralized, and France being unitary and centralized. The United States is frequently regarded as an archetypal federal state, and so it is worth noting that it was omitted from the selection of countries on the basis of the large comparative literature that already exists about emerging adaptation policies in American local governments. Canada was therefore selected instead of the United States in order to broaden the empirical basis of the comparative adaptation policy literature.

In addition to formal structural arrangements governing central-local relations, I also considered institutional and cultural differences in public administration systems, which are understood to influence how policies are designed and implemented. Here I draw on the idea of national administrative traditions, which are defined by Painter and Peters as "both ideas and structures. An administrative tradition is a more or less enduring pattern in the style and

substance of public administration in a particular country or group of countries” (Painter and Peters 2010a, pg. 6). Painter and Peters conceptualize administrative traditions based on four variables: state-society relationships, relationships between administrative and political institutions, legalist vs managerial functions, and mechanisms for ensuring administrative accountability. I aimed to ensure that the countries selected based on Lijphart’s central-local categorization also represented diversity in administrative traditions to examine the extent to which local policy formulation is influenced by different cultures of public management, not just structural aspects of institutional environments.

Finally, on a pragmatic level the selection of countries also took into account the linguistic resources available within my research team, as data collection required coding non-English primary policy documents. Table 1.1 provides an overview of the countries that were selected based on the dimensions described above.

Table 1.1 Country selection criteria

	Canada	Germany	Netherlands	United Kingdom	France
<i>Central-local structure</i>	Federal - decentralized	Federal-decentralized	Semi-federal	Unitary-decentralized	Unitary-centralized
<i>Administrative traditions family</i>	Anglo-American	Germanic	Germanic	Anglo-American	Napoleonic

The largest twenty-five local governments from Canada, France, Germany, the Netherlands, and the United Kingdom were selected for analysis, for a total sample of 125 local governments (see Appendix A for full list). Large local governments are selected because empirical adaptation research suggests that large cities are more likely to be involved in climate change adaptation (Paterson et al. 2017), thus increasing the likelihood that adaptation policies

would be found for each local government. Despite the decision to select only the largest local governments in each country, the population range is quite large and encompasses both large and medium size local governments (maximum population: 2,731,571; minimum population: 108,915) (see Appendix A for full list). The sampling strategy is therefore relativistic about what constitutes a ‘large’ local government; a large local government in one country may be small by the standards of another country. The disadvantage of this selection approach, of course, is that it is not fully random. Nonetheless, insights from this research provide a strong foundation for future hypothesis-testing and contribute to refining existing theories of local adaptation policy design and policy choice.

1.3.3 Methodology of the thesis

This thesis applies several methodological techniques to identify local adaptation policy mixes and examine the institutional and normative contexts of policy choice. The first stage of the research consists of the systematic identification of local adaptation policies from policy documents using content analysis (Chapter 4). Content analysis is a methodological tool for drawing insights from texts that are transparent and replicable. I follow Krippendorff’s definition of content analysis, which understands content to “emerge in the process of a researcher analyzing a text relative to a particular context” (Krippendorff 2013, pg. 25). Embedded in this definition are several key assumptions about the nature of textual analysis. Most importantly, texts are understood to be objects that cannot exist independently from the reader. They contain no objective meaning and therefore depend on the reader for interpretation. The same text can carry different meanings for different readers, which are influenced by the reader’s purpose in considering the text. Consequently, the subjective and unstructured nature of texts requires that the wide range of possible interpretations be narrowed through systematic coding and classification of text that allow the researcher to make inferences about a specific question.

Content analysis is often seen as a qualitative technique, however the methodical extraction of data according to *a priori* defined categories also enables the application of quantitative analysis. Here this is achieved through the detailed elaboration of a coding manual that defines how policies are to be identified from texts and classified within a dataset of local adaptation policies (Appendix A). Data were coded using Atlas.ti Version 8.2.1.

These data form the basis for the second component of the project (Chapter 5), which uses fixed effects regression modelling and multilevel modelling to test nine hypotheses that aim to explain the composition of local adaptation policy portfolios. Fixed effects modelling permits testing of proposed drivers of local policy choice while controlling for heterogeneity between countries. Random intercept multilevel modelling is then used to examine country-level influences on local policy choice. These later models account for the hierarchical nature of the dataset, in which local governments are nested within specific country contexts. Analyses are conducted in R Version 3.5.2. The full list of packages used for this analysis are cited in the chapter.

Finally, in Chapter 7 I apply computational text analysis to identify policy frames guiding local action on adaptation using Structural Topic Modelling (Roberts et al. 2014). Topic modelling can be thought of as an automated form of content analysis, which uses word frequencies and co-occurrences within documents to identify topics that represent the meaning of a document (Blei, Ng, and Jordan 2003). Topic models are built using generative probabilistic algorithms that assume a body of text is composed of some mix of topics, and each individual text within this body is composed of some of these topics. Topic modelling is commonly used in the context of exploratory analysis, but Structural Topic Modelling allows the introduction of document-level meta-data after the unsupervised model is run to conduct hypothesis-testing using standard regression analysis. This analysis is also conducted in R Version 3.5.2.

1.4 Chapter overview

This chapter has explained the context for this research and provided an overview of the conceptual direction and methodological approach taken to examine my research questions. Chapters 3-7 are written as individual papers for publication in peer-reviewed climate change and public policy journals. Chapter 3 is already published in *Climate Policy* and Chapter 6 is published in *Wiley Interdisciplinary Reviews: Climate Change*. Chapter 4 has been re-submitted with revisions following review to *Climatic Change*, and Chapter 5 is in review at *Environmental Politics*. Chapter 7 is currently being prepared for submission to *Nature Climate Change*. The chapters of the thesis proceed as follows.

Chapter 2 provides an overview of the bodies of literature and core concepts that guide this research, specifically with regards to local adaptation policy and multilevel governance, adaptation tracking, policy mixes, and policy styles. These areas of literature are integrated in the thesis to examine emerging local policy approaches to manage climate change impacts and vulnerability and how the institutional and ideological context of local adaptation policy processes influence policy choice.

Chapter 3 provides an overview of key changes in global adaptation governance that are emerging under the 2015 Paris Agreement. It serves to position the scope of this research within an evolving governance landscape characterized by increasing the visibility of subnational governments in driving policy agendas around climate change adaptation. It also contextualizes the need for conceptual and methodological advancement in how we understand and measure climate change policy progress given a growing focus on adaptation policy assessment in the international climate change community. This chapter is the result of my work with the Tracking Adaptation to Climate Change Collaborative and is published as an Outlook Article in *Climate Policy*.

Chapter 4 is the first empirical contribution of the thesis, and presents an argument for a policy instruments approach to the conceptualization and empirical investigation of adaptation. This chapter explains how these policy mixes can be operationalized as variables in an adaptation context. I demonstrate the approach in an analysis of the adaptation policy portfolios of the local governments included in this thesis.

Chapter 5 is the second empirical contribution of the thesis, and draws on a model of policy implementation styles to test key hypotheses about the rationales for policy choice. This chapter examines whether key differences in institutional environments predict adaptation policy implementation styles using fixed effects regression analysis and multilevel modelling. It contributes empirical insights to the adaptation scholarship and suggests some refinements to the theoretical model of policy implementation styles for the case of local adaptation policy.

Chapter 6 represents a methodological contribution to the adaptation literature, and discusses innovations in computational text analysis within the adaptation governance scholarship. This chapter focuses specifically on one technique of computational text analysis, topic modelling, which is being increasingly used in political research to examine issues like public opinion, policy framing, and issue salience across large volumes of text. This paper is the result of collaboration with colleagues at McGill University, University of Leeds, University of Washington, and Wageningen University & Research and is published in *WIREs Climate Change*.

Chapter 7 is the third empirical contribution of the thesis, and applies topic modelling to the policy documents collected during data collection with the goal of identifying the policy frames that underlie adaptation policy development among these local governments. This chapter draws on the methodological proposals made in Chapter 6 to examine underlying ideas

embedded in local policy texts about the role(s) of local governments in managing climate change impacts.

Finally, Chapter 8 concludes the thesis with a discussion on how the findings of each chapter contribute to our understanding of how adaptation policy portfolios are developing at the local level, and what this suggests about drivers of local adaptation policy choices. This chapter explains the significance of this research with regards to the comparative study of adaptation policy, and identifies opportunities for future research that build on the approach applied here. It also reflects on the implications of this research for technical guidance to adaptation policy-makers.

Chapter 2: Literature review and conceptual framework

2.1 Introduction

Chapter 1 outlined the focus of this thesis, which is to address the ‘dependent variable problem’ in adaptation policy research stemming from under-conceptualization of adaptation as an empirical phenomenon. The design of the thesis draws together key concepts from two areas of scholarship: climate change adaptation and public policy. While this research addresses a relatively new issue for local policy agendas, that of climate change adaptation, I draw on established public policy concepts to propose a stronger conceptual foundation for how we understand and study adaptation. The purpose of this chapter is to capture the cross-cutting themes and ideas that underpin the thesis. Where directly relevant to later chapters, the concepts or theories described here are elaborated on in the individual chapters. Detailed literature reviews are also provided in each chapter.

This chapter argues that the study of climate change adaptation policy has made limited progress in conceptualizing and explaining the diverse policy approaches emerging from local governments to address climate change risks. This is due to vagueness around how adaptation is defined, and the tendency for empirical research to focus on either specific forms of adaptation governance or the adoption of certain types of policies such as adaptation strategies, rather than systematically examining what governments actually *do* in relation to adaptation as a policy problem. This chapter examines current approaches to the study of local adaptation policy and proposes that studying adaptation policy from the perspective of policy instruments lends greater clarity to how we can classify and compare adaptation policies. This perspective can also enrich efforts to theorize linkages between these policy choices and the wider policy-making environments in which decisions are made.

2.2 Background literature review

The bodies of literature described below were identified based on their relevance to the central aim of this thesis, which is to advance the conceptual foundation of adaptation policy research by clarifying how we define adaptation as an empirical phenomenon and to examine variations in local policy approaches occurring across different governance contexts. The following sub-sections describe the different bodies of literature that form the intellectual foundation for this research.

2.2.1 Current research on local adaptation policy

Adaptation policy research has developed a strong emphasis on the role of local governments in building resilience to the impacts of climate change. In many ways this reflects geographical traditions in adaptation research, particularly its roots in place-based vulnerability research (Adger 2006; Smit and Wandel 2006; McDowell, Ford, and Jones 2016). This empirical focus on local governance scales, however, also reflects the political mood around climate change at the time of 2008/2009, when attention to adaptation in the academic literature began growing rapidly. This expansion in the climate change research agenda coincided with the failure to secure a new climate agreement at the UNFCCC's Conference of the Parties in Copenhagen in 2009, and a growing pessimism about the ability of national governments to deliver on pledges to 'solve' the climate crisis. Indeed, many of the early movers on adaptation were cities such as New York and Toronto rather than national governments, and the scholarship responded by focusing on how local governments (should) utilize their jurisdiction over land use planning, services, and emergency preparedness to implement adaptation (Burch et al. 2014; Carmin, Nadkarni, and Rhie 2012; Dannevig, Rauken, and Hovelsrud 2012; Fünfgeld 2015; Hjerpe, Storbjörk, and Alberth 2014; Measham et al. 2011; Mukheibir et al. 2013; Picketts et al. 2013; Wang 2013). An assumption quickly developed in the literature that local authorities were best

placed to respond to the impacts of climate change (Nalau, Preston, and Maloney 2015; OECD 2010). Adaptation and resilience became a strategic focus of the new urban agenda (United Nations 2017), and being perceived as a ‘climate leader’ became part of the ‘branding’ of progressive cities competing for investment and to attract economic migration (Whitehead 2013).

With local governments framed as key leaders in the effort to manage emerging climate change impacts, the adaptation literature has focused on understanding what drives local governments to engage with adaptation, and how different political, economic, or institutional factors can support adaptation efforts. As noted above, large cities like New York were widely regarded to be early movers on adaptation, and several studies have suggested that reputational concerns about being perceived as climate leaders and safe sites for economic investment over the long-term were strong motivators for high profile climate change policy initiatives (Solecki, Patrick, and Sprigings 2016; Anguelovski and Carmin 2011). The extent to which elected officials or other policy entrepreneurs perceive climate change to be a significant issue and advocate for strong climate leadership is thus a commonly cited driver of adaptation policy adoption (Hjerpe, Storbjörk, and Alberth 2014; Hughes 2015; Shi, Chu, and Debats 2015). This recognition is often motivated by experienced extreme weather events, which draw public attention to anticipated climate change impacts and build support for adaptation (Anguelovski and Carmin 2011; Hughes 2015; Koski and Siulagi 2016; Shi, Chu, and Debats 2015; Wang 2013; Kalafatis 2018). This hypothesis follows the logic of policy ‘windows of opportunity’ (Kingdon 1984), wherein sudden shocks from disasters such as hurricanes or floods can draw political attention to growing climate change risks and motivate policy responses (Rosenzweig and Solecki 2014). Where climate change action is otherwise hindered by a lack of political consensus, linking adaptation to local risk management priorities and framing it as a sensible ‘no-regrets’ option to protect community investments, rather than as an environmental protection

or moral issue, has sometimes enabled adaptation policy development in circumstances where climate change suffers from low issue legitimacy (Hughes 2015; Fünfgeld and McEvoy 2014).

The diffusion of adaptation beyond early climate change leaders onto local policy agendas is often linked in the literature to participation in urban climate change networks. Networks like C40 or ICLEI are widely seen to serve both normative and technical purposes by influencing political will around climate change action and giving local officials access to information and financial resources that they may not otherwise receive from higher levels of government (Anguelovski and Carmin 2011; Fünfgeld 2015; Hakelberg 2014; Kern and Bulkeley 2009; Reckien et al. 2015). Scholars argue that networks can serve to draw the attention of local decision-makers to the need for adaptation policies, contribute to the establishment of common discourses and norms around the framing of adaptation, generate information and knowledge, and distribute financial and technical resources (Betsill and Bulkeley 2004; Fünfgeld 2015; Hawkins et al. 2015; Hakelberg 2014; Reckien et al. 2015). The extent to which network participation as a general activity has a causal influence on adaptation agenda-setting, however, is unclear (Bassett and Shandas 2010). Some studies note that not all networks generate the same level of commitment from members, and often they can evolve as ‘networks of pioneers for pioneers’ (Kern and Bulkeley 2009; Krause 2012). In short, not all networks are equal, and some may be more substantive in their contributions to policy-making than others.

A second key question in the local adaptation literature is what constrains or limits government engagement with adaptation. A number of studies that examine ‘barriers’ to local adaptation has pointed to limited scientific information, high uncertainty, inadequate political leadership, low institutional capacity (e.g. GDP, financial and staff resources), and competing policy issues as key stumbling blocks to local policy formulation and implementation (Measham

et al. 2011; Burch 2010; Carmin, Nadkarni, and Rhie 2012; Reckien et al. 2015; Aguiar et al. 2018). Barriers perspectives can thus be broadly characterized as providing material interpretations of the failure or success of local governments to adopt adaptation policies (Biesbroek, Klostermann, et al. 2013). A common conclusion is that in the absence of either top-down support from national and regional government or policy coordination across levels of government, sustaining ambitious policy initiatives locally that address the ‘big picture’ of vulnerability reduction is likely to be extremely difficult (Krause, Yi, and Feiock 2015; Porter, Demeritt, and Dessai 2015; Keskitalo et al. 2016; Mukheibir et al. 2013; Eckersley 2018; Nilsson, Gerger Swartling, and Eckerberg 2012). The barriers perspective on adaptation policy processes is strongly critiqued by scholars working in the public policy field, however, who argue that the approach relies on functionalist logic discredited in the social sciences that assumes ‘society’ exists as a coherent and defined (though complex) system, and that barriers thinking has a tendency to black-box the internal mechanisms of institutional and political environments, thus failing to offer testable hypotheses that can improve our understanding of decision-making and policy change (Wellstead et al. 2018; Biesbroek et al. 2015). The barriers literature has tended to result in generic lists of factors that enable or constrain adaptation (Biesbroek, Klostermann, et al. 2013), and which tell us little about how, when, or why combinations of these factors become important across contexts. While some empirical studies have emerged from this critique that demonstrate alternative approaches to understanding policy change or failure (Rayner, McNutt, and Wellstead 2013; Wellstead, Howlett, and Rayner 2013; Wellstead and Stedman 2014), the barriers approach nonetheless remains dominant in adaptation research.

Multilevel governance (MLG) perspectives on local adaptation policy processes offer something of a counter-point to the barriers literature for understanding the (under-)performance

of local governments on adaptation policy adoption and implementation. MLG emphasizes that efforts to design effective adaptation policies must contend with governance environments that are fragmented within and across levels of government and between state and non-state actors, challenging the ability of local actors to leverage authority and resources for substantive policy change (Henstra 2017; Hughes, Chu, and Mason 2018). Local governments are generally the most constitutionally constrained level of government with regards to formal authority and issue jurisdiction, and the extent to which local governments exercise independence over the determination of policy goals and their implementation varies across countries (Sellers and Lidström 2007).

MLG characterizes the adaptation policy arena as existing vertically between different levels of government and horizontally between policy issues (Brown 2012; Eckersley 2018; Keskitalo et al. 2016; Greiving and Fleischhauer 2012), and within the interactions between public and private actors (Busch et al. 2016; Fünfgeld 2015; van Pelt and Swart 2011; Dzebo and Strippel 2015). It emphasizes growing supranational (e.g. the European Union), subnational, and non-state policy authority (Hooghe and Marks 2003), and is interpreted in the climate change literature as signalling a new form of governance anchored among cities, states, regions, civil society organizations, and the private sector rather than traditional forms of hierarchical (i.e. top-down) governance (Hsu, Weinfurter, and Xu 2017; Hsu et al. 2015; Jordan et al. 2015). The role of the central state here is largely seen as a coordinator and enabler rather than a coercive driver of change (Peters and Pierre 2001), echoing the broader debate in political science and policy studies about whether top-down state authority is in decline (Zito 2015).

While MLG has emerged as a key theme in adaptation policy, a bifurcated focus in the empirical literature on the horizontal and vertical dimensions of these governance environments has resulted in sometimes contradictory conclusions on the relationship between MLG and

adaptation policy change, with MLG simultaneously identified as a barrier and a solution to the challenge of adaptation (Chaudhari and Mishra 2016; Corfee-Morlot et al. 2011; Bates et al. 2013; Amundsen, Berglund, and Westskogh 2010; Juhola 2016). Examination of the horizontal dimensions of MLG environments have focused on the role of actor networks such as ICLEI in catalyzing local political momentum around adaptation. From this perspective multilevel governance is framed as a *solution* to managing climate change impacts, with urban climate networks enabling local governments to build their capacity to respond to climate change risks in the absence of support from the central state (Fünfgeld 2015; Hakelberg 2014; Betsill and Bulkeley 2004; Andonova, Betsill, and Bulkeley 2009; Bulkeley et al. 2012). In contrast, emphasis on the vertical dimension of multilevel governance tends to portray decentralized governance as a *barrier* to effective adaptation. Here the central governance challenge posed by adaptation is its nature as a boundary-spanning policy problem that requires coordination across levels of governments and sectors (Bauer and Steurer 2014; Westerhoff, Keskitalo, and Juhola 2011). A key role for high-level governments is establishing a shared understanding of adaptation and reforming institutions to facilitate policy development and implementation, while local governments feed local knowledge into these processes and directly manage the public infrastructure and services important for adaptation (Henstra 2017; Dannevig et al. 2012; Vogel and Henstra 2015). From this perspective, several authors argue that the ability of local governments to achieve effective and long-term policy change is limited in the absence of more coordinated leadership from higher levels of government (Keskitalo et al. 2016; Porter, Demeritt, and Dessai 2015). A basic question therefore remains around what exactly MLG frameworks in adaptation policy research aim to explain, and how descriptions of governance environments can contribute to hypothesis-testing and theory development (Zito 2015).

Eckersley proposes a model of MLG that aims to resolve this ambiguity by building on the concept of central-local power dependency (Eckersley 2017a). The model predicts that where local governments are unable to access sufficient resources from senior government to formulate and implement policy, they are likely to depend more heavily on horizontal actors to increase their policy capacity. Where local governments have sufficient access to resources from higher levels of government, they are likely to prefer hierarchical governance arrangements in which central governments play a stronger role in influencing local policy. Chapter 5 of the thesis picks up on this linkage between local government capacity and multilevel governance, and examines two aspects of vertical institutional environments: i) formal institutional arrangements that govern the fiscal dependency of subnational governments on national governments; and ii) ‘soft’ leadership from central governments on adaptation policy formulation.

In summary, the topic of local adaptation policy has developed quite rapidly over the past decade, but overall this literature remains relatively fragmented with no cohesive conceptual or theoretical framework to inform our interpretations of research findings. This literature has developed a strong focus on describing the dynamics of adaptation agenda-setting, including what drives or hinders engagement by policy-makers with adaptation, and on specific forms of local adaptation governance such as urban climate networks. By integrating the study of local adaptation policy instruments and mixes with the emerging literature around adaptation policy tracking I propose to advance the study of local adaptation policy by systematically characterizing and explaining the actual content of policies. The following section summarizes the scholarship around adaptation tracking, including its relevance to the study of adaptation policy and core conceptual challenges that remain unresolved in this literature.

2.2.2 Current approaches in adaptation tracking

Adaptation tracking refers to a sub-focus within the adaptation assessment literature that aims to characterize and compare trends in adaptation processes, policies, and outcomes across places and scales and over time (Ford and Berrang-Ford 2016). This work is emerging in part as a response to calls for greater government accountability on adaptation, and the need for new methods to monitor progress to this effect (UNEP 2017). While the global goal on mitigating climate change can be measured through emissions reductions or global average temperature change, adaptation is a fundamentally social phenomenon that can only be observed indirectly through institutional and behavioural changes, (avoided) losses, or new opportunities seized (Ford, Berrang-Ford, Biesbroek, et al. 2015). As adaptation becomes further institutionalized in the UNFCCC through mechanisms such as the global stocktake on assessing progress towards the goals of the Paris agreement and within the mandates of government agencies and departments, determining how to measure progress towards meeting adaptation policy goals is becoming an increasingly urgent challenge.

Approaches to tracking adaptation policy change can be conceptualized along a spectrum from policy processes, policy outputs, policy outcomes, to policy impacts (Table 2.1). Each approach contributes a different perspective on the question of policy change, from micro-level aspects of designing and implementing individual projects or programs, to macro-level perspectives on changing global and regional vulnerability. These approaches have roots in different disciplines and provide insight into different aspects of adaptation.

Table 2.1 General approaches to tracking adaptation progress

<i>Approach</i>	<i>Definition</i>	<i>Adaptation-relevant examples</i>
Policy process	Project or program-level inputs and activities, such as funding, human resources, and stakeholder meetings.	(Conevska et al. 2018)

Policy output	Formal actions undertaken by government, such as adoption of flood risk mitigation legislation or implementation of a climate impacts surveillance and monitoring system.	(Lesnikowski et al. 2016; Eisenack and Stecker 2012)
Policy outcome	The results attributable to particular policy outputs, such as extreme weather-related costs minimized or lives saved.	(Fisher et al. 2015)
Policy impact	Overall progress towards vulnerability reduction, such as crop yields or weather-related losses.	ND-GAIN Country Index, Global Climate Risk Index

Policy process perspectives are prevalent in program-level evaluations of policies, particularly in the development sector and recent national audits of adaptation policy action in high-income countries (Office of the Auditor General of Canada 2018; Brooks et al. 2011; European Court of Auditors 2017; Fisher et al. 2015). Challenges around the feasibility of scaling up indicators such as funding or human resources to entire policy portfolios, however, has limited its use in national and subnational adaptation tracking research. On the other end of the spectrum, policy impacts monitoring draws heavily from environmental sciences and can be observed in global vulnerability indices such as ND-GAIN, which aggregates quantitative indicators of climate change exposure, adaptive capacity, and adaptation readiness to provide a global picture of where vulnerability is worsening or improving. These types of metrics offer a glimpse at the ‘end-goal’ of adaptation efforts but are generally disconnected from policy changes occurring across jurisdictions. Outcome assessment is in some sense considered the ‘holy grail’ of adaptation assessment, and is concerned with determining the effectiveness and success of adaptation interventions in reducing vulnerability and increasing adaptive capacity. It remains a largely intractable ambition, however, owing to disagreement around what constitutes ‘successful’ adaptation, challenges in establishing causal linkages between adaptation interventions and changes in vulnerability over the long-term, and difficulty in disentangling intersections between adaptation and related policy areas such as sustainable development or

disaster risk management (Christiansen, Martinez, and Naswa 2018; Dupuis and Biesbroek 2013).

Given these limitations, the adaptation tracking literature has developed a strong focus on policy output-based research (Ford et al. 2013). This literature aims to systematically identify and categorize adaptation policy outputs across places, scales, and sectors (Lesnikowski et al. 2015; Lesnikowski et al. 2016; Lesnikowski et al. 2011; Biagini et al. 2014; Gagnon-Lebrun and Agrawala 2007; Araos et al. 2016; Kamperman and Biesbroek 2017). In the case of local adaptation policy tracking, a variety of survey, case study, and text-based methods have been used to analyze trends in adaptation policy adoption by local governments. One of the earliest large comparative studies was conducted by Carmin et al. on 468 member cities of ICLEI-Local Governments for Sustainability, an international network of cities engaged with climate change planning (Carmin, Nadkarni, and Rhie 2012). Their findings point to the growing importance of adaptation in local climate change policy agendas, with 68% of respondent cities reporting early engagement with adaptation planning and 18% of cities reportedly at the implementation stage of the policy process. Most of these local governments were found to be focusing on processual policy actions, including engagement across city departments and with other levels of government or the private sector, holding public meetings, building information portfolios about current adaptation work, grant writing, and adoption of general adaptation plans or sectoral plans. Subsequently, surveys of municipal action on climate in the United States and Europe have also observed an emphasis on processual policy action, with a growing number of local governments conducting assessments, developing adaptation working groups, or adopting adaptation plans, but with limited indication that these are being implemented through on-the-ground action (Woodruff and Stults 2016; Aguiar et al. 2018). More recent cross-national studies have applied systematic document coding methods to examine reported adaptation initiatives.

Araos et al. analyze adaptation trends in large cities around the world and find evidence that some cities are completing adaptation interventions such as coastal management, green infrastructure, and water supply management (Araos et al. 2016), but nonetheless over 80% of the cities reviewed demonstrate no explicit engagement with adaptation.

As evidence of adaptation policy adoption has grown and the methodological literature on adaptation policy assessment has matured, efforts to develop more standardized approaches to the study of adaptation policy have emerged under the term ‘adaptation tracking’. Adaptation tracking describes the dependent variable problem as one of the ‘grand challenges’ for adaptation scholarship, with implications for how we define policy, classify and compare different types of adaptation policies, and distinguish between symbolic and substantive adaptation policies (Ford, Berrang-Ford, Biesbroek, et al. 2015). Ford and Berrang-Ford propose four principles to guide the design of adaptation tracking research that are motivated by a need to better standardize the methods and techniques used by researchers studying where and how adaptation is taking place across diverse contexts. These principles include definitional *consistency* in what ‘counts’ as adaptation, *comparability* of metrics across spatial and temporal units of analysis, *comprehensiveness* of data that enables observation about generalizable trends, and the conceptual *coherence* of metrics that capture the substance of adaptation policies (Ford and Berrang-Ford 2016).

While the adaptation tracking literature has made significant contributions to adaptation policy studies by explicitly problematizing how we define adaptation, its predominant focus on methodological aspects of policy analysis have largely framed the dependent variable problem as a technical challenge (Ford and Berrang-Ford 2016). There has been comparatively less focus on addressing its underlying roots as a conceptual issue (Green-Pedersen 2004; Dupuis and Biesbroek 2013). In this thesis I propose to address this gap by integrating the concept of policy

mixes from the public policy literature. The advantage of adopting this existing concept in the context of adaptation tracking is two-fold. First, the concept has a well-developed theoretical foundation linked to literatures on policy design, policy change, and governance (Howlett 2019; Peters and Pierre 2016a; Eliadis, Hill, and Howlett 2005), which are core concerns within the adaptation literature. This rich scholarship provides key entry points for hypothesis development and theory-building about how ideas, institutions, actors, and processes explain adaptation policy formulation and implementation. Second, conceptualizing the adaptation responses of governments within the policy instruments literature situates these responses with the broader context of how governments manage societal issues. Rather than ‘reinventing the wheel’ around how we understand adaptation as a policy issue, drawing on the policy mixes concept recognizes that governments address climate change impacts alongside a wide range of other policy issues, and that adaptation policy responses are influenced by policy traditions in areas such as spatial planning or water management. The following section elaborates on the concept of policy mixes, beginning first by defining public policies and their relationship to policy instruments and policy mixes, and then concluding with a discussion on what how empirical study of adaptation policy mixes can contribute to our understanding of emerging policy approaches on adaptation.

2.3 A conceptual framework for advancing adaptation policy research: Policy mixes and policy styles

Public policy is a sub-field of political science focused on analyzing and explaining the outputs and outcomes of political processes. These outputs are broadly understood as the actions (or non-actions) of public actors (generally governments) to address an issue of societal relevance (Knill and Tosun 2012). A fundamental challenge underlying policy analysis is making sense of the wide range of activities undertaken by government such that it can be modelled, compared, and explained. Policy analysis therefore relies on the classification of

public policies to enable empirical study of policies across places, policy sectors, levels of government, or over time.

Howlett and Cashore propose a two-level taxonomy of public policies based on two components: policy goals and policy means (Howlett and Cashore 2009). Each component is interpreted at three levels of abstraction, from high level policy ideas (*policy goals*) and norms guiding implementation preferences (*policy means*), to program-level policy objectives (*policy goals*) and instruments (*policy means*), and finally at the level of specific design qualities regarding policy requirements (*policy goals*) and use (*policy means*). Individual policies can be described based on these six elements (Table 2.2).

Table 2.2 Taxonomy of policy components

	High-level	Program-level	Operational-level
Policy goals	(A) General ideas governing policy development	(C) Formal policy goals	Specification of desired change
Policy means	(B) Preferences guiding policy implementation	(D) Policy instruments	Calibration of policy targeting

Adapted from Howlett and Cashore (2009)

I propose to use this taxonomy to conceptualize and categorize adaptation policies with the goal of capturing the content of adaptation policy approaches emerging among local governments. Policy mixes are defined as the bundles of program-level policy goals and instruments that evolve over time as governments adopt or dismantle adaptation policies (del Rio and Howlett 2013). To this end, I adopt Dupuis and Biesbroek's definition of adaptation as:

The process leading to the production of outputs in forms of activities and decisions taken by purposeful public and private actors at different administrative levels and in different sectors, which deals intentionally with climate change impacts, and whose outcomes

attempt to substantially impact actor groups, sectors, or geographical areas that are vulnerable to climate change. (Dupuis and Biesbroek 2013, pg. 1,480)

Each chapter of the thesis sheds light on the four aspects of local adaptation policies highlighted in Table 2.2. Chapter 4 focuses on policy mixes by identifying combinations of formal policy objectives (cell C) and policy instruments (D) from local policy documents retrieved from city council archives. Chapter 5 examines emerging policy implementation styles (B), and tests key hypotheses about rationales behind policy instrument choice that reflect decision-maker preferences. Chapter 7 examines the ideas held by policy-makers about the nature of adaptation as a policy problem, and interprets what these signal about underlying norms guiding policy choice (A).

To develop the general taxonomy of policies described in Table 2.2 in the context of policy mixes, I also adopt a more specific taxonomy of policy instruments that guides coding of policy documents conducted in Chapter 4. Policy instruments are defined as “techniques of governance that, one way or another, involve the utilization of state authority or its conscious limitation” to address a given policy problem (Howlett 2005, pg 31). The theoretical taxonomies of policy instruments arose from an understanding that ‘policy’ encompasses a wide range of government activities, and simplification of this complexity is necessary to advance the robust empirical study of how states govern, and the policy choices that political actors make (Linder and Peters 1984). Adopting of a policy instruments perspective on the outputs of adaptation policy processes addresses a key issue in comparative adaptation policy studies: how to conceive of adaptation policy as an object of analysis that can be defined coherently and consistently across contexts (Ford and Berrang-Ford 2016; Dupuis and Biesbroek 2013).

A number of taxonomies have been proposed that describe the form and function of policy instruments. Some emphasize differences between types of policies, while others classify policies based on their level of similarity (Howlett 1991). Here I follow Howlett's proposed taxonomy that integrates two dimensions of policies (Howlett 2005): i) the *governing resources* of states; and ii) the *functional logic* of policy instruments, which captures the approach governments take to achieving their policy goals. The resource dimension is drawn from Christopher Hood's NATO typology, which represents a classification scheme of the types of resources that governments have at their disposal (Hood 1983): nodality (information tools), authority (regulatory tools), treasure (financial tools), and organization (institutional reforms). Henstra applies this typology in the context of adaptation to categorize different types of interventions, for example climate change scenarios (nodality), flood construction levels (authority), purchase of vulnerable lands (treasure), and climate-proofing government buildings and operations (organization) (Henstra 2016). The functional dimension of the taxonomy corresponds to the logic of government action. Do governments aim to directly affect society through delivery of services and goods (substantive policy instruments), or do governments aim to indirectly provoke behavioural change or updating of beliefs and norms (procedural policy instruments)?

Policy instrument choice has an important influence over whether and how public policy is implemented, and how likely governments are to achieve their objectives. Public policy perspectives on policy instrument choice argue that instrument selection is not simply a technocratic process of identifying the 'best' instrument to achieve a given policy goal. Indeed, there is never any objective best instrument to address a policy problem. The design of policy approaches depends on the nature of the policy problem, the character of the instruments themselves (such as the extent to which they require direct government intervention in society

and the scope of their impact on policy targets), and the context in which policy processes are occurring (Howlett 2018). Choices between alternative instruments are made based on how actors make sense of a policy problem and reflect preferences for particular types of instruments that emerge in the context of the institutional legacies and path dependencies that influence decision-making (Landry and Varone 2005; Linder and Peters 1989; Biesbroek, Peters, and Tosun 2018).

Debate around the existence of ‘policy styles’ is closely linked to the literature on policy instrument choice, and reflects a strong influence of new institutionalist thinking in the policy instruments literature (Hall and Taylor 1996). Policy styles provide a conceptual lens for drawing out the relationship between the agency of actors and formal and informal institutions that shape decision-making processes. The literature on policy styles emphasizes that most decision-making processes occur within the context of existing organizational structures and policy mixes (Howlett and Tosun 2018a). These historical legacies reinforce certain norms and learned routines that are reproduced within organizations and result in a certain degree of durability and predictability in the policy-making approaches favoured by policy actors (Richardson, Gustafsson, and Jordan 1982). Empirical examination of variations in policy styles across places, levels of government, and policy issues is also a useful heuristic device for observing geographic variations in the policy approaches favoured by governments (Bailey 2007).

The earliest references to policy styles came from Jeremy Richardson, whose 1982 volume *Policy Styles in Western Europe* describes two dimensions of policy styles: i) government attitudes towards policy planning, namely reactive or anticipatory; and ii) the relationship between government and other actors in the policy-making process, for example whether government aims to reach consensus with interest groups on policy action or whether it governs by imposing policy decisions (Richardson, Gustafsson, and Jordan 1982). A review by

Howlett on competing theories of policy choice, however, argued that most existing policy instrument typologies were highly sensitive to national context, and that the existence and nature of policy styles should be evaluated based on policy outputs, specifically the policy goals and instruments that characterize policy mixes. He thus defined policy styles as the “observed preferences of national governments for certain types of instruments given the nature of state-society relations existing in each nation” (Howlett 1991, pg 16).

The policy styles literature draws from the new institutionalist turn in political research that gained momentum in the 1990s, and emphasizes the tendency for path dependencies and institutional lock-in to produce incremental policy changes that represent significant challenges for policy innovation (Hall 1993; Lindblom 1979; Pierson 2000; Sorensen 2014; Termeer and Dewulf 2018). The logic of this framework is that policy decisions are the result of underlying beliefs and assumptions that steer decision-making routines, and that actors will tend to return to the same types of instruments that they believe have worked in the past. Deliberately aligning new policy instruments with existing policy styles is thus a key design criteria hypothesized to increase the likelihood of successful and effective policy implementation (Howlett 2018). Debate on the existence of policy styles declined during the 1990s and early 2000s with the increased focus on globalization and diffusion of new policy paradigms such as New Public Management (NPM), but interest has recently re-emerged in the literature (Howlett and Lejano 2012). This is partially attributed to observations of divergence across country contexts in the effects of general reform movements like NPM, which points to the tendency for domestic institutions to influence whether and how new ideas and routines are adopted into practice (Yesilkagit 2010).

The idea of policy styles has significant implications for adaptation policy scholarship because it challenges the logic underlying much of the research that suggests adaptation policy failure is the consequence of certain material, attitudinal, or political barriers that can be removed

or minimized (Eisenack et al. 2014; Biesbroek et al. 2015). Policy styles suggests instead that sources of policy failure often lie in poor policy design and ‘goodness of fit’ between policy proposals and context (Howlett and Rayner 2013). This draws into question the universalism of standard recommendations for improving adaptive capacity through increased material resources, and instead demands that we focus attention on understanding the political, cultural, and institutional context of decision-making processes (Howlett and Mukherjee 2014). Furthermore, the policy styles literature cautions against allowing policy recommendations to be guided by normative biases about what adaptation ‘should’ look like, and instead to consider alternative policy recommendations through the lens of ‘goodness of fit’ between new ideas and the institutional contexts in which decisions are taken and policy will be implemented. The challenge for proponents of deeper, transformational changes that shift the status quo around how governments approach adaptation policy-making therefore becomes balancing the acceptability of policy interventions to decision-makers with continuous efforts to establish new beliefs and routines that shape how governments respond to climate change impacts (Termeer, Dewulf, and Biesbroek 2017).

2.4 Conclusion

This thesis stands to make an important contribution to adaptation policy research by expanding the study of policy adoption beyond single types of policy instruments, such as regulatory instruments (Townshend et al. 2013; Nachmany et al. 2014; Townshend et al. 2011; Fankhauser, Gennaioli, and Collins 2015) or strategic plans (Heidrich et al. 2016; Reckien et al. 2014; Reckien et al. 2015; Shi, Chu, and Debats 2015). Some studies have analyzed large numbers of diverse policies (Lesnikowski et al. 2011; Lesnikowski et al. 2016; Lesnikowski et al. 2015; Biagini et al. 2014; Austin et al. 2016; Austin et al. 2015; Araos et al. 2015; Araos et al. 2016), but these studies are largely exploratory or descriptive in nature and do not conceptualize

the linkages between instruments within a policy portfolio or seek to explain the composition of these policy mixes.

This chapter has summarized the areas of literature that serve as the foundation for this research. These literatures include local adaptation policy, emerging adaptation tracking approaches, the related concepts of policy instruments and policy mixes, and the role of policy styles in influencing policy choices. I apply policy mixes to the analysis of how local governments are adapting to climate change and examine variations in these policy responses in light of multilevel institutional environments and the policy ideas underlying local adaptation policy discourses. These threads are integrated across the chapters. The following chapter begins this study with a discussion of the evolving landscape of adaptation governance, which situates the emphasis on local adaptation with the framing of adaptation as a multilevel governance problem. The thesis then turns to the empirical aspects of this research, including the identification of policy mixes, multilevel drivers of local adaptation policy choice, and adaptation policy framing.

Preface to Chapter 3

The visibility of climate change adaptation policy has increased rapidly over the past two decades. This chapter situates the thesis within the growing need for more robust approaches to conceptualizing, comparing, and assessing adaptation policy progress following the 2015 Paris Agreement adopted by 21st Conference of the Parties to the UN Framework Convention on Climate Change. It also anchors the empirical focus of the thesis on local adaptation policy mixes within the increasingly multilevel landscape of adaptation policy and governance. This work was completed during my PhD in my capacity as a Project Lead with the Tracking Adaptation to Climate Change Collaborative (TRAC3).

This chapter is published in *Climate Policy* under the category of Outlook Article:

Lesnikowski A, Ford J, Biesbroek R, Berrang-Ford L, Maillet M, Araos M, et al. What does the Paris Agreement mean for adaptation? *Clim Policy*. 2017;17:825–31.

Chapter 3: What does the Paris Agreement mean for adaptation?

Abstract

The Paris Agreement takes a significant step forward in strengthening the adaptation pillar of global climate policy. By widening the normative framing around adaptation, calling for stronger adaptation commitments from states, being explicit about the multilevel nature of adaptation governance, and outlining stronger transparency mechanisms for assessing adaptation progress, the Agreement is a milestone in ongoing efforts to make adaptation an equal priority with mitigation. Significant work remains to be done, however, to clarify how the long-term goal for adaptation set out in Article 7 will be meaningfully realized. The challenge for Parties in implementing the Paris Agreement will be to establish credible commitments from state and non-state actors with regards to adaptation planning, implementation, and financing.

3.1 Introduction

On December 12th 2015 at the 21st meeting of the Conference of the Parties (COP21), the Paris Agreement to combat climate change was adopted by the member states of the UN Framework Convention on Climate Change (UNFCCC, or ‘the Convention’). The Agreement will succeed the Kyoto Protocol in 2020 and constitute a cornerstone of global climate governance for the coming decades. Adaptation emerged as a focus area under the Convention in 2001 but is still not equal to mitigation with regards to target-setting, financing, and institutional frameworks. The outcomes from COP21 build on previous decisions and work streams to establish a stronger roadmap for deepening the emphasis on adaptation planning and implementation under the Convention. The Paris Agreement strengthens adaptation in four ways: i) it broadens the normative framing around adaptation, ii) it integrates stronger adaptation commitments from state actors, iii) it is explicit about the multilevel nature of adaptation governance, and iv) it strengthens mechanisms for enhanced transparency on assessing adaptation progress (UNFCCC 2015).

3.2 Paris broadens the normative framing around adaptation

International agreements such as Paris are important barometers of the underlying norms that shape international discourse on issues like climate change (Haas 2002; Simmons 2010), and the COP meetings contribute to this process as sites of discursive struggles over issue framings and appropriate policymaking approaches. The Paris Agreement is reflective of the processes by which climate change discourses and agendas emerge, persist, and change. Under previous decisions adaptation was largely approached as an issue of biophysical exposure affecting regions with low levels of economic development (Schipper 2006). The Preamble of the Agreement, however, reflects a widening discourse within the UNFCCC beyond the framing of climate change as a challenge of exposure and impacts to one that acknowledges intersections

between climate change impacts, human rights, and culture. Such framing within the Convention first emerged in the Preamble to the Cancun Agreement (2010), which indicated an opening to the human rights discourse by making reference to resolution 10/4 of the Human Rights Council concerning the implications of climate change for human rights and in particular those most vulnerable to climate change impacts. The preamble to the Agreement builds on this by acknowledging a universal concern for justice and human rights, including ‘respective obligations on human rights, the right to health, the rights of indigenous peoples, local communities, migrants, children, persons with disabilities and people in vulnerable situations and the right to development, as well as gender equality, empowerment of women and intergenerational equity.’

Furthermore, in noting the importance of climate justice and the cultural significance of the environment (‘Mother Earth’), the tone of the preamble expands the problematising of environmental impacts of climate change beyond just a scientific focus on ecosystem health to one that recognises the diversity of existential significances attached to the environment across cultures. This mirrors the evolution of adaptation in the IPCC reports since the Second Assessment Report, which framed adaptation more narrowly with respect to climate change impacts, to subsequent reports that link adaptation more broadly to vulnerability processes (T. J. Bassett and Fogelman 2013). This discourse is important in driving conversations about the significance of climate change for development and human security, and is suggestive of a shift in international climate change negotiations toward a greater inclusiveness of non-state voices and the broader contexts of social change (Fook 2017; Ford, Maillet, et al. 2016).

3.3 Paris sets the groundwork for stronger adaptation commitments from state actors

By establishing an explicit long-term adaptation goal in Article 7, the Paris Agreement formalises the international consensus on the urgency of vulnerability reduction and reinforces that adaptation is a key pillar of the Convention. Beginning from the Marrakesh COP7 in 2001, the UNFCCC had framed adaptation as almost exclusively a challenge for low-income countries. Adaptation provisions in COP decisions thus focused on establishing modes for providing technical assistance and financing from developed countries through the Adaptation Fund and the Least Developed Countries (LDC) work programme (e.g. the LDC expert group and the National Adaptation Programmes of Action), and later through the Nairobi Work Program (COP11, 2005). The shift from focusing on short-term adaptation needs and priorities to medium- and long-term goals began at COP13 in 2007, where the Bali Road Map first expressed the need for a ‘shared vision for long-term cooperative action,’ a sentiment that appeared again in the Cancun Agreement and the Durban Outcomes (2011). This shift reflected the growing scientific consensus that the climate was already changing and associated impacts would be felt across all countries, thus necessitating some level of adaptation to address growing vulnerabilities. Finally in 2010, the Cancun Adaptation Framework made the central importance of adaptation under the Convention explicit by stating that ‘adaptation must be addressed with the same priority as mitigation’ and providing the initial organisational and financial structures to support enhanced work on adaptation across *all* Parties (UNFCCC 2011).

A fundamental challenge for achieving this equal prioritisation with mitigation is the relative fuzziness of adaptation as a policy area. Mitigation policy constitutes a response to a clear problem source (greenhouse gas emissions) and can be measured and tracked using standardised and accepted indicators (e.g. tonnes of carbon). In contrast, adaptation is difficult to define and track, especially in relation to policy issues like development or disaster risk

management (Ford and Berrang-Ford 2016; Magnan and Ribera 2016). This ambiguity underlies the challenge of operationalising the Cancun Agreement's call to address adaptation and mitigation as equal priorities and build on existing modes for capacity-building and financing to progress adaptation implementation at different scales and across countries.

The Paris Agreement provides a key opportunity to translate capacity-building and financial assistance into tangible policies by linking the global long-term goal for adaptation (Article 7, para 1) with the Intended Nationally Determined Contributions (INDCs). Nearly 90 percent (142) of the 169 UNFCCC Parties that submitted INDCs in the lead up to COP21 included discussions about impacts and vulnerability, their national institutional context for adaptation, and planned or implemented adaptation actions. The INDCs thus provide a foundation for the Agreement by giving context and substance to the adaptation goal and setting out what adaptation activities countries are willing to undertake. By pursuing a decentralised, country-driven process to determining adaptation needs and priorities, the INDCs encourage adaptation commitments that are contextually sensitive and politically realistic. These commitments are formalised in Article 7, which calls on all Parties to engage in assessments of impacts and vulnerability, the adoption of national adaptation plans, determination of nationally prioritised actions, and implementation of monitoring and evaluation of these actions. For developed country Parties, Article 9 further specifies responsibilities for mobilising scaled-up climate financing to support adaptation and mitigation needs, accompanied by a mandatory biennial reporting requirement to monitor progress on resource commitments (Article 9). The formalisation of adaptation commitments through the INDCs and Agreement is thus a significant step forward in realising the likelihood of credible commitments from Parties to 'engage in adaptation planning processes and the implementation of actions' (Article 7, para 9).

3.4 Paris reflects a multilevel view on climate change politics

The language in the Paris Agreement marks a notable departure from a state-centric view of global climate politics and emphasises the multi-level, non-hierarchical nature of climate change governance. For example, while the Cancun Agreement ‘Agrees that adaptation is a challenge faced by all Parties’ (para 11), in the Paris Agreement ‘Parties recognize that adaptation is a global challenge faced by all with local, subnational, national, regional, and international dimensions’ (Article 7, para 2). This framing is more in line with the politics of climate change scholarship that characterises the global climate change regime as fundamentally polycentric and shaped by diverse actor networks rather than state-centric and top-down (Jordan et al. 2015).

Furthermore, decision 1/CP.21 explicitly recognises the need to mobilise and cooperate with non-state actors like cities, local communities, Indigenous peoples, businesses, and civil society. Networks of non-state actors such as the International Indigenous Peoples’ Forum on Climate Change and the C40 have played substantial roles as interest groups advocating for larger state commitments to mitigation politics and resilience initiatives. This pressure may help hold states accountable to adaptation priorities and climate financing commitments stated in the INDCs and so help achieve the adaptation goal set out in the Paris Agreement (Keohane and Victor 2016). Discussions about how to integrate the private sector into climate financing mobilisation remain a priority for further deliberation, including how states can incentivise private sector engagement with adaptation, and how governments and the private sector can find common ground with regards to objectives and outcomes for adaptation (Pauw et al. 2015).

3.5 Paris sets out a more robust institutional framework to enhance transparency around adaptation commitments and progress

The fundamental challenge for all international agreements is establishing rules and procedures that bind actors to that agreement in the long-term (North 1993). Rather than adopting a top-down implementation style that relies on coercive policy instruments, the UNFCCC relies on soft instruments and mechanisms, such as learning and mimicry, and so seeks a gradual diffusion of adaptation across space and time (Fiorino 2006). The greatest potential contributions of the Paris Agreement to adaptation are thus procedural in nature, particularly the introduction of adaptation communications (Article 7, para 10), a regular global stock-take of progress under the Convention (Article 7, para 14; Article 14), and a transparency framework to track progress on implementation of INDCs and adaptation actions under Article 7 (Article 13). The integration of these more standardised and regularly implemented monitoring, reporting, and evaluation mechanisms has the potential to fill the current reporting gaps for adaptation, make INDC pledges more focused with successive submissions, and render enforcement of the Paris Agreement more feasible over time (Ford et al., 2015; Lesnikowski, Ford, Biesbroek, Ford, & Heymann, 2016). More detailed reporting guidelines from the UNFCCC are necessary for improving consistency in how countries report progress towards meeting adaptation policy goals and treaty obligations, and will help policy-makers identify policy and financing gaps within and across countries (Lesnikowski, Ford, Berrang-Ford, Barrera, & Heymann, 2015).

3.6 The road ahead for adaptation after the Paris Agreement

The effectiveness of an international agreement ultimately depends on the ability of institutions to be self-enforcing due to some combination of reputational concern and normative buy-in from state actors (Simmons 2010). In the case of the Paris Agreement, the procedural gains made through the establishment of a regular stock-take and adaptation communications provide enhanced transparency around national adaptation planning and may increase the

accountability of state Parties to the adaptation goals set out in the INDCs. The expanded language around human rights and the cultural dimensions of climate change impacts also indicates that climate change vulnerability is increasingly being framed as a global challenge for ensuring human well-being along multiple dimensions, rather than as just an economic development issue. These areas of progress may be key mechanisms by which the Agreement can achieve a level of self-enforcement among Parties in the long-term.

Nonetheless, a number of key questions remain that will impact the extent to which this goal can be meaningfully realised across Parties. The first concerns the identification of appropriate reference points within countries from which to assess whether we are successfully ‘enhancing adaptive capacity, strengthening resilience and reducing vulnerability to climate change’ (Article 7, para 2). The Kyoto Protocol set reference dates to aid in emissions reduction target setting, but determining such a reference point (or points) for adaptation requires a more complicated data collection process to understand where we are now with regards to adaptive capacity and adaptation actions within and across sectors, organisations, and institutions. This task is rendered more complex owing to the deeply context-specific nature of adaptation, not only with regards to the nature of vulnerable people, places, and ecosystems but also in terms of how adaptation is integrated into existing constellations of policies, laws, rules, programs, and mandates within countries and at different levels of government (Amaru and Chhetri 2013).

Third, review processes for assessing progress on adaptation commitments will need to balance robustness and comparability of units or indicators that capture key aspects of vulnerability and adaptive capacity with being contextually appropriate (Ford and Berrang-Ford 2016). Transparent and consistent decision-making on climate financing will require clarity on how adaptation intersects with broader development and risk reduction efforts, and thus what constitutes a ‘progression beyond previous efforts’ (Article 9, para 3). The diversity of

perspectives on this question was evident during the Adaptation Committee’s consultation forum at the 2016 Adaptation Futures gathering in Rotterdam, and will have significant implications for goal-setting, climate financing, and progress reviews.

Fourth, procuring adequate financing to support adaptation efforts is a critical outstanding challenge for achieving the ambitions of the Agreement. Article 9 of the Agreement states that ‘developed countries shall provide financial resources to assist developing country Parties’ and ‘should aim to achieve a balance between adaptation and mitigation;’ however, the Agreement is silent on quantifying exactly how much financing should be produced by the public and private sectors, and where the spending of funds should be focused. Whether and how developed countries will follow through in mobilising and sustaining commitments of \$100 billion by 2020 remains to be seen. Ensuring that funds are equally distributed between mitigation and adaptation projects may also prove challenging given the soft language in the Agreement around the need to balance funds and the tendency for private sector investment to be directed at mitigation projects rather than adaptation.

Adaptation still lags behind mitigation at the country level in terms of political leadership and resource allocation. The provisions of the Paris Agreement, however, begin to establish the processes and structures necessary to catalyse societal momentum around adaptation through a broader discourse about climate change and human well-being, cooperation between state and non-state actors, national agenda-setting, and the creation of stronger reporting and evaluation mechanisms. The roadmap set out in the Agreement therefore constitutes an important milestone for adaptation.

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Preface to Chapter 4

A number of approaches to assessing adaptation policy change are proposed in the literature, but progress towards developing conceptual approaches that link empirical observations with general theories of policy change is limited. This chapter contributes to addressing the ‘dependent variable problem’ in adaptation policy research and examines the first research question of the thesis: what policy approaches are local governments taking to deal with climate change adaptation? I argue that the concept of policy mixes provides a promising path forward in addressing persistent challenges around measurement bias, and demonstrate its application in adaptation policy research using systematic coding of policy documents to identify adaptation policy goals and policy instruments.

This chapter has been re-submitted with revisions following review to *Climatic Change*.

Chapter 4: A policy mixes approach to conceptualizing and measuring climate change adaptation policy

Abstract

Comparative research on climate change adaptation policy struggles with robust conceptualization and measurement of adaptation policy. Using a policy mixes approach to address this challenge, we characterize adaptation policy based on a general model of how governments govern issues of societal interest. We argue that this approach allows for context-sensitive measurement of adaptation policy, while being both comparable and parsimonious. This approach is tested in a study of adaptation policies adopted by 125 local governments located in Canada, France, Germany, the Netherlands, and the United Kingdom. Using a systematic data collection protocol, a total of 3,328 adaptation policies were identified from local council archives between the periods of January 2010 to May 2017. Results of this analysis suggest that there is structured variation emerging in how local governments govern climate change adaptation, which justifies calls for comparative policy research to use measurements that capture the totality of adaptation policies being adopted by governments rather than focusing on specific types of adaptation policy. We conclude with a discussion of key topics for further developing of this model.

4.1 Introduction

Over the last decade, adaptation to impacts of climate change has emerged as a core component of the climate change policy agenda (Magnan and Ribera 2016; Aylett 2015). Growing concern with reducing vulnerability to climate change impacts and building adaptive capacity is encouraging a rapid increase of adaptation policy adoption by national and subnational governments (Reckien et al. 2018; Ford, Berrang-Ford, Bunce, et al. 2015; Lesnikowski et al. 2016). With the emergence of these new policy initiatives, a basic empirical question has arisen of how to make sense of this evolving governance landscape (Jordan and Huitema 2014a). How we ascribe meaning to policy as an empirical phenomenon poses a fundamental conceptual issue for adaptation scholarship, with some authors arguing that unclear conceptualization of adaptation policy in the literature is a key barrier to theory-building in adaptation policy research (Dupuis and Biesbroek 2013). How we conceptualize climate change adaptation is critical for both the theory of adaptation governance and for developing useful advice to decision-makers on improving adaptation efforts and assessing progress on policy goals. Different conceptualizations of adaptation lead to different explanations of adaptation policy change that can be difficult to reconcile and evaluate, and presents significant obstacles to knowledge accumulation.

Here we address this ambiguity by proposing a conceptual approach rooted in the policy sciences, specifically policy mixes. We examine what should be measured from a policy mixes perspective on adaptation, and how this approach can be operationalized using systematic coding protocols for analyzing policy texts (Berrang-Ford, Pearce, and Ford 2015). Our conceptual approach begins from an understanding of public policies as the actions of public actors (generally governments) to address challenges of societal interest. Policy approaches to addressing boundary-spanning challenges like climate change adaptation can encompass a wide

range of policy goals and policy instruments, which are defined as the various techniques available to governments to achieve their policy goals, such as regulations, market interventions, or behavioural nudges (Howlett 1991). The policy instruments scholarship recognizes that governments rarely address policy goals through a single policy instrument; instead policy mixes consisting of multiple goals and instruments tend to develop over time, especially where jurisdiction over policy issues is shared among agencies or levels of government (del Rio and Howlett 2013). Here we argue that the concept of policy mixes offers a robust path forward in conceptualizing adaptation policy, and demonstrate its usefulness by conducting a comparative analysis of adaptation policy mixes among local governments in five countries.

Local governments provide an interesting ‘test case’ for the study of adaptation policy mixes because they are highly diverse in institutional and environmental context, and approach adaptation from different perspectives about how local governments should respond to growing climate change risks. Consequently the local adaptation policy landscape is highly diverse and poses challenges for comparison across contexts (Vogel and Henstra 2015). We examine emerging policy mixes in 125 local governments located in Canada, France, Germany, Netherlands, and the United Kingdom through systematic content analysis of local policy documents published between January 2010 and May 2017. The following section situates the study of policy mixes within current comparative approaches in adaptation policy research, and presents the logic and assumptions underlying a policy mixes perspective on adaptation policy. We then describe the research design that guided data collection, and present results on emerging policy mixes among the local governments sampled. The paper concludes with a discussion on the potential contributions of adopting a policy mixes approach to the comparative adaptation policy literature.

4.2 Conceptualizing and measuring adaptation policy mixes

While early studies that track the emergence of adaptation as a policy issue have made valuable empirical contributions to our understanding of where and how adaptation policy is emerging on government agendas, progress towards a broader theoretical understanding of adaptation policy change is still limited. Adaptation policy tracking has largely been debated as a methodological challenge (Berrang-Ford, Pearce, and Ford 2015; Ford and Berrang-Ford 2016), but linking advances in systematic research design with theoretical debates about governance approaches to adaptation is critical for proposing concrete solutions on how to deal with these challenges and refine comparative methodological techniques (Bednar and Henstra 2018). Here we argue that progress on the development of robust methodological frameworks for understanding adaptation policy change requires more advanced conceptual foundations underpinning empirical research.

4.2.1 Measurement issues in systematically classifying and comparing adaptation policy

As a complex and boundary-spanning policy issue, adaptation presents several challenges for systematic policy measurement and comparison that the adaptation literature has attempted to resolve in various ways. First, the impacts of climate change are wide-ranging with implications for how governments manage the built environment, public health and safety, livelihoods, economic stability, culture and heritage, and ecosystem health, among other areas. Adaptation policies therefore encompass diverse goals, and are characterized by a heterogeneous policy environment with actors from multiple policy sectors working both separately and across organizational boundaries to design and implement policies (Dąbrowski 2018; Runhaar et al. 2018). While some areas of environmental policy like air pollution reduction or greenhouse gas mitigation rely heavily on regulatory or incentive-based policy instruments such as energy efficiency standards or carbon taxes, governments tend to employ a wide range of tools for

adaptation, from ‘soft’ tools such as public education campaigns or knowledge-building programs, to ‘hard’ tools such as regulatory reforms and financial incentives (Mees et al. 2014; Henstra 2016). Furthermore, many of the goals that adaptation policies aim to achieve are expressed qualitatively and resist comparison based on quantification. The global goal on adaptation set out in Article 7 of the Paris Agreement, for example, states “Parties hereby establish the global goal on adaptation of enhancing adaptive capacity, strengthening resilience and reducing vulnerability to climate change, with a view to contributing to sustainable development and ensuring an adequate adaptation response in the context of the temperature goal referred to in Article 2” (UNFCCC 2015).

Two primarily approaches to simplifying this complexity are proposed in the adaptation policy literature: i) classifying policies based on functional typologies, and ii) characterizing adaptation based on specific policy adoption events. Both of these approaches have their advantages, but neither has proposed a fully satisfactory answer to the question of how we conceptualize and measure adaptation. The categorization of policies based on functional typologies reflects an inductive approach to classification that is characteristic of early adaptation policy research (Lesnikowski et al. 2011; Pearce et al. 2018; Ford and King 2015; Biagini et al. 2014; Eisenack and Stecker 2012; Araos et al. 2016). This work contributed important empirical insights into emerging efforts to respond to climate change impacts, but has tended to lead to typologies that are highly sensitive to the priorities, roles, and responsibilities of the organizations that author the texts used to compile policy data (Eisenack and Stecker 2012; Biagini et al. 2014). Early work sought to nuance this approach by integrating a distinction between ‘groundwork’ and ‘adaptation’ analogous to two distinct stages in adaptation policy processes, preparation for policy action and the implementation of actual adaptations (Lesnikowski et al. 2011). The assumption that the one stage would always precede the other

proved to be problematic, however, when confronted with the messiness of ‘real-world’ policy-making and the nature of adaptation as process of managing climate change impacts and vulnerability rather than an end-point (Levin et al. 2012).

Limitations also arise around how to translate these typologies into measurements for large-n research designs. Given that large scale comparison requires some degree of quantification to represent similarities and differences either cross-sectionally or longitudinally, typological studies have relied on measurements of policy density to synthesize patterns in policy adoption across places, policy sectors, and levels of government. These measurements represent the number of policies adopted by a government entity. Several recent studies in the climate change policy literature have proposed an additional analytical layer to policy density that accounts for the balance of different instrument types within a policy mix, analogous to the idea of policy diversity (Schmidt and Sewerin 2018; Costantini, Crespi, and Palma 2017; Lesnikowski et al. 2015). The validity of this approach, however, suffers from the underlying assumption that a greater number of policy instruments (or greater diversity of instruments) implies a ‘better’ adaptation policy mix or greater likelihood of successful climate risk reduction. In reality, the extent to which adaptation requires only a few policy instruments or many policy instruments reflects how narrowly decision-makers define adaptation as a policy problem, and is likely to vary across places, policy sectors, and levels of government (Massey and Huitema 2013). Furthermore, reliance on density measurements neglects a fundamental purpose of policy research, which is to understand the relationship between the content of public policies and the political and institutional environments that they emerge from (Howlett and Mukherjee 2018).

The second branch of adaptation policy research has tended to rely on selective moments of policy adoption that are interpreted as signaling commitment on adaptation policy development. Often these moments are the adoption of a strategic adaptation policy or the

decision to join a climate change policy network (Reckien et al. 2018; Reckien et al. 2014; Olazabal et al. 2019; Heidrich et al. 2013; Heidrich et al. 2016; Kamperman and Biesbroek 2017; Fünfgeld 2015). While this approach has facilitated larger-scale comparisons than is typically done using typology-based approaches, the additional scalability has come at the expense of more nuanced measurements of adaptation policy (Biesbroek, Berrang-Ford, et al. 2018). Consequently, much of the explanatory research emerging in the adaptation policy literature produces only a vague understanding of emerging adaptation efforts that do not say anything about what governments actually do in response to climate change impacts. This approach limits our ability to make observations about a range a key questions for both theoretical development and refined policy advice, for example what explains variations in emerging policy approaches to adaptation or whether some governing approaches are more effective in addressing climate change impacts than others (Javeline et al. 2014).

The proliferation of different approaches to characterizing adaptation policies has resulted in a relatively idiosyncratic empirical literature that limits accumulation of evidence around even simple ideas such as policy ‘leaders’ or ‘laggards’ (Dupuis and Biesbroek 2013). Adaptation policy research has struggled with how to conceptualize adaptation in such a way that the diversity of policy approaches that are emerging under the broad banner of climate change adaptation is accounted for, while also maintaining comparability of measurements across contexts. The following section examines the conceptual foundations of this debate and argues that the idea of policy mixes provides a promising pathway forward in addressing these measurement challenges. In doing so we build on several recent papers that propose a policy instruments perspective on adaptation policy formulation (Henstra 2016; Mees et al. 2014; Macintosh, McDonald, and Foerster 2015; Macintosh, Foerster, and McDonald 2014; Keskitalo et al. 2016; Thistlethwaite and Henstra 2017).

4.2.2 A policy mixes approach to measuring and comparing adaptation policy

Policy mixes are defined as combinations of policy goals and policy instruments that emerge over time around a specific policy issue (Howlett and Rayner 2007a). The concept builds on a taxonomy of public policies proposed by Howlett and Cashore that distinguishes between two dimensions of policies, policy goals and policy means (Howlett and Cashore 2009), which exist at three levels of abstraction (Table 4.1). Policy mixes exist at the second, programmatic level of this taxonomy. Goals constitute the strategic policy objectives explicitly stated by decision-makers, while instruments constitute the means by which these goals will be implemented.

Table 4.1 Taxonomy of adaptation policy

	Abstract	Program-level	Operational
Policy goals	Beliefs about the nature of climate change risk and purpose of adaptation	Strategic policy objectives	Specific policy targets (i.e. desired policy impacts)
Policy means	Preferred policy approaches to adaptation	Policy instruments	Processual aspects of instrument design

Modified from Howlett and Cashore (2009)

The policy mixes literature observes that governments address only the simplest policy problems through single goals and instruments, and more often policy approaches involve multiple goals and policy instruments that can exist across policy sectors and even administrative levels of government (Rogge and Reichardt 2016; Rosenow, Kern, and Rogge 2017; Mees et al. 2014; Rayner, Howlett, and Wellstead 2017). Mixes reflect temporal dynamics, as individual policies tend to accumulate over time and result in a complex policy landscapes wherein governments address policy problems through multiple pathways (Adam et al. 2018). The co-existence of multiple goals and instruments points to complexities inherent within policy mixes that present significant challenges for effective policy implementation. A large literature has

emerged around how ‘optimal’ policy mix can limit contradictory or redundant goals and instruments, and optimize of complementarity and synergy (Cejudo and Michel 2017; Howlett and Rayner 2007a). The tendency for policy mixes to emerge incrementally over time through processes of layering, drift, conversion, and replacement, as opposed to through rational and technical decision-making processes, presents challenges for optimizing the design of policy mixes, and points to the importance of historical policy legacies in decision-making, particularly the potential for institutional ‘lock-in’ that constrains future decision-making (Howlett and Rayner 2008; Eckersley 2017b). As such, thinking on the emergence and evolution of policy mixes draws from the literature on historical institutionalism (Pierson 2000).

Del Rio and Howlett propose a typology of policy mixes that theorizes their structure based on possible combinations of policy goals, policy instruments, and whether policy efforts are occurring across multilevel levels of government (del Rio and Howlett 2013). They propose eight types of policy mixes, which we simplify here given our focus on only local government policy mixes (Table 4.2). These types include complex policy mixes (multiple goals, multiple instruments), simple policy mixes (multiple goals, single instrument), complex instrument mixes (single goal, multiple instruments), and simple instrument mixes (single instrument, single goal).

Table 4.2 Policy mixes at one level of government

		Policy goals	
		<i>Multiple goals</i>	<i>Single goal</i>
Policy means	<i>Multiple instruments</i>	Complex policy mix	Complex instrument mix
	<i>Single instrument</i>	Simple policy mix	Simple instrument mix

Adapted from del Rei and Howlett 2013

To operationalize our study of local adaptation policy mixes we draw on both the adaptation literature and the policy instruments literature (Berrang-Ford, Pearce, and Ford 2015; Howlett 1991).

As noted above, adaptation policy goals tend to be highly qualitative and diffused across diverse policy sectors, which creates a challenge for systematic identification of policy goals in comparative research. Here we propose to take the level of diversity of climate change impacts embedded in adaptation policy mixes as a proxy measurement for adaptation policy goals. We interpret this as reflecting prioritization of risks and policy sectors within adaptation policy mixes.

To identify and classify adaptation policy instruments we draw from Howlett and Rayner (Howlett and Rayner 2007b), who define policy instruments based on two attributes: the governing resource that state actors rely on to implement policy, and the governing logic that governments use to achieve a desired change. The governing resource dimension utilizes a well-known typology identified by Christopher Hood that identifies four types of resources available to government: i) information (*nodality*), ii) regulation (*authority*), iii) finance (*treasure*), and iv) institutional influence (*organization*) (Hood 1983). The dimension of governing logic specifies two distinct approaches that governments can take to implement policy: direct provision of services and services (*substantive policy instruments*), or indirect efforts to change the beliefs and behaviour of actors (*procedural policy instruments*).

The advantage of the policy mix approach is that a vast number of very specific types of instruments can be parsimoniously identified, classified, and compared based on these underlying dimensions, irrespective of policy sector or level of government. This provides operational flexibility in research designs, while preserving consistency, comprehensiveness,

comparability, and coherence in measurement (Ford and Berrang-Ford 2016). Furthermore, a policy mixes approach avoids comparing policies strictly on the basis of material indicators such as budget allocations or staffing resource allocations, which introduce a bias towards resource-intensive policies at the expense of soft tools such as public awareness campaigns.

We demonstrate the scalability of the policy mix approach in a study of adaptation policy mixes among local governments. Specific climate change impacts and policy instruments identified through this analysis are drawn from the adaptation literature (Lesnikowski et al. 2015; Henstra 2016) and public policy theory (Howlett and Rayner 2007b; del Rio and Howlett 2013; Howlett 2000). Specification of policy instruments were then refined to reflect empirical research on local government engagement with adaptation (Macintosh, Foerster, and McDonald 2014; Keskitalo et al. 2016; Araos et al. 2016). Table 4.3 provides an overview of these policy instruments and their classification based underlying governing resources and governing logics.

Table 4.3 Taxonomy of local adaptation policy instruments

		Principal governing resource			
		<i>Nodality</i>	<i>Authority</i>	<i>Treasure</i>	<i>Organization</i>
Governing logic	<i>Substantive</i>	Advice; education and training; reports and assessments; monitoring and evaluation	Land use planning regulations; infrastructure performance standards; building regulations; strategic planning tools; intergovernmental mandates	User charges; grants; subsidies; loans; direct expenditures (e.g. infrastructure spending); demonstration projects	Procurement / local government operations; local government facilities management

<i>Procedural</i>	Exhortation; public outreach; sustainable practices labelling	Agreements between governments and/or non- governmental actors; advisory group creation; public hearings; joining urban climate networks	Research funding; interest group funding	Conferences and workshops; organizational reforms
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Adapted from Howlett and Rayner, 2007

We argue that a policy mixes approach to conceptualizing and measuring adaptation policy addresses both limitations in the comparative adaptation policy literature: the challenges of systematically comparing across diverse adaptation policy approaches, and the need for more nuanced approaches to measuring the content of policy mixes. Rather than attempting to identify comprehensive lists of adaptation policies, our policy mixes approach directs analytical attention to the constitutive parts that define all policies, and can be scaled across levels of government or across different policy sectors. Importantly, our results point to the level of complexity contained in emerging adaptation policy mixes that is lost if research designs only focus on particular types of policy instruments.

4.3 Methods

4.3.1 Case selection

The sample for this study consists of 125 local governments in five countries (Canada, France, Germany, Netherlands, and the United Kingdom). ‘Local government’ is defined as the lowest level of government with administrative responsibility over all or most local service provision (e.g. waste and water management), land use planning, and building permitting. In the case of this study, these units are municipalities (Canada, Germany, Netherlands), communes (France), and local authorities/metropolitan districts/London boroughs (United Kingdom). Two

main reasons exist for selecting local governments in these five countries. First, accessibility of data collection was an important consideration in selecting local governments for analysis. Given that a unique dataset of policy instruments needed to be constructed, ease of online access to primary policy documents and the language abilities of the research team were critical. Reliance on online availability of documents can be problematic in medium and low-income countries, and so only local governments in high-income countries were considered for inclusion in the sample.

Second, we aimed to identify local governments that have already have emerging adaptation policy mixes to demonstrate the value of our approach; the purposive selection strategy thus aimed to maximize inclusion of local governments with a high likelihood of having existing adaptation policy mixes. Current research suggests that large urban areas are more likely to be engaged in adaptation policy design, and that these countries are among the forerunners on taking adaptation action globally (Paterson et al. 2017; Campos et al. 2017; Shi et al. 2016; Reckien et al. 2014; Lesnikowski et al. 2015). Given this trend, the largest 25 local governments from each country were included in the sample, for a total sample of 125 local governments (for a complete list see Appendix A).¹

4.3.2 Data collection

The documentation for this dataset was collected from local council online archives covering the period January 2010 to May 2017. This time horizon reflects the establishment of adaptation as equal in priority with mitigation in international climate policy (UNFCCC 2011), and coincides with when local governments began to make council meeting documents more

¹ It is worth noting that nonetheless there is significant variation in population among sampled local governments, from 108,915 (Alphen aan den Rijn, Netherlands) to 3,520,031 (Berlin, Germany) (for full details see Table 3).

fully accessible online. Archival searches were conducted for each local government using the keyword ‘climate change’ to identify all available documentation from past council meetings containing references to climate change. In cases where there were missing years in online archives, requests were sent to the local government’s records office for digital copies of the relevant meetings. If no reply was received, then a web search was performed of the local government’s general website to identify any pages or files related to climate change from missing years. A total of ≈6000 documents were retrieved for coding. Documents include meeting agendas, meeting minutes, decision records, staff or consultant reports, records of rezoning and construction applications, and strategic planning documents.

Each document was examined for content explicitly pertaining to climate change adaptation. For example, policy instruments adopted to manage general risks like flooding or biodiversity were included if there was a mention of current or future climate change impacts. Climate change references that were unrelated to adaptation (namely mitigation content) were excluded from further analysis. To be considered sufficiently robust for inclusion in the dataset, the text needed to provide a clear description of what type of policy instrument was being chosen. If the instrument was not already formally adopted, a concrete indication of a timeline for its adoption was required for inclusion, such as an expected date or specified budget. References to potential instruments that could be considered or adopted in the future were excluded from the dataset.

4.3.3 Policy instrument coding

The text retained as adaptation-relevant was then coded using a unique coding manual containing indicators for year of instrument adoption, policy framing, policy instrument category, climate impact category, policy target, policy impact, departmental responsibility, and policy scope. All text classification was conducted in Atlas.ti, and the data were extracted in an

Excel file. Under the indicator ‘policy instrument category’ instruments were coded as either substantive or procedural, allowing no double coding of instruments. Where policy instruments described other policy instruments (e.g. strategic adaptation plans that summarize current or future adaptation policies) then the embedded policy instruments were also coded individually. Identification of the underlying governing resource for each instrument was determined based on the NATO typology (Hood 1983; Howlett and Rayner 2007b). This fit was determined *a priori* (see Table 4.2 for details).

4.3.4 Analytical approach

To analyze these data we use a combination of descriptive and inferential statistics. We first summarize the general structure of policy mixes found in our dataset based on the typology of policy mixes described in Table 4.2. We operationalize a simplified analysis of policy goals based on the climate change impacts that are addressed by individual policy instruments. Specifically, we examine the degree of policy goal complexity in local policy mixes using a Simpson’s Diversity Index calculation, which accounts for the number of climate change risks present in each policy mix and their relative abundance. Following this, we describe policy instrument mixes along the two dimensions of policy instruments described in Table 4.3, governing resources and governing logics. We examine the relative frequency of governing resources and logics both between country clusters and within country clusters, which demonstrates the diversity of policy approaches represented in complex policy mixes. Finally, we examine the relationship between policy goals and policy instruments within these policy mixes based on a non-parametric (Spearman’s) correlation matrix.

4.4 Results

4.4.1 Data description

A total of 3,328 policy instruments were identified in 119 local governments (Table 4.4). Of the 125 local government units included in the sample frame, only six demonstrated no textual evidence of adaptation policy instrument adoption. All six are located in either Germany (Augsburg, Bielefeld, Leipzig, Wiesbaden) or the Netherlands (Alphen aan den Rijn, Zoetermeer). With the exception of Leipzig (population=560,472), all of these non-adaptors have populations under 500,000. Overall, local governments in the UK tend to adopt the largest number of policy instruments and local governments in the Netherlands tend to adopt the fewest. Within-country variation in the number of policy instruments adopted is lowest in the Netherlands and highest in Canada, though the standard deviation reported in Table 4 is strongly influenced by Toronto (without Toronto the standard deviation of Canadian local governments is still high at 32.36).

Table 4.4 Descriptive statistics (Frequency of observations/instruments by local government)

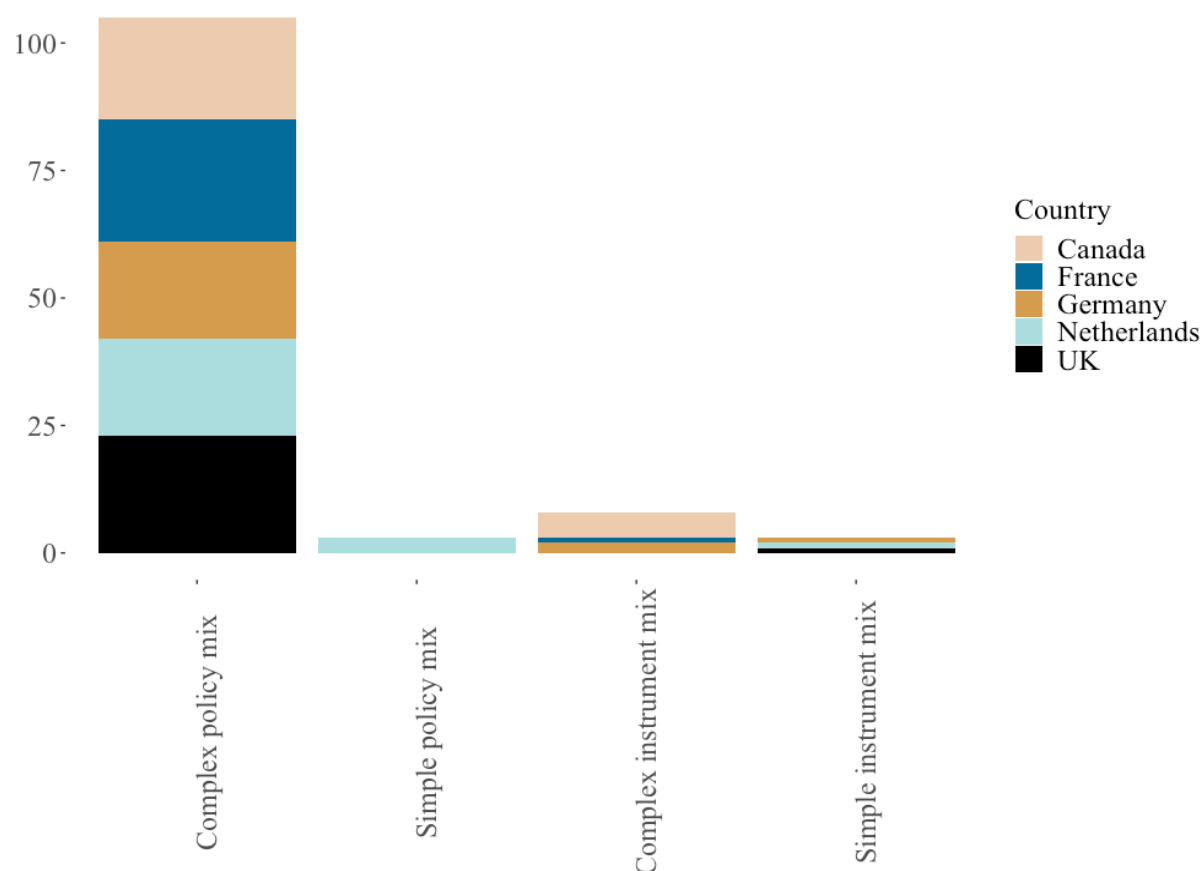
	All	Canada	France	Germany	Netherlands	United Kingdom
N. LGs	119	25	25	21	23	25
Total	3328	933	613	569	221	986
Min	1	2	2	1	1	1
Max	211	211	81	116	27	89
Mean	27.97	37.32	25.76	27.10	9.61	39.44
Median	16	16	14	19	7	38
Std. Dev.	31.88	48.09	24.20	29.64	8.23	27.27

4.2 Emerging policy mixes

We find an extremely high prevalence of complex policy instruments among the local governments in our dataset (multiple policy goals and multiple policy instruments), reflecting conventional thinking in the policy mixes literature that policy mixes tend to grow over time with incremental (and often ad hoc) additions of new goals and instruments (Howlett and Rayner

2013) (Figure 4.1). On average we find that local governments address five climate change impacts in their policy mixes and adopt 28 policy instruments.

Figure 4.1 Policy mix composition



Only three local governments each were identified as having simple policy mixes (multiple policy goals and one policy instruments) and simple instrument mixes (one policy goal and one policy instrument). All simple policy mixes were identified among local governments located in the Netherlands, where three local governments were found to have only one policy instrument that addresses multiple climate change impacts. In two cases this instrument is a spatial planning tool (a Waterplan addressing flooding and heat risk – Almere, Netherlands; a Municipal Sewerage Plan addressing flooding and heat risk – Maastricht, Netherlands), while in the remaining case the instrument is a political agreement under the Deltaprogramme to address

risks of sea level rise, flooding, drought, and heat (Dordrecht, Netherlands). These simple policy mixes thus all signify efforts to target intersections between different climate risks (e.g. flooding and heat) and mainstream responses through existing policy instruments.

The three local governments with simple instrument mixes were identified in Germany, the Netherlands, and the United Kingdom. These mixes are more procedural in nature, with two simple instrument mixes constituting organizational development (creation of a working group on climate change – North Lanarkshire, UK) and an assessment report (on heat risk in a changing climate – Dresden, Germany), and the third simple instrument mix constituting spatial planning (a Waterplan addressing water management in a changing climate – Ede, Netherlands).

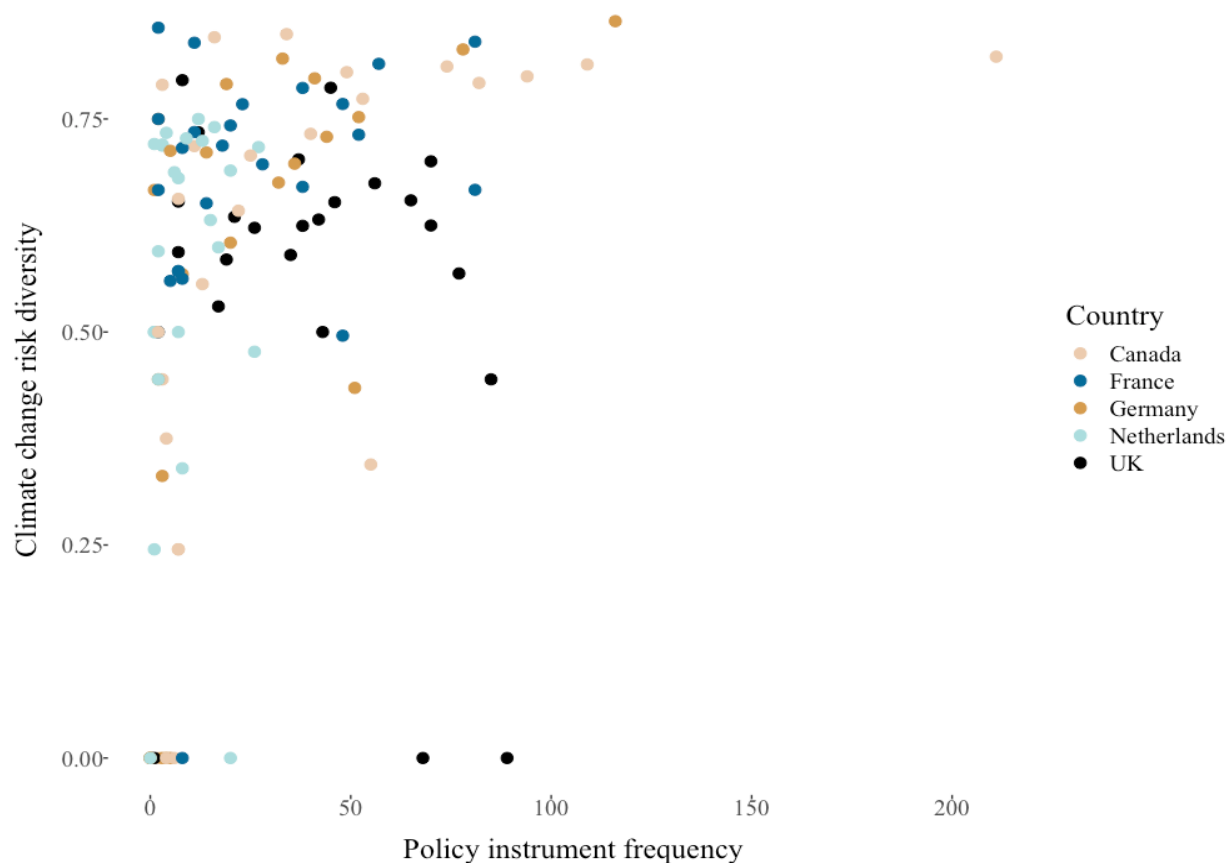
Finally, eight complex instrument mixes (one policy goal and multiple policy instruments) were found among local governments located primarily in Canada ($n = 5$), but also in France ($n = 1$) and Germany ($n = 2$). Seven of these complex instruments mixes had policy goals that only addressed climate change impacts generally without specifying individual impacts such as flooding or extreme heat, suggesting that these local governments are only loosely mainstreaming adaptation into existing policies rather than developing clear policy goals that reflect key risks.

4.3 Policy goals and instruments

If we examine policy goals and policy instruments as separate components of policy mixes, we observe variations in both geography and the relationship between goals and instruments. This suggests that i) there are differences across country context in the types of policy instruments that local governments tend to adopt, and ii) there is variation in the types of policy instruments that are commonly adopted to address particular types of climate change impacts. The diversity of self-reported climate change risks addressed in policy mixes appears to

be moderately associated with the number of instruments contained in a mix, which may suggest some level of ‘matching’ between the number of policy instruments in a mix and the number of policy goals (Figure 4.2). Nonetheless, a number of local governments are also found to have high policy goal diversity and small numbers of policy instruments, so it appears that this is not necessarily the case across all local governments.

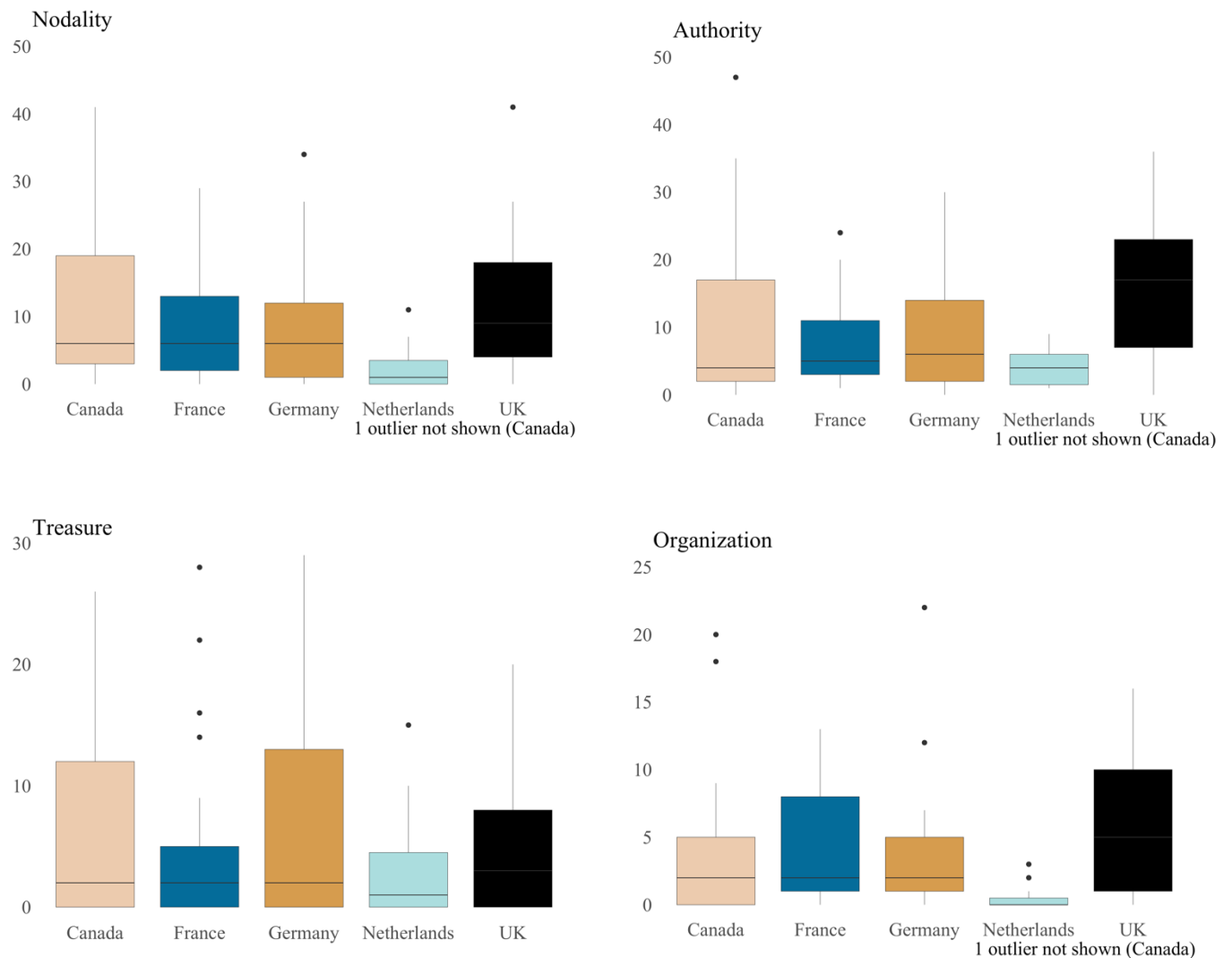
Figure 4.2 Policy goal diversity



Geographic patterns in policy instrument mixes point to differentiated configurations emerging in policy instrument choice among local governments. Figure 4.3 captures this distribution by country cluster of the governing resources being directed at adaptation according to the NATO typology described in Section 2.2. Overall, we find a high reliance on nodal (i.e. informational) and authoritative governing resources within the dataset, with nearly an equal

number of instruments are identified within these groups (nodality: n = 1,125; authority; n = 1,117). Together nodal and authoritative instruments constitute 67 percent of the total instruments found, while 18 percent of the remaining instruments were treasure-based and 13 percent of instruments were organizational. While the median levels of each government resource tend to be relatively even across resources, variability within country clusters is differs quite significantly, with generally lower levels of variation found among Dutch local governments and higher levels found among Canadian, German, and UK local governments. French local governments have relative low levels of variation in all categories except that of organizational policy instruments, where they exhibit quite high variation. This suggests that there are differences both *between* countries in the types of governing resources that local governments rely on for adaptation, and *within* countries in the degree of similarity of governing resources used by local governments.

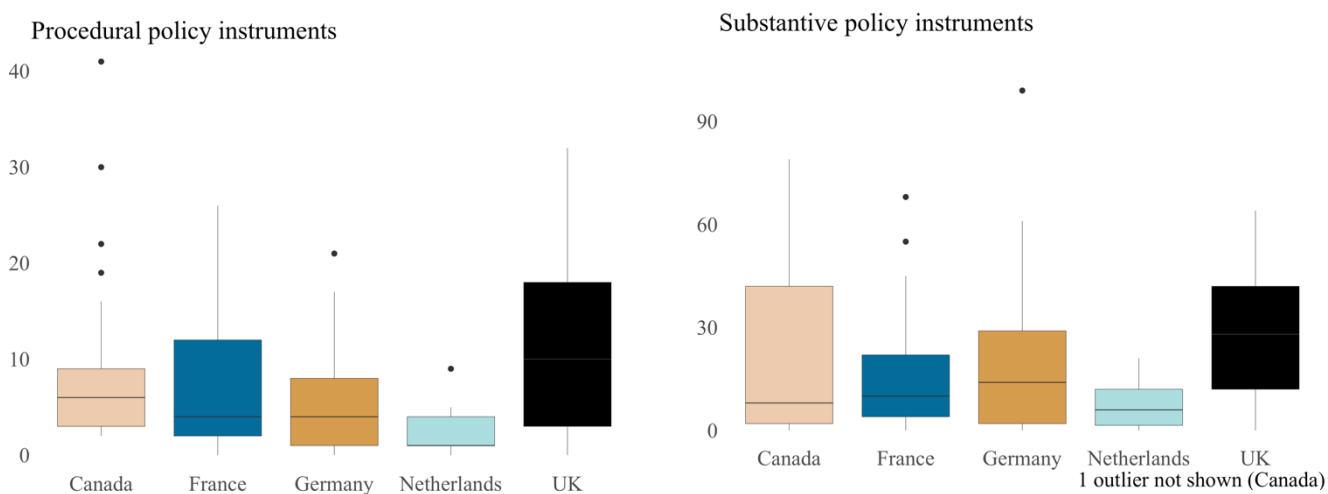
Figure 4.3 Governing resources



We observe similar differences among country clusters if we consider the general governing logic that local governments take on adaptation (Figure 4.4). We find that overall local governments tend to adopt more substantive approaches to adaptation, with high reliance on instruments such as reports and assessments, direct expenditures on public works, strategic planning initiatives, spatial planning, and adjustments to municipal operations. This implies that local governments overall are focusing on directly delivering adaptation-relevant services or goods to communities. In the Canadian context, however, we find high variability in the numbers

of substantive instruments being adopted and low variability in the adoption of procedural policy instruments, suggesting that there is a larger variability in substantive policy adoption among Canadian local governments. This contrasts with local governments in the other four countries, where we observe smaller variability in substantive policy adoption relative to procedural policy adoption. This likely reflects the highly devolved institutional context of local decision-making in Canada, where the responsibilities and competencies of local governments are derived from subnational (provincial) government. This devolution of authority has particularly significant implications for climate change adaptation as the federal government has shared jurisdiction with provinces around environmental agenda-setting, and chooses to exercise minimal influence on local-level policy decisions.

Figure 4.4 Governing logic: substantive and procedural instruments per country



We also examine policy instrument adoption by type of substantive or procedural instrument to further elucidate differences in policy instrument adoption across country clusters (Table 4.5). While certain categories of policy instruments are more common across all local governments, we observe variations between countries in the relative frequency of policy

instrument categories. If we take commonly adopted substantive policy instruments in Germany and the Netherlands as an example, we find a strong emphasis on direct expenditures in the Dutch context, while German local governments demonstrate an even mix of reports and assessments, land use regulations, and direct expenditures. As another example, local governments in the UK demonstrate much higher adoption of institutional changes such as the creation of new staff positions, departments, or working groups than local governments in any other country context.

Table 4.5 Policy instrument mixes by share of instrument type

		Country				
		Canada	France	Germany	Netherlands	United Kingdom
Total obs.: Substantive instruments		711 (76%)	417 (67%)	446 (78%)	167 (76%)	707 (72%)
Total obs.: Procedural instruments		222 (24%)	202 (33%)	123 (22%)	54 (24%)	279 (28%)
Substantive Instruments (% share of total)						
<i>Nodality</i>	Advice	---	---	0.35	---	---
	Education and training	0.96	2.75	0.70	0.45	1.01
	Reports/assessments	23.04	14.05	15.47	12.22	20.39
	Monitoring/evaluation	3.43	2.91	2.99	0.90	1.12
<i>Authority</i>	Land use planning regulations	4.29	6.79	16.52	14.83	8.42
	Infrastructure standards	2.36	1.62	2.11	0.45	2.13
	Building regulations	2.25	1.62	2.11	0.45	2.13
	Strategic planning ¹	13.29	12.44	7.21	13.57	22.92
<i>Treasure</i>	User charges	0.96	---	1.05	---	---
	Subsidies/grants	2.25	4.20	2.99	3.17	1.01
	Direct expenditures	12.86	13.57	17.22	26.24	12.58
	Demonstration projects	0.64	1.62	1.05	1.36	0.61
<i>Organization</i>	Operations	9.43	5.01	5.45	0.45	1.42
	Facilities	0.11	1.45	0.35	---	0.10
Procedural Instruments (% share of total)						
<i>Nodality</i>	Exhortation	4.93	---	0.18	0.45	0.91
	Public outreach	8.90	14.05	9.14	10.41	7.30
	Certification/labelling	0.11	1.13	0.35	---	---
	Knowledge networks	1.71	4.52	3.51	3.17	3.25
<i>Authority</i>	Public hearings	0.32	---	---	---	0.10

	Political agreements	1.93	2.91	0.35	5.88	1.93
	Advisory group creation	0.11	0.97	---	0.45	0.81
<i>Treasure</i>	Research funding	0.11	---	---	0.45	0.10
<i>Organization</i>	Institutional changes	3.11	3.07	6.33	3.62	11.66
	Conferences/workshops	1.61	5.98	1.76	---	2.23

NOTE: In categories with n=0 for all countries, instrument was removed from table for clarity.

¹ Including strategic adaptation planning

These patterns suggest that there are some structured differences between countries in how local governments approach adaptation policy design. If we consider the relationship between policy goals and policy instruments within these policy mixes, it appears that the adaptation governing approaches emerging among local governments are influenced by prioritization of particular impacts. Table 4.6 summarizes correlation coefficients between each climate change impact and policy instrument measured in our data. Most notably, strong positive correlations (≥ 0.70) are observed between flood risk and certain types of substantive policy instruments (e.g. direct expenditures, spatial planning, strategic planning). This indicates that where flood risk is prioritized within local adaptation policy agendas, the adaptation governing approaches of local governments are likely to be more substantive in nature.

Table 4.6 Correlation matrix for policy goals and policy instruments (Spearman’s correlation)

	Climate change impact																
	Biodiversity	Cold	Drought	Economy	Energy	Erosion	Flooding	Heat	Storms	Disease	Air qual.	Water	General	SLR	Wildfires	Food	Desertification
Substantive policy instruments																	
Nodality																	
Advice	0.148	0.132	0.048	0.182	-0.064	-0.05	0.104	0.173	-0.086	-0.048	0.308	0.186	0.102	-0.073	0.238	-0.065	-0.012
Education / training	0.408	0.148	0.079	0.247	0.425	0.195	0.309	0.216	0.349	0.24	0.02	0.218	0.438	0.171	0.062	0.295	-0.046
Reports / assessments	0.619	0.344	0.171	0.303	0.491	0.412	0.698	0.431	0.511	0.18	0.253	0.35	0.745	0.265	0.195	0.461	0.072
Monitoring / evaluation	0.508	0.287	0.079	0.284	0.389	0.329	0.481	0.423	0.368	0.282	0.208	0.346	0.428	0.147	0.273	0.415	-0.058
Authority																	
Spatial planning	0.545	0.298	0.166	0.165	0.348	0.326	0.708	0.424	0.367	0.11	0.29	0.404	0.488	0.322	0.233	0.322	0.026
Infrastructure standards	0.424	0.476	0.143	0.115	0.367	0.313	0.492	0.413	0.464	0.235	0.292	0.272	0.491	0.157	0.188	0.293	-0.054
Building regulations	0.302	0.271	0.044	0.3	0.262	0.13	0.323	0.585	0.314	0.496	0.363	0.525	0.15	0.051	0.332	0.28	0.189
Strategic planning	0.595	0.412	0.221	0.179	0.473	0.384	0.706	0.266	0.427	0.068	0.147	0.344	0.71	0.233	0.108	0.314	-0.108
Adaptation planning	0.548	0.247	0.074	0.179	0.311	0.212	0.394	0.47	0.35	0.186	0.326	0.259	0.544	0.079	0.191	0.252	0.054
Treasure																	
User charges	0.379	0.215	0.038	0.533	0.342	0.211	0.366	0.134	0.279	0.315	0.16	0.366	0.198	0.046	0.029	0.267	0.267
Subsidies / grants	0.484	0.361	0.022	0.305	0.45	0.209	0.459	0.353	0.346	0.202	0.164	0.49	0.377	0.134	0.102	0.457	-0.063
Loans	0.148	0.274	0.122	-0.031	0.23	0.256	0.156	0.153	0.193	0.283	0.22	0.173	0.159	-0.052	-0.023	0.214	-0.008
Direct expenditures	0.683	0.438	0.326	0.306	0.443	0.378	0.793	0.571	0.465	0.187	0.318	0.602	0.535	0.233	0.219	0.444	0.132
Demonstration project	0.36	0.22	0.047	0.27	0.278	0.287	0.292	0.397	0.127	0.31	0.323	0.431	0.281	-0.004	-0.03	0.29	0.184
Organization																	
Operations	0.567	0.337	0.062	0.262	0.46	0.363	0.456	0.465	0.469	0.331	0.297	0.502	0.53	0.093	0.226	0.41	0.092
Facilities	0.33	0.212	0.064	0.26	0.218	0.096	0.043	0.244	0.125	0.11	0.346	0.344	0.194	0.031	0.078	0.196	-0.025
Procedural policy instruments																	
Nodality																	
Exhortation	0.152	0.166	-0.094	-0.004	0.084	0.249	0.165	-0.086	0.265	0.056	-0.087	0.037	0.199	0.074	-0.009	0.229	-0.042

Public outreach	0.642	0.276	0.13	0.298	0.453	0.293	0.585	0.494	0.415	0.253	0.359	0.444	0.522	0.199	0.249	0.465	0.107
Labelling	0.33	0.018	0.025	0.044	0.1	-0.087	0.033	0.283	0.029	0.164	0.009	0.273	0.204	-0.129	-0.058	0.186	-0.021
Authority																	
Political agreements	0.155	0.094	0.228	0.109	0.148	0.228	0.236	0.09	0.143	0.057	-0.094	0.142	0.36	0.375	0.074	0.09	-0.075
Advisory group creation	0.118	-0.121	-0.003	-0.107	0.061	-0.036	0.151	-0.015	0.029	0.06	-0.143	0.031	0.181	0.146	0.165	0.135	-0.029
Public hearings	-0.053	0.067	-0.022	-0.062	0.024	0.058	-0.118	-0.167	-0.002	-0.068	0.041	-0.154	0.082	-0.105	-0.047	-0.093	-0.017
Urban networks	0.405	0.127	0.027	0.166	0.419	0.205	0.355	0.211	0.395	0.087	0.056	0.177	0.509	0.295	0.223	0.334	-0.071
Treasure																	
Research funding	0.03	-0.061	0.007	-0.054	-0.078	-0.061	0.045	-0.082	-0.106	-0.059	0.055	-0.058	0.114	0.022	-0.04	-0.08	-0.015
Organization																	
Conference / workshops	0.356	0.062	-0.077	0.127	0.277	0.21	0.218	0.171	0.184	0.095	0.026	0.18	0.468	0.111	0.129	0.334	0.082
Institutional reform	0.352	0.256	0.08	0.135	0.346	0.306	0.529	0.19	0.375	0.087	0.129	0.119	0.622	0.131	0.067	0.177	-0.012

NOTE: Climate change impact categories with fewer than two observations are removed from table for clarity.

4.5 Discussion

Here we build on recent efforts in the adaptation policy literature to examine emerging policy efforts through the theoretical lens of policy instruments. We propose that the concept of policy mixes offers a promising path forward in addressing the pernicious challenge of how to conceptualize and measure adaptation action as an empirical phenomenon, and has particular potential for improving the robustness of comparative adaptation research. In this article we operationalize policy mixes based on two components of public policies – goals and instruments – and design a systematic protocol for identifying and comparing adaptation policy mixes across diverse country contexts. We demonstrate the value of our approach by examining the composition of policy mixes adopted by 125 local governments located in five countries.

Our results indicate that the adaptation policy approaches of local governments are characterized by complex policy mixes that contain multiple policy goals and policy instruments. Local governments are adopting policy goals that address a multitude of climate change risks, and many, indeed sometimes hundreds, of individual policy instruments to implement their policy goals. Furthermore, our analysis suggests that within this complex policy environment there is structured variation emerging across jurisdictions around how adaptation is being governed by local governments, for example with a stronger emphasis on strategic planning and organizational development among local governments in the UK and on direct expenditures in the Netherlands. We believe this sheds new light on old debates in the policy literature about the tendency for governments to develop distinct approaches to governing policy problems that becoming institutionalized over time and influence how policy goals are articulated and policy instruments are chosen (Freeman 1985; Lampis 2013). If similar patterns are emerging in the adaptation sphere, then attention to the rich theoretical literature on policy choice and processes

of change in policy mixes is key to understanding how different approaches to adaptation governance emerge across contexts and are sustained or change over time (Howlett 2019) .

These findings are significant because they support our argument that adaptation policy research needs to move toward more nuanced measurements of adaptation policy that capture the diversity of policy instruments being adopted to meet adaptation policy goals. By adopting a policy mixes approach we are able to do this in such a way that avoids eclectic typologizing and situates adaptation policy formulation within general theories about how governments govern. Rather than develop a unique typology of adaptation policy instruments, as is characteristic of the existing adaptation policy literature, we propose to measure adaptation policy mixes based on the climate change impacts addressed under adaptation policy goals and the governing resources and logic of policy instruments. Our approach allows for flexibility in categorization of specific policy instruments across contexts, while maintaining comparability based on two fundamental dimensions of policy instruments. Perhaps most critically, interpreting adaptation policies based on policy mixes situates adaptation responses within the broader literature on modes of governance that theorizes different government responses to climate change impacts (Bednar and Henstra 2018). This approach encompasses the whole range of activities that governments can undertake to achieve policy goals, and so provides an entry-point for developing a robust comparative study of adaptation policy change.

The study of adaptation policy mixes also has the potential to make tangible contributions beyond the scientific study of adaptation. The introduction of new mandates through the 2015 Paris Agreement to report progress towards the Global Goal on Adaptation has brought the issue of how we define and measure adaptation policy progress to the forefront of international negotiations on adaptation governance (Lesnikowski et al. 2017). With new requirements in place for national reporting of adaptation progress to the Secretariat of the UN Framework

Convention on Climate Change, the question of how we scale up local, regional, and national assessments of adaptation policy action to the global level is front and centre in climate change negotiations (Craft and Fisher 2018). Analysis of policy goals and instruments through a policy mixes lens would contribute to increased reporting transparency by clarifying the definition of adaptation policy without needing to specify universal criteria for what this looks like across contexts (Berrang-Ford et al., in review). This also supports research around critical policy evaluation questions such as how we determine that policy goals are being met and adaptation efforts are meaningful across sectors and jurisdictions, how similar adaptation interventions perform under different contextual conditions, whether certain places adapt better than others based on particular aspects of institutional or political environments, and how the institutionalization of particular policy instruments creates different ‘winners and losers’ from adaptation, the effects of which can become increasingly difficult to change over time.

Notwithstanding the conceptual robustness of this approach, it faces similar challenges with regards to operationalization and implementation as existing adaptation studies. Coding entire policy landscapes around an issue as wide-ranging as climate change adaptation requires more resource intensive research designs than those that focus on single moments of policy adoption, often requiring the use of systematic data collection protocols that aim to identify all instances of policy adoption within given parameters. The literature on systematic approaches to studying adaptation policy adoption offers methodological insights how to scale up policy studies beyond a focus on single policy instruments (Berrang-Ford, Pearce, and Ford 2015), and should be more widely integrated into explanatory research about local adaptation policy choice. This approach nonetheless has room to evolve with the exploration of techniques for increasing the efficiency of this approach, for example by integrating web scraping to identify policy documents containing climate change references or even experimenting with automated policy

coding (Burscher, Vliegthart, and De Vreese 2015). The larger challenge is how to scale up this methodological approach, which relies heavily on textual data, to places that are data scarce, particularly local governments in least-developed country contexts. Integration of grey literature and reports from development agencies or non-governmental organizations are regarded as important sources of data in these contexts, but more explicit validation of the comparability between these texts and those authored by governments themselves is needed in the literature.

A further area of development for a policy mixes perspective on adaptation is elaborating the longitudinal dimensions of this model. The study that we conduct here focuses only on changes in the structure of policy mixes and not adjustments to the design of individual policy instruments themselves. Additionally, it follows a logic of policy accumulation and does not account for the reversal or termination of policies (Jordan, Bauer, and Green-Pedersen 2013). Fully capturing the stringency of adaptation policy goals and likelihood of policy instruments to deliver on these goals requires analysis of what are termed policy settings and calibrations, meaning the specific requirements of policies – often expressed as targets – and the strictness with which they will be implemented (Howlett and Cashore 2009).

Analytical attention to the temporal dimensions of policy mixes is better developed in the climate change mitigation literature, where comparative research on instruments like energy efficient regulations has analyzed settings and calibrations using metrics such as the scope of emissions targets and their relative ambition, budgetary allocations to instruments, and specificity of implementation requirements (Schaffrin, Sewerin, and Seubert 2015; Schaffrin, Sewerin, and Seubert 2014; Schmidt and Sewerin 2018). Direct adoption of these types of metrics in the context of adaptation policy is challenging, however, given that adaptation policies are characterized by policy goals that are frequently qualitative in nature (e.g. ‘increase resilience to change’) and involve highly heterogeneous policy instruments that raise validity concerns about

the appropriateness of applying universal criteria like budget allocations to assess the adequacy of policy interventions. Experimentation with measuring longitudinal aspects of adaptation policies is still largely unaddressed in the literature (Lesnikowski et al. 2016), but is urgently needed to build a stronger scientific foundation for the assessment of adaptation policy progress and implementation effectiveness.

4.6 Conclusion

In this article we argue that defining and measuring adaptation policy based on the underlying dimensions of policy mixes can help overcome current challenges to knowledge accumulation and theory building in adaptation policy research. The findings of this study demonstrate the value of our approach, particularly its ability to capture differences in how governments are responding to climate change impacts and its scalability across levels of government and policy sectors. Integration of the policy mixes concept with systematic approaches to analyzing adaptation policy change can support more comprehensive research on adaptation policy based on how governments actually govern, without privileging one governing style over another. As interest grows in developing instruments-based approaches to studying adaptation policy, we believe that an explicit focus on policy mixes will contribute to a more theoretically robust literature and to support the design, implementation, and evaluation of adaptation policy.

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Preface to Chapter 5

This chapter tests a theoretical model of policy implementation styles that aims to explain local adaptation policy choice. This addresses the second research question of the thesis: how do local and national policy environments influence the adaptation policy choices of local decision-makers? I test hypothesized drivers of local adaptation policy choice from using fixed effects regression analysis to analyze local-level variables and multilevel modelling to analyze national-level variables. The findings of this analysis reinforce the importance of multilevel institutional environments in influencing local policy choices.

This chapter has been submitted to *Environmental Politics*.

Chapter 5: Policy implementation styles and local governments: The case of climate change adaptation

Abstract

Adaptation to impacts of climate change is a key pillar of the climate change policy landscape, and the adoption of policies that respond to changing environmental risks has rapidly increased over the past decade. Our understanding of why governments are adopting particular adaptation policy approaches is still underdeveloped, however, with much of the explanatory adaptation policy research focused on understanding agenda-setting dynamics. This study aims to address this gap by operationalizing a model of policy implementation styles to test key hypotheses about local adaptation policy instrument choice. Eight hypotheses are derived from this model about local and national drivers of local policy choice, and are tested with a sample of 125 local governments using fixed effects linear regression and multilevel modelling. We find that the relationship between environmental, political, and institutional context and local adaptation policy choice varies between policy implementation approaches, suggesting that one-size-fits-all advice to policy-makers on adaptation policy design is likely to be inadequate in supporting effective local adaptation policy.

5.1 Introduction

Climate change is already being felt globally, and policies to adapt to growing risks such as more frequent and intense flood events and heat waves or changing patterns in vector-borne disease are rapidly emerging across countries and levels of government (Lesnikowski et al. 2016; de Coninck et al. 2018). While historically climate change mitigation policies have tended to follow from more centralized decision-making processes regarding policy goals like greenhouse gas emissions reduction targets, adaptation has emerged largely from autonomous and bottom-up processes (Jordan and Huitema 2014b; Schipper 2006). This has resulted in a diverse policy landscape containing a variety of policy approaches across countries, with a growing number of adaptation policy initiatives emerging among local governments (Araos et al. 2016; Carmin, Anguelovski, and Roberts 2012; Castán Broto and Bulkeley 2013; Heidrich et al. 2016; Hughes 2015; Reckien et al. 2018). Examples of such approaches include top-down governance that relies on regulatory tools such as land use planning and building codes, market-based approaches that rely on incentive schemes and market interventions, and bottom-up community-based governance that relies on voluntary participation from citizen groups and non-governmental associations (Bednar and Henstra 2018).

Understanding why local governments adopt a particular policy approach on adaptation is a key question for the climate change scholarship. A substantial literature has grown around the question of what drives adaptation on the agenda of local governments, and how policy adoption is facilitated or constrained by political, economic, and social factors (Hjerpe, Storbjörk, and Alberth 2014; Hughes 2015; Shi, Chu, and Debats 2015; Wang 2013; Reckien et al. 2014; Fünfgeld 2015; Measham et al. 2011). These studies provide important empirical insights into how factors like material resources, left-leaning political environments, and public acceptance of climate change science increases the likelihood that adaptation becomes a public policy issue,

but this literature has several limitations (Hughes 2015; Koski and Siulagi 2016; Reckien et al. 2015, 2018; Shi, Chu, and Debats 2015; Tang et al. 2010; Wang 2013; Wood, Hultquist, and Romsdahl 2014). First, the research questions driving this work tend to focus on understanding agenda-setting dynamics, rather than explaining patterns in adaptation policy instrument adoption. Second, the comparative adaptation policy literature tends to rely on the presence of a strategic adaptation plan as a singular event representing adaptation policy. This has led to an over-emphasis in the explanatory literature on this one type of adaptation policy response that is unable to explain the diverse approaches to adaptation policy design emerging across local policy contexts. Studies with more nuanced dependent variable definitions tend to focus on patterns in only one or a few countries, and are primarily qualitative in nature (Keskitalo et al. 2016; Macintosh, Foerster, and McDonald 2014). Third, hypotheses in existing studies have largely drawn from literature concerning barriers and drivers of adaptation, which is critiqued for under-theorizing political processes and providing inadequate explanations of adaptation policy change (Biesbroek et al. 2015; Wellstead, Howlett, and Rayner 2017).

In this study we examine local adaptation policy choices from the perspective of policy implementation styles. This perspective emphasizes the political and institutional context of decision-making processes, and argues that patterns in policy instrument adoption represent preferences for particular policy instruments that reflect institutionalized approaches to policy formulation (Howlett 1991). Policy instrument choices are not simply a process of identifying a technically ‘correct’ policy response to a given problem; rather, policy choices should be understood as reflecting institutional arrangements and norms, problem framing, interest group pressures, and the characteristics of target populations (Krause et al. 2019).

We apply a theoretical model of policy instrument choice proposed by Howlett et al. to understand adaptation policy approaches being adopted by local governments. We test eight

hypotheses on policy instrument choice based on theorized dimensions of implementation styles using fixed effects and multilevel statistical analysis. The following section describes the theoretical framing for this paper and the hypotheses tested. We then summarize the data and statistical approach used for analysis, our results, and implications for further refining our theoretical understanding of local adaptation policy development.

5.2 Theoretical framework: Policy instrument choice

5.2.1 *Policy instrument choice*

Understanding policy instrument choice is a fundamental question for public policy research (Howlett 2019; Peters and Pierre 2016b). The failure of governments to adopt ambitious adaptation policies in spite of a scientific consensus on the urgency of climate change risks indicates that a clearer understanding of the institutional and political context for decision-making is needed (Hughes 2017). Adaptation policy scholars have advocated a policy instruments perspective on policy formulation, arguing that it can help us to better understand what governments do in response to climate change impacts (Henstra 2016; Keskitalo et al. 2016; Mees et al. 2014; Macintosh, Foerster, and McDonald 2014; Macintosh, McDonald, and Foerster 2015). Empirical attention to policy instruments, understood as the ends and means of policies, has gained traction in climate change mitigation policy research (Schaffrin, Sewerin, and Seubert 2014; Schmidt and Sewerin 2018; Schaffrin, Sewerin, and Seubert 2015; Rogge, Kern, and Howlett 2017; Rogge and Reichardt 2016). Nonetheless, empirical up-take of an instruments perspective in the climate change adaptation literature is still limited.

The particular instruments that governments choose to implement their policy goals and the form that instrument mixes take over time speaks to the perceived role of government in managing societal problems and provides a signpost for predicting how governments will approach policy problems in the future. Over the past two decades, the policy instruments

literature has developed a focus on understanding how and why specific combinations of instruments accumulate over time, and what these mixes suggest about different governance modes (Adam et al. 2018). ‘Instrument mixes’ refer to bundles of individual policy instruments adopted by governments in response to a particular policy problem; these mixes can emerge either through deliberate policy design processes or incrementally over time (Howlett and Mukherjee 2014). Howlett et al. propose that policy instrument choices are shaped by two factors: the capacity of the state to act within certain limitations, and the complexity of the policy environment in which decisions are made (Howlett, Ramesh, and Perl 2009). Capacity encompasses both formal and informal aspects of policy-making, namely the material capacity of governments to formulate and implement policy, and the extent to which government action around a given issue is perceived to be legitimate by stakeholders and the general public (Howlett 2005). The complexity of the policy environment captures sector-specific dynamics, including the nature of the substantive policy issue (e.g. climate change adaptation), and composition of individual actors or interest groups participating in or targeted by policy decisions.

Based on these dimensions, Howlett et al. theorize the existence of four policy implementation styles. 1) Governments with high capacity that are facing more complex policy environments are predicted to utilize the organizational power of government to achieve their policy goals through instruments that directly deliver public provision and oversight of goods and services. 2) Governments with high capacity but dealing with simpler issues are expected to use regulatory instruments to require compliance with certain policy goals. 3) In comparison, governments with low capacity and facing high complexity issues will turn to financial incentives that shift some of the responsibility for uptake and implementation to individuals or groups (e.g. companies). 4) Finally, governments with low capacity but dealing with simple

policy issues are expected to use information-based tools and voluntary commitments to encourage behavioural changes of actors in a policy subsystem.

Table 5.1 summarizes Howlett et al.'s four hypothesized implementation styles based on the two dimensions described above, and interprets each style with respect to policy instruments commonly used by local governments. These policy instruments are examples of local government jurisdiction over service delivery, infrastructure building and maintenance, land use planning, and building approvals, and forms of outreach between local government and citizens. Implicit here is the understanding that local governments are embedded within country contexts, and derive their powers and authorities from constitutional arrangements determined at higher levels of government. It is therefore expected that local policy instrument choices will reflect to some extent the formal constraints on local governing set at regional or national levels, and national or regional cultures around decision-making processes and state-society relations (Loughlin et al. 2011).

Table 5.1 Model of local policy implementation styles

		Policy environment complexity	
		<i>High</i>	<i>Low</i>
Government capacity	<i>High</i>	<i>Public provision and oversight</i> Direct spending; institutional reforms; mandates; demonstration projects; operations; facilities; advice-giving; personnel education and training; reports and assessments	<i>Regulatory corporatism</i> Spatial planning laws; infrastructure standards; building regulations; strategic plan adoption; advisory group creation; public hearings
	<i>Low</i>	<i>Directed subsidization</i> User charges; grants and subsidies; loans; research funding	<i>Institutionalized voluntarism</i> Public outreach; policy networks; public exhortations; monitoring and evaluation; conferences and workshops; inter-governmental agreements; labelling

Adapted from Howlett et al. (2009). Examples of commonly used policy instruments in italics.

5.2.2 Policy implementation styles and local climate change adaptation

We examine whether the two theorized dimensions of policy implementation styles described previously (government capacity and policy environment complexity) predict local adaptation policy approaches. Our hypotheses are constructed to reflect the multilevel context of local governments, which are embedded within particular country contexts and derive their authority and issue jurisdiction from higher levels of government. The hypotheses are therefore explicit about the role of vertical institutional environments on local policy choices. The following section specifies eight hypotheses about drivers of local adaptation implementation styles, and describes how we operationalize our hypotheses using local and national predictor variables (Table 5.2).

Table 5.2 Description of hypotheses

Theoretical hypothesis		Analytical hypothesis	Expected relationship
<i>Local governing capacity hypotheses</i>			
H1	Higher resource capacity is positively associated with public provision and oversight and regulatory corporatism	A larger local population is positively associated with implementation via public provision of goods and services and regulatory measures (and negatively associated with implementation via directed subsidization and institutionalized voluntarism)	+ (-)
H2	Higher sectoral legitimacy is positively associated with public provision and oversight and regulatory corporatism	Larger adaptation policy portfolios are positively associated with implementation via public provision of goods and services and regulatory measures (and negatively associated with implementation via directed subsidization and institutionalized voluntarism)	+ (-)
<i>National governing capacity hypotheses</i>			
H3	Higher resource capacity is positively associated with public provision and oversight and regulatory corporatism	Lower dependency on inter-governmental resource transfers is positively associated with local adaptation policy implementation via public provision of goods and services and regulatory measures (and negatively associated with implementation via directed	- (+)

		subsidization and institutionalized voluntarism)	
H4a	Higher sectoral legitimacy is positively associated with public provision and oversight and directed subsidization	Greater national adoption of adaptation policy instruments is positively associated with local implementation via public provision of goods and services and regulatory measures (and negatively associated with implementation via directed subsidization and institutionalized voluntarism)	+ (-)
H4b	Higher sectoral legitimacy is positively associated with public provision and oversight and directed subsidization	National mandates on local adaptation are positively associated with local implementation via public provision of goods and services and regulatory measures (and negatively associated with implementation via directed subsidization and institutionalized voluntarism)	+ (-)
<i>Local policy environment hypotheses</i>			
H5	Higher complexity of the policy environment is positively associated with public provision and oversight and directed subsidization	A larger local manufacturing economy is positively associated with local adaptation policy implementation via public provision and oversight and directed subsidization (and negatively associated with implementation via regulatory corporatism and institutionalized voluntarism)	+ (-)
H6	Higher complexity of the policy problem is positively associated with public provision and oversight and directed subsidization	Greater diversity of risk environment is positively associated with local adaptation policy implementation via public provision and oversight and directed subsidization (and negatively associated with implementation via regulatory corporatism and institutionalized voluntarism)	+ (-)
<i>National policy environmental hypotheses</i>			
H7	Higher complexity of the policy environment is positively associated with public provision and oversight and direct subsidization	Less corporatist decision-making cultures are positively associated with local adaptation policy implementation via public provision and oversight and directed subsidization (and negatively associated with implementation via regulatory corporatism and institutionalized voluntarism)	- (+)
H8	Higher complexity of the policy problem is positively associated with public provision and oversight and directed subsidization	Larger countries are positively associated with local adaptation policy implementation via public provision and oversight and directed subsidization (and negatively associated with implementation via regulatory corporatism and institutionalized voluntarism)	+ (-)

5.2.3 Government capacity

Governing capacity encompasses both the ability of governments to leverage skills and resources to formulate and implement policy, and the extent to which government action on a policy problem is perceived as legitimate by policy actors and the public (X. Wu, Ramesh, and Howlett 2015). We draw on the empirical adaptation literature to identify proxy variables for these two aspects of governing capacity.

Local predictors of governing capacity

H1: A larger local population is positively associated with implementation via public provision of goods and services and regulatory measures (and negatively associated with implementation via directed subsidization and institutionalized voluntarism).

Financial and institutional capacity (e.g. GDP, revenue sources, staff resources) have been widely identified in the literature as factors enabling or constraining local adaptation efforts (Hughes 2015; Measham et al. 2011; Shi, Chu, and Debats 2015). Several studies find evidence that adaptation planning efforts are more highly associated with large cities, which have bigger tax bases to draw on and are more able to access resources through urban climate networks like C40 (Reckien et al. 2015; Araos et al. 2016). We therefore adopt one proxy variable for local governing capacity that is assumed to co-vary with the ability of local governments to leverage skills and resources in designing adaptation policies: *local population*. Larger local governments are assumed to have higher organizational and fiscal capacity, resulting in higher internal policy capacity (Paterson et al. 2017).

H2: Larger local adaptation policy portfolios are positively associated with implementation via public provision of goods and services and regulatory measures (and negatively associated with implementation via directed subsidization and institutionalized voluntarism).

The state capacity dimension of the implementation styles model also encompasses soft aspects of capacity, namely perceived legitimacy around government action on a policy problem. Where existing procedures or new policy issues are highly contested in the eyes of policy actors and the public, governments are expected to focus more strongly on building consensus around the need for government action (Schneider and Ingram 1990). The importance of perceived legitimacy for adaptation action is observed in the climate change literature, where the extent to which elected officials perceive they are able to provide strong political leadership is a commonly cited driver of adaptation policy adoption (Hjerpe, Storbjörk, and Alberth 2014; Hughes 2015; Shi, Chu, and Debats 2015; Ford and King 2015). Similarly, building consensus around the importance of adaptation and the appropriate approach to implementing adaptation goals are shown in the literature to shape local policy approaches (Cashmore and Wejs 2014; Fünfgeld and McEvoy 2014). Where consensus is strong, we expect local governments to take more direct policy action on adaptation. Here we adopt the *total number of policy instruments* contained in local policy portfolios as a proxy measure for local support for adaptation action. Where local governments adopt a larger number of instruments, we assume that support for adaptation is higher on local political agendas.

National predictors of governing capacity

H3: Lower dependency on inter-governmental resource transfers is positively associated with local adaptation policy implementation via public provision of goods and services and

regulatory measures (and negatively associated with implementation via directed subsidization and institutionalized voluntarism).

While local governments are commonly regarded as being ‘closest’ to the problem of climate impacts and adaptation (Nalau, Preston, and Maloney 2015), they are also the most constrained level of government with regards to autonomy and revenue-generating authority (Loughlin et al. 2011). This can limit the ability of cities to take a leading role in climate change planning (Bulkeley and Betsill 2005; Measham et al. 2011; D. M. Brown 2012; Amundsen, Berglund, and Westskogh 2010). Considering vertical dispersions of authority within countries recognizes that instrument choice represents the exercise of power (Kassim and Le Galès 2010). This power is observable at the local level in the autonomy and authority of local governments to make these political decisions (Eckersley 2017a). Our national-level proxy measure for governing capacity captures the level of dependency between local and national governments using *Vertical Fiscal Imbalance (VFI)*. VFI is a measure of the extent to which lower levels of government are dependent on financial transfers from the central government, and captures asymmetry in the taxing and spending capacities of subnational government (Aldasoro and Seiferling 2014). High VFI is associated with higher budgetary constraints on subnational government, and lower local governing autonomy.

H4a: Greater national adoption of adaptation policy instruments is positively associated with local implementation via public provision of goods and services and regulatory measures (and negatively associated with implementation via directed subsidization and institutionalized voluntarism).

H4b: National mandates requiring local adaptation policy action are positively associated with local implementation via public provision of goods and services and regulatory measures (and

negatively associated with implementation via directed subsidization and institutionalized voluntarism).

Our national predictors also capture country-level political support for adaptation action. Similar to our local-level predictor, we measure the level of national prioritization of adaptation based on country-level climate change policy portfolios, specifically the *total number of adaptation policy instruments* contained in national policy portfolios (Lesnikowski et al. 2016). Furthermore, we consider that even where national governments adopt few policy instruments, national mandates requiring local-level adaptation can increase local government engagement with adaptation policy-making by allowing otherwise risk-averse decision-makers to pursue innovative policies while displacing blame for possible policy failures onto national governments (Howlett 2014). An example of a national mandate was the United Kingdom's National Indicator 188 under its performance monitoring system of local governments (active between 2008-2010), which assessed whether local governments were conducting vulnerability assessments and adaptation planning (Porter, Demeritt, and Dessai 2015). We include a dummy variable capturing whether there is a national mandate for local governments to do some level of adaptation planning.

5.2.4 Policy environment complexity

The complexity of local policy environments is interpreted along two key dimensions: the constellation of actors participating in a political system, and the nature of climate change impacts perceived as a policy problem.

Local predictors of policy environment complexity

H5: A larger local manufacturing economy is positively associated with local adaptation policy implementation via public provision and oversight and directed subsidization (and negatively associated with implementation via regulatory corporatism and institutionalized voluntarism).

Policy-makers make decisions based on perceived feasibility of policy alternatives, including the political risk associated with certain courses of action and ideological constraints on what is considered acceptable government action (Linder and Peters 1989). This is observed in empirical studies of sustainability and climate change policy adoption, which suggest that economic and issue-based coalitions and voting behaviour influence decision-making outcomes; where pro-environment and left-leaning voter behavior is high, local governments are more likely to adopt climate change policies (Kalafatis 2018; Krause 2013; Krause 2011; Sharp, Daley, and Lynch 2011; Wood, Hultquist, and Romsdahl 2014; Wang 2013). Data sources with comprehensive coverage of local voting behavior and interest group participation across the countries included in this study are non-existent, so we select a demographic variable found in US-based studies of local sustainability policy adoption to be associated with more conservative political attitudes on environmental policy as a proxy measure for the complexity of local actor networks: the extent to which the local economy is *dependent on manufacturing*. Larger manufacturing sectors are assumed to be associated with pro-business political climates, lower acceptability of government regulation, and a generally lower emphasis on environmental policy agendas (Krause 2011b; Krause 2011c; Portney 2003). We are therefore interpreting policy environment complexity as the political complexity surrounding adaptation decision-making, meaning the “degree of difficulty in negotiating agreements among the parties involved” in solving a policy problem (Peters 2005, pg. 358), but acknowledge that there are facets of this idea such as the composition of actor networks that are not captured here due to data constraints.

H6: Greater diversity of the climate change risks exposed to is positively associated with local adaptation policy implementation via public provision and oversight and directed subsidization (and negatively associated with implementation via regulatory corporatism and institutionalized voluntarism).

An important aspect of decision-making environments is the nature of the policy problem itself. The implementation styles model predicts that where policy problems are bounded in scope and more easily targeted in policy interventions, governments are more likely to use either authoritative instruments or information-based tools. In contrast, increasing complexity in the nature of the policy problem is associated with organizational reforms that directly deal with issues, and incentive-based actions that enable flexible responses from actors. Here we assume that more diverse climate change risk profiles implies greater policy complexity, and thus greater likelihood that local governments will adopt organizational reforms or incentive-based policy schemes. We calculate a Simpson's diversity index score for the range of climate change impacts addressed in local adaptation policy portfolios, and use this number as a proxy for the complexity of the local climate change risk environment.

National predictors of policy environment complexity

H7: Less corporatist decision-making cultures are positively associated with local adaptation policy implementation via public provision and oversight and directed subsidization (and negatively associated with implementation via regulatory corporatism and institutionalized voluntarism).

A fundamental concept for understanding the structure of policy environments is the nature of the relationship between state and society. Institutionalized beliefs about the appropriate exercise of state authority and the negotiation of this authority between public and

private actors are pillars of governance and public administration theories, and are important explanatory variable for understanding public policy outcomes (Lijphart 1999; Loughlin et al. 2011; Painter and Peters 2010b). These institutional arrangements are typically juxtaposed between two types of relationships: corporatism and pluralism. Corporatism is generally understood as centralized coordination between the state and small numbers of interest organizations, and is associated with stronger traditions of cooperation and consensus-building (Jahn 1998). In contrast, pluralist traditions are more open, with a larger number of societal interests competing for power and the ability to influence policy agendas (Lijphart 1999). Environmental policy research has developed a significant focus on the relationship between corporatist institutional arrangements and environmental performance, arguing that institutional negotiation among a smaller number of interest groups promotes long-term trust and ability to overcome collective action problems (Fiorino 2011). Indeed, empirical studies of national institutions and environment performance have suggested that countries with corporatist forms of interest mediation have better environmental performance outcomes and adopt more policy instruments compared to countries with greater competition between interests (Scruggs 1999; Liefferink et al. 2009; Walti 2004). Owing to collinearity between pluralism and corporatism measures in our dataset, we select only the degree to which national decision-making displays *corporatist features* to operationalize out hypotheses about national decision-making contexts (Biesbroek, Lesnikowski, et al. 2018). More corporatist policy environments are associated with lower complexity, as they involve fewer actors and greater emphasis on consensus-building.

H8: Larger countries are positively associated with local adaptation policy implementation via public provision and directed subsidization (and negatively associated with implementation via regulatory corporatism and institutionalized voluntarism).

Finally, we also consider the complexity of the country-level climate change risk context. All five countries captured in our sample are considered to have relatively high capacity to adapt to climate change owing to their high socio-economic status (see Notre Dame Global Adaptation Index). Rather than measuring adaptive capacity or relative vulnerability, we therefore focus on the diversity of risks that countries face in a changing climate, and adopt the size of the country measured in square kilometers as a proxy measurement for this diversity. Larger countries with more diverse risk profiles are expected to emphasize comprehensive adaptation planning processes in local adaptation planning guidance, and encourage actors to take adaptive steps based on their unique circumstances.

5.3 Methods

We apply a systematic content analysis approach to identify local adaptation instrument mixes, which requires inventorying government policy documents (Howlett, Kim, and Weaver 2006). We use domain-specific key words ('climate change' and 'adaptation') to define the boundaries around adaptation policy. Local adaptation policy portfolios were analyzed and individual policy instruments were coded according to a deductively determined list of local policy instruments (Appendix A for details on policy instrument categories). Policy instruments are grouped within implementation styles based on the categories described in Figure 1 above, and a measure of the overall presence of that style within a local policy approach is derived using the ratio of that style to the other styles within a policy portfolio.

5.3.1 *Study sample*

Our sample consists of a total of 125 local governments from five countries (Canada, France, Germany, Netherlands, United Kingdom). 'Local government' is understood here as the lowest tier of government that carries responsibility over land use planning, building, and all or most local service provision. This includes municipalities (Canada, Germany, Netherlands),

communes (France), and local authorities/metropolitan districts/London boroughs (United Kingdom). These countries were selected because they represent diverse state structures, policy styles, and climate change risk contexts, suggesting there may be structured variation in local policy implementation styles (Painter and Peters 2010a; Howlett and Tosun 2018b). The language abilities of the research team was an additional important consideration for accessibility to primary policy documents. Finally, our goal was to identify local governments where adaptation is likely to be occurring, so data were collected from the largest 25 local governments in each of these countries. This decision was made in light of findings from the literature that large cities are more likely to be engaged with adaptation planning (Araos et al. 2016; Reckien et al. 2015). Policy instruments were identified in 119/125 of these local governments (see Appendix A for the list of cities and details on policy portfolio coding procedures).

5.3.2 Independent variable measures

Given the absence of robust cross-country data sources on local governments, we integrated independent variable data from several major databases based on the proxy variables specified above. These sources include national statistics offices, the OECD, the Comparative Political Data Set, the Centre for Cities European Cities Data Tool, Lesnikowski et al.'s (Lesnikowski et al. 2016) national climate change adaptation policy database, and our own unique dataset of local government policy instruments. We identify four variables at the local government level and five variables at the national level (Table 5.3).

Table 5.3 Independent and dependent variables

		Mean	Std. Dev.	N
Local explanatory variables				
<i>Governing capacity</i>				
Local population	Continuous variable (log transformed) from Statistics Canada (2016), National Institute of Statistics and Economic Studies	466,714.28	484,328.18	125

	France (2013), Federal Statistical Office of Germany (2015), Statistics Netherlands (2017), Office for National Statistics UK (2016).			
Total local policy instruments	Continuous variable capturing the number of individual adaptation policy instruments observed in each local government's policy portfolio.	26.62	31.68	125
<i>Policy environment</i>				
Impact diversity	Simpsons diversity index representing range of climate change impacts addressed in each local policy portfolio.	0.47	0.33	125
Manufacturing employment	Continuous variable capturing share of employment in mining and quarrying; manufacturing; electricity, gas, and air conditioning; water supply and sewerage, waste management, and remediation activities. From the Centre for Cities European Cities Data Tool (France, Germany, Netherlands, UK) and Statistics Canada.	11.06	4.44	107
National explanatory variables				
<i>Governing capacity</i>				
Vertical Fiscal Imbalance (VFI)	Continuous variable capturing transfer dependency and subnational borrowing capacity from the IMF (Aldasoro and Seiferling 2014).	40.72	25.07	5
Total national policy instruments	Continuous variable capturing the number of adaptation policy instruments observed in each national government's policy portfolio (Lesnikowski et al. 2016)	84	58	5
National mandate	Dummy variable measuring whether there is a national mandate for local-level adaptation action in place (1/0:Y/N). '1' found in Code of Urban and Code of the Environment (France), Spatial Planning Act (Germany), Climate Change Act and National Planning Framework (UK). '0' found for Canada and Netherlands.	0.60	0.49	5

<i>Policy environment</i>				
Corporatism	Continuous variable normalized between 0 and 1 defined as degree of compromise mediated by the state between conflicting interest organizations (Jahn 2014).	0.51	0.43	5
Country size	Continuous variable (log transformed) capturing country size by total number of square kilometers. From Wikipedia.	2,253,355	3,886,087	5
Dependent variables (from the authors database)				
Public provision with oversight	Share of local adaptation portfolio representing a policy instrument mix consistent with a public provision implementation style.	0.38	0.24	125
Regulatory corporatism	Share of local adaptation portfolio representing a policy instrument mix consistent with a regulatory corporatism implementation style.	0.32	0.24	125
Directed subsidization	Share of local adaptation portfolio representing a policy instrument mix consistent with a regulatory corporatism implementation style.	0.02	0.05	125
Institutionalized voluntarism	Share of local adaptation portfolio representing a policy instrument mix consistent with a regulatory corporatism implementation style.	0.23	0.21	125

5.3.3 Data analysis

We use fixed effects regression modelling and multilevel modelling to test the hypotheses described above. Fixed effects regression analysis (FE) is applied to our local-level predictors of implementation styles to control for variance related to country clustering. FE regression analysis thus allows us to examine the importance of local predictors for explaining within-group variation. Random intercept multilevel modelling (RE) is applied to explain country-level variation because it accounts for the hierarchical nature of the dataset, in which local governments are clustered within countries (Hox, Moerbeek, and van de Schoot 2010). We use restricted maximum likelihood estimation with the Kenward-Roger correction, which is recommended for studies with small sample sizes at Level 2 (McNeish and Stapleton 2016).

Owing to concerns of overfitting, we do not run combined models for our local and national predictors and so cannot draw any firm conclusions regarding interactions between variables at different levels. Rather, we interpret findings from both sets of models in light of empirical insights from the adaptation literature and the implementation styles model, which suggest promising directions for further investigation of interactions between local and national policy formulation dynamics.

The local population and country size variables are log transformed due to the wide range of values for these predictors. No other variables are scaled or centered. We examine each model result for sensitivity to outliers, multicollinearity, and assumptions of homogeneity and linearity and report on these as necessary (Appendix B). All analyses were completed in R Version 3.5.2 using the lme4, lmerTest, sjstats, QuantPsyc, and vegan packages (Bates et al. 2015; Kuznetsova, Brockhoff, and Christensen 2017; Lüdtke 2019; Fletcher 2012; Oksanen et al. 2018).

5.4 Results

5.4.1 Descriptive results

The average number of policy instruments identified for each local government is 26.62 (st. dev: 31.68). Before running statistical analyses, we plot the relationship between implementation style and the total number of policy instruments by country cluster (Figure 5.1). As expected, few local governments have an implementation approach consisting of just one implementation style. Those that do tend to have very few instruments within their policy portfolios ($n < 5$). This suggests that as policy portfolios grow increasingly complex, local implementation styles tend to become more hybrid in nature.

Figure 5.1 Prevalence of policy implementation styles by country

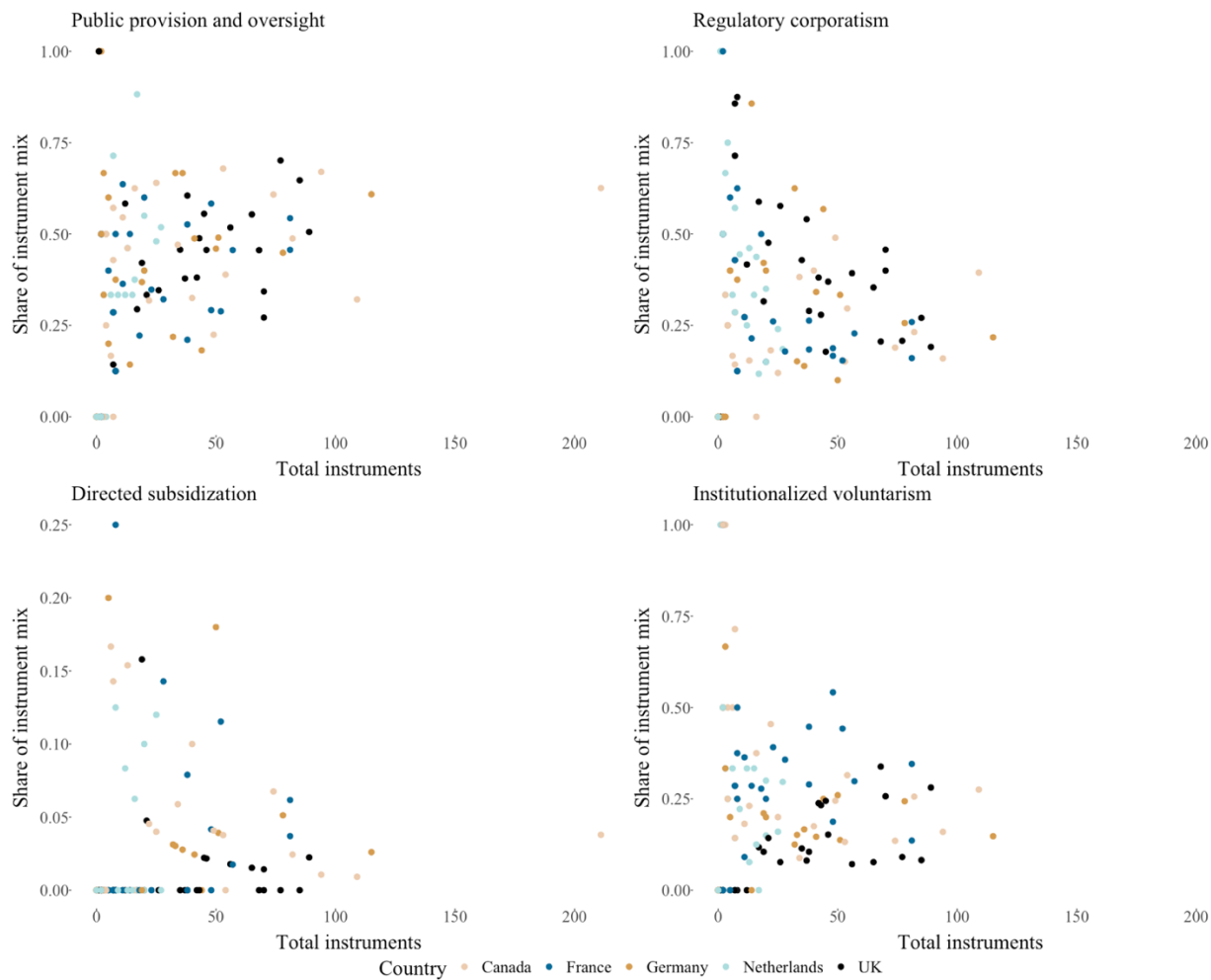


Table 5.4 provides mean values of implementation styles disaggregated by country. We observe that public provision and oversight, regulatory corporatism, and institutionalized voluntarism are widespread among the local governments surveyed, with 80-87 percent of local governments adopting instruments indicative of these approaches. The precise balance between these categories, however, shows slight variation across countries. Far fewer local governments are found to have instrument mixes containing a direct subsidization implementation style (35 percent). The largest number of local governments with directed subsidization instruments are located in Canada (14 of 44), with the fewest located in the Netherlands (5 of 44). Additionally, among those local governments that do have an

implementation approach encompassing directed subsidization, it constitutes a much lower share of their overall profile compared to the other implementation styles.

Table 5.4 Average composition of local instrument mixes by country (%)

	Public provision and oversight	Regulatory corporatism	Directed subsidization	Institutionalized voluntarism
Canada	0.37	0.23	0.04	0.36
France	0.36	0.31	0.03	0.30
Germany	0.41	0.23	0.02	0.17
Netherlands	0.27	0.40	0.02	0.23
United Kingdom	0.45	0.41	0.01	0.12

Correlation tests indicate that public provision and oversight, regulatory corporatism, and institutionalized voluntarism have the strongest likelihood of co-occurring ($p < 0.01$), but institutionalized voluntarism and direct subsidization are not likely to co-occur (Table 5.5).² Given that public provision and oversight and regulatory corporatism are predicted by high government capacity but institutional voluntarism is predicted by low government capacity, the co-occurrence of these implementation styles within local instrument mixes is a first indication that the theoretical model of implementation styles may not be consistent with local adaptation implementation approaches identified in this sample.

Table 5.5 Spearman's correlation matrix of local implementation styles

	Public provision and oversight	Regulatory corporatism	Directed subsidization
Regulatory corporatism	-0.33***		
Directed subsidization	0.17*	-0.18**	
Institutionalized voluntarism	-0.23***	-0.27***	0.07

$p < 0.10^*$; $p < 0.05^{**}$; $p < 0.001^{***}$

² The direction of the relationship should not be interpreted from these estimates, as an increased share of one style necessarily means a lower share of another style.

5.4.2 Local-level predictors of local implementation styles

Four fixed effects regression models, one per theorized implementation style, are estimated to assess whether governing capacity and the complexity of policy environments predict local adaptation instrument mixes. Table 5.6 presents results from base FE models and full FE models.³ The predictive power of each model ranges across implementation styles but is generally low, with local-level variables predicting 18 percent of variation in regulatory corporatist mixes but 0 percent of variation in directed subsidization mixes.

Table 5.6 Local hypothesis models

Table 5.6a Fixed Effects base models

	Implementation styles ¹			
	Public provision and oversight	Regulatory corporatism	Directed subsidization	Institutionalized voluntarism
	+ <i>Country FE</i>	+ <i>Country FE</i>	+ <i>Country FE</i>	+ <i>Country FE</i>
Constant	0.37*** (0.05)	0.23*** (0.05)	0.04*** (0.01)	0.36*** (0.04)
R ²	0.07	0.11	0.03	0.16
Adjusted R ²	0.03	0.08	0.00	0.13

Table 5.6b Fixed Effects models

	Implementation styles ²			
	Public provision and oversight	Regulatory corporatism	Directed subsidization	Institutionalized voluntarism
<i>Population</i>	0.02 (0.07; 0.04)	-0.00 (-0.01; 0.04)	0.02 (0.20; 0.01)	-0.01 (-0.03; 0.04)
<i>Portfolio size</i>	0.002** (0.26; 0.001)	-0.002** (-0.25; 0.001)	0.00 (0.07; 0.00)	-0.00 (-0.03; 0.00)
<i>Manufacturing</i>	0.01* (0.20; 0.01)	-0.01 (-0.17; 0.01)	-0.00 (-0.00; 0.00)	0.01 (0.10; 0.01)
<i>Risk profile</i>	0.21** (0.24; 0.09)	0.28*** (0.33; 0.08)	-0.03 (-0.14; 0.02)	-0.16** (-0.20; 0.08)

³ Base models refer to regression models containing only country fixed effects. Full models contain country fixed effects and local predictor variables.

	+ Country FE	+ Country FE	+ Country FE	+ Country FE
Constant	-0.24 (0.53)	0.31 (0.48)	-0.14 (0.13)	0.52 (0.47)
R ²	0.18	0.27	0.06	0.24
Adjusted R ²	0.12	0.21	0.00	0.18

Standardized beta coefficient and standard errors in parentheses;

p ≤ 0.10; p ≤ 0.05**; p ≤ 0.01***;*

FEs = fixed effects (dummy variables for country membership)

¹ *Regression models containing only country fixed effects.*

² *Regression models containing country fixed effects and local predictor variables.*

Significance of individual predictors is low across all models, with portfolio size significant for predicting public provision and oversight and regulatory corporatism, and risk profile and manufacturing sector significant for predicting regulatory corporatism (Table 5.6b). We find mixed support for our local-level hypotheses. Hypothesized drivers of public provision and oversight are consistent with the theoretical model of implementation styles, with higher governing capacity and higher policy complexity associated with institutional reforms, direct spending, education and training, and undertaking of climate change assessments and reports.

Results for the remaining three implementation styles differ from what is predicted by the implementation styles model. First, we find that regulatory corporatism is generally associated with lower governing capacity, and lower complexity in the stakeholder environment but higher complexity in terms of the problem context. This suggests that higher capacity is not necessarily a constraint on the adoption of regulatory policy instruments, which contrasts with suggestions in the adaptation literature that low capacity is a barrier to substantive adaptation policy adoption. As was the case with public provision and oversight, results diverge between our two proxy measurements for complexity of the policy environment. We find that regulatory corporatism is associated with lower complexity in the actor environment (i.e. a smaller manufacturing sector), but higher complexity in the problem context. It may therefore be the case that local adoption of

regulatory instruments is more likely when two conditions are met: issue urgency is perceived to be higher, but the constellation of actors in the decision-making environment also have a higher tolerance for coercive government intervention. This model is robust to removal of outliers (Appendix B).

Second, institutionalized voluntarism appears most associated with contexts where there is low governing capacity, low levels of risk diversity, but higher complexity in the political environment, rather than low capacity and low complexity as expected. This suggests that governments facing stronger constraints on policy action signal their resolve to act on climate change adaptation by adopting instruments that encourage normative or behavioral changes, for example through public outreach campaigns or hosting conferences and workshops, but without making deeper policy action through adjustments to institutional arrangements, regulations, or incentive schemes. Comparison of probability distributions in this model indicate the possibility of outliers (Appendix B). Removal of three outliers provokes sensitivity in model outputs, with the estimates for local population and total policy instruments becoming positive but highly nonsignificant (see Appendix B for model outputs with outliers removed). Given the small and non-random sample used here, however, we interpret this model based on the results from the full sample.

Directed subsidization constitutes a much lower share of observed local instrument mixes, which may partially explain the poor predictive power of the model. What the results initially suggest, however, is that selection of policy instruments like subsidy schemes or user chargers seem to be higher among local governments with high governing capacity but facing low complexity policy environments, specifically lower dependency on the manufacturing sector and narrower risk profiles. Among the local governments surveyed, financial instruments were commonly found to be adopted in response to flood-related risk, so it may be that local

governments adopt directed subsidization when their risk focus is comparatively narrower but their ability to fund subsidies and grants or enforce instruments like user charges and loan programs is higher.

The large number of zero values in the directed subsidization dependent variable resulted in heavy skewness in the models (Appendix B). We therefore also ran this model omitting observations where the dependent variable value was equal to zero. These results suggest some sensitivity around our proxy measurement for issue legitimacy (total instrument adoption): Population: 0.01, β : 0.08, SE: 0.01, $p = 0.58$; Total instrument adoption: -0.00, β : -0.36, SE: 0.00, $p = 0.01$; Manufacturing: -0.00, β : -0.05, SE: 0.00, $p = 0.75$; Risk profile: -0.14, β : -0.53, SE: 0.04, $p \leq 0.01$. These results are not necessarily inconsistent with the interpretation described above, however. Where issue legitimacy is lower but capacity is high and the climate change problem environment is less complex, local governments may choose financial instruments to encourage changes in a non-coercive manner. The standardized beta values and significance levels for total instrument adoption and manufacturing also suggest that larger community consensus is more important than consensus among particular economic interest groups. Model performance is high and robust to removal of outliers, with an Adjusted R-squared of 0.41.

5.4.3 National-level predictors of local implementation style

The FE regression models allow us to control for between-country variance and examine only the effects of local-level predictors on local implementation styles. FE models do not allow for estimation of country-level variables, however, so we use multilevel models to examine whether country-level characteristics influence local implementation styles. Owing to concerns

of overfitting with such a small number of Level-2 groups ($j = 5$), 16 mixed models were run separately for each national-level predictor.

Results of the baseline models are summarized in Table 5.7a. A key observation from these models appears to be that national-level contextual factors may matter more for some local implementation styles than others. ICC values represent the extent to which observations within clusters are similar to observations from other clusters; higher ICC values represent greater differentiation between groups. ICC results for the baseline models are notably higher for institutionalized voluntarism (0.16) and regulatory corporatism (0.10), and are low in the case of public provision and oversight and directed subsidization. Individual predictor variables are largely non-significant, which may be due to the small sample size at Level 2 of the models (Figure 5.7b).

Table 5.7 National hypothesis models

Table 5.7a Multilevel base models

	Implementation styles			
	Public provision and oversight	Regulatory corporatism	Directed subsidization ¹	Institutionalized voluntarism
Constant	0.38*** (0.03)	0.32*** (0.04)	0.03*** (0.004)	0.24*** (0.04)
AIC	2.94	-1.61	-387.47	-29.72
ICC	0.04	0.10	0.00	0.16

Table 5.7b Multilevel models (by national predictor and implementation style)

	Implementation styles			
	Public provision and oversight	Regulatory corporatism	Directed subsidization	Institutionalized voluntarism
<i>VFI</i>	-0.00 (0.00)	0.01** (0.001) ¹	-0.00 (0.00) ¹	-0.002 (0.002)
Constant	0.40*** (0.07)	0.20** (0.04)	0.04** (0.01)	0.30** (0.08)
AIC	16.27	4.52	-372.20	-17.66
ICC	0.06	0.00	0.00	0.17
<i>National portfolio size</i>	0.003* (0.001) ¹	-0.002 (0.002)	0.00 (0.00)	-0.00 (0.00)

Constant	0.23** (0.06)	0.41** (0.12)	0.03 (0.01)	0.28 (0.14)
AIC	11.40	10.24	-370.61	-17.60
ICC	0.00	0.11	0.01	0.20
<i>National mandate</i>	0.09 (0.05)	0.002 (0.09)	-0.01 (0.01)	-0.10 (0.08)
Constant	0.32 (0.04)***	0.32** (0.07)	0.03** (0.01)	0.29** (0.07)
AIC	6.46	3.48	-378.35	-25.91
ICC	0.02	0.14	0.00	0.14
<i>Corporatism</i>	-0.07 (0.07)	0.01 (0.11)	-0.01 (0.01)	-0.06 (0.11)
Constant	0.41*** (0.05)	0.31** (0.07)	0.03** (0.01)	0.26** (0.07)
AIC	7.36	3.19	-378.39	-25.35
ICC	0.04	0.14	0.01	0.19
<i>Country size</i>	0.01 (0.02)	-0.03 (0.02)	0.004 (0.002) ¹	0.03 (0.02)
Constant	0.23 (0.24)	0.74** (0.23)	-0.03 (0.03)	-0.18 (0.27)
AIC	10.79	3.74	-377.75	-24.08
ICC	0.06	0.05	0.00	0.11

Standardized beta coefficient and standard errors in parentheses;

p ≤ 0.10; p ≤ 0.05**; p ≤ 0.01****

¹ *Singular fit warning*

National predictors of local adoption of an institutionalized voluntarism policy approach indicate that lower dependency on inter-governmental resource transfers (VFI), low national leadership on adaptation (national portfolio size and national mandate), low levels of cooperative decision-making (corporatism), and larger country contexts (size) are associated with heavier reliance on information-based and voluntary policy instruments. This is consistent with the picture that emerges from local-level predictors, which suggests that where capacity is low but complexity is high local governments will turn to soft policy approaches. The negative coefficient on VFI is particularly interesting, as it challenges assumptions that greater local fiscal autonomy is associated with more substantive policy adoption. The literature on fiscal decentralization has suggested that greater dependency on top-down government transfers can

improve coordination between levels of government, whereas greater decentralization of revenue-generating autonomy can increase the risk of policy deficits at lower levels of government (de Mello Jr. 2000). Our results are consistent with this logic, especially in light of the national leadership models.

Regulatory corporatism, on the other hand, appears to be associated with higher dependency on inter-government resource transfers (VFI), the presence of national mandates, national cultures of cooperative decision-making (corporatism), and smaller country size. This implementation approach seems to emerge even where national governments are less engaged in adaptation policy formulation themselves, suggesting that national mandates matter more for local regulatory policy adoption than the presence of large national adaptation planning processes. This mirrors Keskitalo et al.'s observation that mandatory national regulations on adaptation are more likely to result in local resource prioritization that sustains adaptation work over the long-term (Keskitalo et al. 2016). Some level of centralized coordination on adaptation may therefore be necessary for more substantive local adaptation to occur.

Our finding on the positive association between national and local cultures of cooperative decision-making, however, requires some additional research with a larger sample, as the removal of outliers reverses this relationship and indicates instead that more corporatist national cultures are negatively associated with local regulatory corporatist styles. This points to a broader question for the literature on policy styles: do local decision-making styles reflect national decision-making styles, which would be consistent with the idea of a national policy style, or do some countries exhibit differences in national and subnational decision-making styles, which would suggest a scalar dynamic to the emergence of policy styles?

Within country clustering was low in the case of public provision and oversight (ICC: 0.04), which suggests that national context is less important for the adoption of policy instruments associated with this implementation style. Nonetheless, results for all models are consistent with our hypotheses.

Models predicting local directed subsidization approaches to adaptation are similar to those for public provision and oversight, indicating that this style is associated with fiscal decentralization (VFI), national adoption of adaptation policies (but not the presence of national mandates), and higher complexity in national policy environments (low cooperative decision-making and large country size). As with our local-level predictors, an additional set of models is run for the directed subsidization models that remove dependent variable values of zero ($n_0 = 81$) in order to improve model normality. Results for national governing capacity are somewhat more consistent with our national-level hypotheses, with national leadership on adaptation being negatively associated with directed subsidization (national policy portfolios and mandates) and positively associated with less dependency on inter-governmental resource transfers. Policy environment complexity becomes negatively associated with local policy choice, however, which is consistent with our local-level model results but inconsistent with national-level hypotheses; this suggest that lower complexity of national adaptation policy environments is associated with higher local adoption of direct subsidization instruments.

Four models were flagged by singular fit errors, generating a null ICC and indicating that even with only one predictor these models may be over-fitted. To simplify these models we therefore ran additional OLS linear regression models for each model: i) VFI and regulatory corporatism; ii) VFI and directed subsidization; iii) national portfolio size and public provision and oversight; and iv) country size and directed subsidization (full results in Appendix B). These

models slightly improve the significance levels of these predictors, with no change in direction of the estimates. Models are found to be robust to removal of outliers (not reported).

5.5 Discussion

This study contributes to a growing body of research that aims to advance explanatory research on adaptation policy formulation. We seek to explain local policy instrument choices by identifying eight local and national-level variables from a model of policy implementation styles that we hypothesize explain local adaptation policy approaches. The statistical power of the models summarized here is generally low, but nonetheless these results provide useful insights for refining our theoretical understanding of adaptation policy instrument choice. Unsurprisingly, we find that most local policy approaches represent hybrid forms of the four theoretical implementation styles proposed by Howlett et al. Public provision and oversight and regulatory corporatism are particularly common among the local governments surveyed here, while directed subsidization constitutes a relatively small component of local policy approaches.

The results of our fixed effect and random intercept multilevel models indicate mixed support for theorized drivers of local policy instrument choice. Figure 5.2 provides a summary of observed differences between the theoretical model of implementation styles proposed by Howlett et al. and our models of the local and national dimensions of local adaptation policy choice.

Figure 5.2 Predictors of local adaptation implementation styles

Figure 5.2a Theoretical model

		Policy environment complexity	
		<i>High</i>	<i>Low</i>
Government capacity	<i>High</i>	Public provision and oversight	Regulatory corporatism
	<i>Low</i>	Directed subsidization	Institutionalized voluntarism

Adapted from Howlett et al. (2009)

Figure 5.2b Empirical model (local-level predictors)

		Policy environment complexity	
		<i>High</i>	<i>Low</i>
Government capacity	<i>High</i>	Public provision and oversight	Directed subsidization
	<i>Low</i>	Regulatory corporatism Institutionalized voluntarism	

Figure 5.2c Empirical model (national-level predictors)

		Policy environment complexity	
		<i>High</i>	<i>Low</i>
Government capacity	<i>High</i>	Public provision and oversight	Regulatory corporatism
	<i>Low</i>	Institutionalized voluntarism Directed subsidization	

We generally observe that adoption of public provision and oversight instrument mixes is consistent with higher government capacity and policy environment complexity. Contrary to expectation, however, regulatory corporatist approaches are occurring in the context of lower local governing capacity and higher perceived climate risk complexity, but where local political environments are less dominated by manufacturing interests. This suggests that adoption of substantive adaptation policy instruments such as land use planning regulations or higher performance standards for public infrastructure is possible even where local governments are tackling multiple impacts of climate change with high material constraints, but as suggested elsewhere the absence of oppositional coalitions representing traditional economic interests is likely to facilitate the adoption of regulatory instruments (Kalafatis 2018).

Inter-governmental relationships between local and national governments appear to further explain these policy choices; our multilevel models suggest that regulatory approaches to local adaptation – such as those adopted through land use planning instruments – are more likely where there are mandates from national governments requiring local initiatives on adaptation, and stronger resource dependency of subnational governments on national government. Furthermore, local governments are more likely to rely on voluntary adaptation measures where they have low local governing capacity and face high political complexity, but national governments do not assume an active role in encouraging adaptation. In the absence of national mandates but where local governments have higher governing capacity, there appears to be a higher likelihood of adopting instruments of incentive-based instruments such as grants, subsidies, and loans. This points to a critical question about long-term prospects for policy implementation. Top-down mandates may be effective for encourage substantive policy adoption in the form of regulatory change, but can implementation be sustained over time where local governments face greater resource constraints and dependence on inter-governmental resource

transfers? Further research is needed on whether implementation outcomes differ from local governments that begin with more procedural approaches to building a localized adaptation policy agenda and internal policy capacity, and later move towards the adoption of regulatory or incentive-based policy instruments. This also raises questions about the extent to which voluntary and information-based policy choices are indicative of a largely symbolic approach to adaptation, whereby local governments adopt adaptation policy goals but lack either the political will and/or capacity to push deeper policy change through organizational, regulatory, or financial mechanisms (Blühndorn 2007). Overall our findings suggest that local adaptation policy choices should be understood in the context of both local and national policy environments, and that national leadership on local adaptation may make a key difference in the choice between more a more direct policy approach and approaches that shift greater responsibility for policy uptake to non-state actors.

A major challenge in comparative local policy research is the lack of comprehensive data on the institutional arrangements local governments or political changes equivalent in scope to those at the national level (Kantor and Savitch 2005). Here we attempted to overcome these data challenges by compiling a unique dataset of national and local variables from multiple sources (Section 3), but nonetheless we had to rely on coarse proxy measurements for local variables due to data scarcity. The low significance levels that we find for both local and national-level predictors may be attributable to the challenges in operationalizing the concepts described here, and further empirical research should be done to determine the sensitivity of these findings to measurement decisions. Additionally, the analytical power of the multilevel models presented here is limited by the small number of non-random groups (countries) in Level 2 of our models ($j = 5$). We apply modifications to our models based on recommendations for small sample sizes (see section 3 for further details), but caution that the results of our national models should not be

generalized beyond the five countries included in our sample. Results on Level 2 hypotheses should therefore be considered as primarily exploratory in nature, and examined further with a larger sample size.

Our results have several important implications for the study of local adaptation policies. First, we observed that the relationships between theorized predictors of policy choice and local adaptation policy formulation are not consistent across all hypotheses. This may be partially due to sensitivity in proxy measurements or our small sample size, but the results of our multilevel models suggest that inter-governmental relationships are also important for explaining when and how hypothesized local drivers of policy instrument choice matter. A larger multilevel analysis on local adaptation policy formulation is warranted that has sufficient statistical power to explicitly test hypotheses about interactions between local and national variables.

Second, this study also indicates that dependent variable design in explanatory adaptation policy research needs to account for variations in the types of policies being adopted across contexts. The differences we observe here in predictors of local policy implementation styles suggest that observations or policy recommendations drawn from singular moments of policy adoption may fail to explain other types of policy development. Advancing insights on adaptation policy formulation therefore requires greater nuance around how we conceptualize and measure adaptation in order to minimize bias in research design.

Finally, our results also have implications for how we develop policy recommendations on local climate change adaptation. Most strikingly, these findings challenge conventional understandings of about the role of ‘capacity’ understood as the material resources and formal autonomy of local governments, particularly in the literature on ‘barriers’ to adaptation (Measham et al. 2011). We suggest that further effort needs to be made in the empirical literature

to disentangle how we understand ‘capacity’ in the context of local government, particularly regarding the role of resource exchanges with higher levels of government and inter-governmental coordination on adaptation (Eckersley 2017). These results suggest that the role of internal governing capacity varies across policy implementation approaches, and so general recommendations around increasing material resources or decision-making power as a way to encourage local adaptation may not be effective or appropriate across all contexts.

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Preface to Chapter 6

The following chapter contributes to the adaptation literature by arguing that integrating computational text analysis techniques, specifically topic modelling, into current approaches in adaptation governance research represents an opportunity to examine key questions from new perspectives. This chapter serves two purposes within the thesis. First, it provides an introduction to the assumptions and procedures underlying topic modelling as it is used in the final empirical chapter of the thesis (Chapter 7). Second, it justifies the novelty of the methodological contributions in Chapter 7 to the adaptation literature. The manuscript is the result of a joint effort by the Adaptation Tracking Collaborative, for which I acted as Project Manager through my PhD.

The chapter is published in *WIREs Climate Change* under the category of Focus Article:

Lesnikowski A, Belfer E, Rodman E, Smith J, Biesbroek R, Wilkerson J, et al. Frontiers in data analytics for adaptation research: Topic modeling. *WIREs Clim Chang*. 2019;10(3):e576.

Chapter 6: Frontiers in data analytics for adaptation research: Topic modelling

Abstract

Rapid growth over the past two decades in digitized textual information represents untapped potential for methodological innovations in the adaptation governance literature that draw on machine learning approaches already being applied in other areas of computational social sciences. This article examines the potential for text mining techniques, specifically topic modeling, to leverage this data for large-scale analysis of the content of adaptation policy documents. We provide an overview of the assumptions and procedures that underlie the use of topic modeling and discuss key areas in the adaptation governance literature where topic modeling could provide valuable insights. We demonstrate the diversity of potential applications for topic modeling with two examples that examine: (a) how adaptation is being talked about by political leaders in United Nations Framework Convention on Climate Change; and (b) how adaptation is being discussed by decision-makers and public administrators in Canadian municipalities using documents collected from 25 city council archives.

6.1 Introduction

Text-based research methods have been a cornerstone of qualitative social science methods since the 1950s (Lasswell 1952). These approaches see documents as meaningful artifacts that can be analyzed for their thematic and semantic content (Krippendorff 2013), and they form a core component of the climate change adaptation governance literature. In lieu of directly observable and measurable indicators such as greenhouse gas emissions, adaptation governance research relies on written records, surveys, and interviews as its primary information sources about how different actors are responding to climate change impacts. Content analysis methods are commonly applied to sources such as strategic planning documents, government reports, peer-reviewed and grey literature, and media stories (Lesnikowski et al. 2016; Araos et al. 2016; Ford et al. 2015; Labbé et al. 2017; Belfer, Ford, and Maillet 2017; Biesbroek et al. 2018). These studies indicate a growing number of adaptation policies, programs, and interventions being adopted in the public sector to address current and projected risks.

The reliance on hand-coding textual data sources, however, has two major limitations. First, its use in large comparative analyses is constrained by the limited volume of documentation that can reasonably be analyzed using manual techniques. This challenge is becoming increasingly relevant with the proliferation of ‘big data’ sources such as social media or digitized legislative records (Beelen et al. 2017). The adaptation governance literature is certainly not alone in this challenge; computational tools for extracting data from large volumes of text are increasingly being used across the humanities and social sciences, where most data available to researchers are in the form of text (Benoit, Laver, and Mikhaylov 2009; DiMaggio, Nag, and Blei 2013; Shim, Park, and Wilding 2015; Laver and Benoit 2003).

Second, the design of research protocols for manual content analysis often relies on the *a priori* determination of conceptual categories, which is challenging given the mutable and

contested nature of key concepts in adaptation governance (Levin et al. 2012; Pollitt 2015; Head 2014), the fuzziness of adaptation as a distinct problem from issues like risk management (Dabrowski 2017; Hetz 2016; Viguié and Hallegatte 2012; Uittenbroek, Janssen-Jansen, and Runhaar 2013; Bauer and Steurer 2014; Wamsler and Pauleit 2016), and differences in the understanding and use of these concepts across places and sectors (Keenan, King, and Willis 2016; Dupuis and Knoepfel 2013). While identification and classification of adaptation in stand-alone climate policies is relatively straightforward, identifying adaptation-relevant policies from related domains such as water management or sustainable development is a key limitation in current content analysis approaches (Dupuis and Knoepfel 2013).

These limitations have significant implications for what gets ‘counted’ as adaptation, and have generated debate about the extent to which existing datasets are representative of the approaches that different actors are taking to address adaptation (Craft and Fisher 2018). Issues of reporting bias in document retrieval and analysis pose challenges for the validity of results from manual content analysis. A larger empirical investigation of how policy-makers talk about adaptation and position it relative to intersecting policy issues would nuance our interpretations of textual data and improve future research designs that use code-based analysis. Balancing feasibility, representativeness, and conceptual validity in methodological approaches is thus a major challenge for adaptation governance research (Ford et al., 2015), but the rapid increase of information available through government websites, legislative databases, academic databases, and internet search engines provides an opportunity to integrate text mining research techniques into adaptation governance research that can help make sense of this complexity (Ford et al., 2016).

We argue here that the ability to efficiently analyze large volumes of text could contribute important insights on adaptation governance practices across contexts, revealing

relationships between ideas and issues or even uncovering new ways of thinking about adaptation. This could shed light on how key concepts or themes are understood in policy documents or grey literature, and how consistent the conceptual categories and definitions used in adaptation governance research are with their use by practitioners and decision-makers.

The absence of text mining approaches in adaptation governance research suggests a lack of awareness around computational text techniques. The integration of methods from other disciplines into adaptation research is observable in the case of systematic review protocols, which were developed in the health sciences and are increasingly popular for synthesizing emerging evidence around adaptation policies and practices (Berrang-Ford, Pearce, and Ford 2015). Here we demonstrate the untapped potential of computational text methods to address the limitations of manual analysis.

We focus on one text mining technique in particular: topic modelling. Topic models are statistical models that use unsupervised machine learning algorithms to discover the existence and distribution of ‘topics’ across a body of documents based on word frequencies and co-occurrences. This technique can be understood as a form of automated content analysis, which can be helpful for interpreting the content of documents given questions such as:

- How do politicians, policy-makers, or private sector actors talk about adaptation, and how has this changed over time?
- In what context(s) is adaptation talked about?
- How is interest in, and discourse around, adaptation evolving?
- How can we conceptualize adaptation as a relational construct that is sensitive to place, scale, and time?

A number of recent papers discuss applications – and potential perils – of topic modelling in social science and environmental science research (Hillard, Purpura, and Wilkerson 2008; Grubert and Algee-Hewitt 2017; Wiedemann 2013; Quinn et al. 2010; Vilares and He 2017; Wilkerson and Casas 2017; Grimmer and Stewart 2013). Nonetheless, topic modelling has barely permeated the climate change literature, with the majority of existing examples limited to studies that use social media data to analyze coverage of climate change issues (Jang and Hart 2015; Kirilenko and Stepchenkova 2014; Cody et al. 2015; Williams et al. 2015), including skepticism and belief about climate change (Boussalis and Coan 2016; Elgesem, Steskal, and Diakopoulos 2015; Farrell 2016), and social representations of adaptation (Lynam 2016; Lynam and Walker 2016). Applications of topic modelling for adaptation research are thus largely unexplored, despite the potential to expand text-based analysis to much larger scales than is currently possible. This has the potential to make significant contributions to the study of adaptation governance, both with regards to exploratory research and hypothesis generation, and for adaptation tracking.

The following section elaborates on the key ideas and assumptions underlying topic modelling. We then demonstrate the topic modelling process using two examples. The first example analyzes speeches given by country representatives to the United Nations Framework Convention on Climate Change (UNFCCC) at the beginning of the annual Conference of the Parties (2010-2016), providing insight into how the issue of adaptation is discussed by politicians within the UNFCCC negotiations. The second example uses city council meeting minutes and staff reports for the 25 largest cities in Canada to analyze how adaptation policy is being approached by Canadian local governments. These two examples demonstrate: i) that topic modelling can be applied to different scales of analysis; ii) diverse types of text can be analyzed using this method; and iii) there are multiple approaches to implementing topic models and

assessing model robustness when selecting and validating models. We conclude with a discussion on areas in the adaptation governance field where this approach could be applicable.

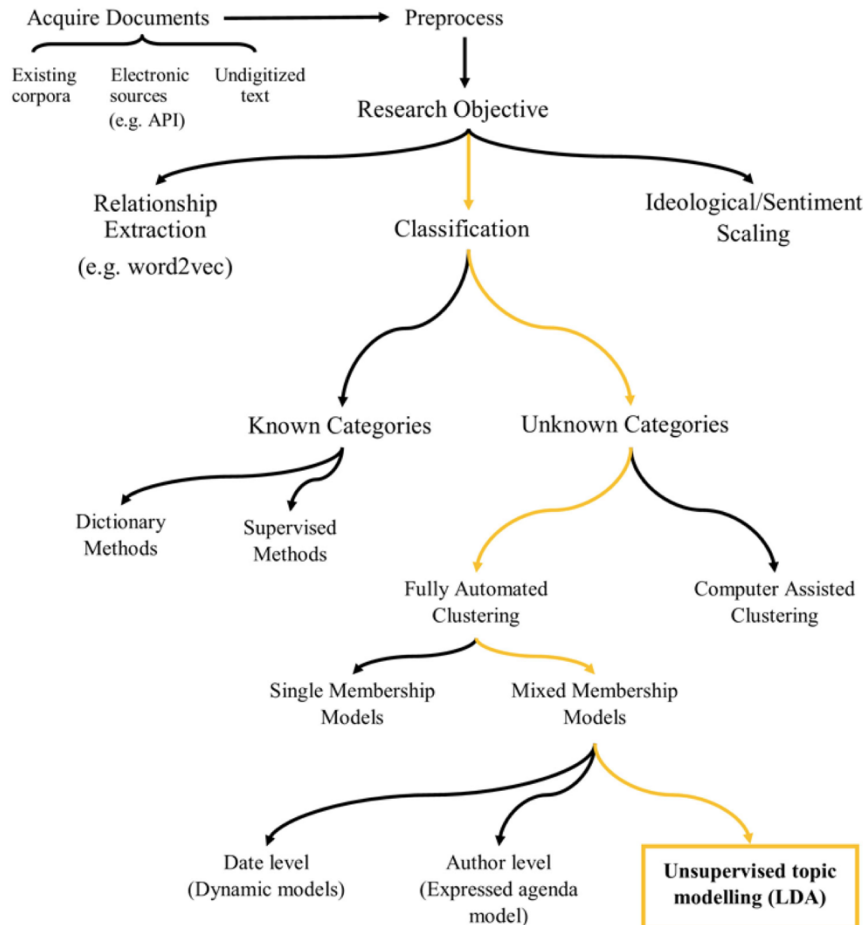
6.2 An introduction to topic modelling

Over the past two decades, text mining approaches have proliferated in social science research (Grimmer and Stewart 2013; Hopkins and King 2010). A primary benefit of text mining is the ability to scale up text analysis to sort and categorize large volumes of data that would otherwise require resource-intensive hand-coding (Jelodar et al. 2018; Quinn et al. 2010). Accordingly, it is particularly valuable in exploratory research, where little is known about a dataset, and researchers are interested in discovering unknown patterns or trends in the data or are seeking external validation of inductively determined categories. Recent advances in topic modelling also mean that this approach can also be used for research of a more deductive nature, supporting development of hypothesis-based models that use information such as document author, scale, location, or relationships between documents to understand topic results (Blei & Lafferty, 2006a; Chang & Blei, 2009; Mcauliffe & Blei, 2008; Rosen-Zvi, Griffiths, Steyvers, & Smyth, 2004; Yin, Cao, Han, Zhai, & Huang, 2011). Nevertheless, it remains essential that researchers externally validate the results of such models, including bringing subject matter expertise to bear on the substantive interpretation of model results (Grimmer and Stewart 2013).

At its most fundamental level, text mining extracts information about structures and patterns from large volumes of text, such as word frequency or correlation between words. This approach can be used for various applications (Figure 6.1). For example, common uses for text mining in social science research are the classification, clustering, and analysis of word patterns in texts (Bickel 2017), and the extraction of semantic meaning from text, for example with regards to the identification of sentiment or emotion (Onyimadu et al. 2013; Ravi and Ravi 2015; Cambria et al. 2013), the positions held by political parties or individuals on a given issue (Will

et al. 2011; Laver and Benoit 2003), or the evolution of document content over time (Allee, Elsig, and Lugg 2017; Wilkerson, Smith, and Stramp 2015) (see Grubert and Siders 2016 for a more extended review of text mining approaches in the environmental sciences).

Figure 6.1 Topic modelling as a text mining technique



Adapted from Grimmer and Stewart (2013)

Topic modelling deals with the problem of document classification using themes (i.e. topics) contained in each document (Figure 1). It produces a generative probabilistic model that relies on three analytical layers: i) a collection of documents for analysis, referred to as a corpus;

ii) the individual documents within the corpus; iii) and the individual words within each document. Essentially, the model assumes that a particular corpus contains some pre-existing set of topics, and that each document within the corpus contains some mix of these topics. Each topic has a set of words most strongly associated with that topic, which are identified based on the probability of co-occurrence between words.

The topic model will thus generate three observations: i) lists of words that are most important to a particular topic; ii) the topics that are most important to any particular document within a corpus; and iii) a set of topics that characterize an entire corpus. Topic models can be single-membership, where each document can belong to a single topic (Grimmer 2010; Quinn et al. 2010), or mixed-membership, where each document is assumed to be composed of multiple topics (Blei, Ng, and Jordan 2003). After the model identifies a set of topics in a corpus, researchers interpret and label these topics. For example, a collection of parliamentary speeches might contain words such as ‘hospital,’ ‘doctor,’ and ‘medicine,’ which a researcher might interpret as broadly related to health. Similarly, terms such as ‘emissions,’ ‘resources,’ and ‘green’ could be interpreted as concerning the environment. The topic model examines the frequency of co-occurrence between these words; the algorithm will then predict if a particular speech that discusses the public health implications of climate change has a high prevalence of both the health and environment topics, relative to words associated with other topics such as ‘economy,’ or ‘military.’

Several important assumptions underlie the most common types of topic models (e.g. latent Dirichlet analysis). First is the ‘bag-of-words’ assumption (BoW), which states simply that the order of words in a document is irrelevant, and language particularities such as syntax and grammar can be ignored. Essentially, this means that the model does not ascribe inherent meaning to words; rather, meaning is derived from the frequency of word appearance in

documents, and relative to other words within a single document. In processing a topic model, a simplified representation of a corpus is produced in the form of a word-document matrix, which specifies the frequency of each word over each document (Liu et al. 2016). In some cases, however, word order can be central to topic identification and interpretation; hierarchical topic modelling techniques have been developed to overcome the BoW assumptions, which assume that words within a topic are conditional on the previous word and use bigrams rather than unigrams (Wallach 2006). The extent to which the BoW assumption is appropriate to the topic modelling task in question is for researchers to consider when selecting a topic modelling algorithm (Blei 2012).

Second, all topic models assume that the number of topics (denoted by the letter k) is fixed, and derives this information based on instructions from the researcher about the number of topics to search for. Selecting k is a critical step in topic modelling and implies that while topic models are considered an unstructured form of machine learning, they still require input and interpretation from the researcher. In short, there is never any entirely automated topic model. Various techniques are available to assist in the selection of k . Strictly mathematical approaches to k selection calculate the log-likelihood of held-out training and testing documents and identify how well the model predicts topics in the test set. This approach is based on maximizing model fit, however, and has been shown to not necessarily correlate well with human judgment (Chang et al. 2009). Selecting the number of topics to run in a topic model therefore requires some level of researcher judgement and iteration. As guiding principles for model selection, Roberts et al. suggest that k identification should be guided by the *cohesiveness* of the topics (meaning that high-probability words co-occur within documents), and the *exclusivity* of the topics (meaning the likelihood that top words for each topic also appear in other topics) (Roberts et al. 2014).

There are a number of topic model algorithms available, and they make additional assumptions of which researchers need to be aware (Alghamdi 2015). In the examples described here, we apply a latent Dirichlet algorithm (LDA), which is one of the most commonly used topic models in the social sciences and available to new topic modelling users through various R packages, and an LDA variation called a robust latent Dirichlet algorithm (Jelodar et al. 2018; Liu et al. 2016; Grubert and Algee-Hewitt 2017; Goldstone and Underwood 2012; Mimno and David 2012; Wilkerson and Casas 2017). Our first example (COP speeches) uses the *Topic Models* R package (Grün and Hornik 2011), a LDA model explained by Blei et al. (Blei, Ng, and Jordan 2003). Our second example uses a robust latent Dirichlet allocation model (*rllda* package in Python), which builds on the LDA model by using a spectral clustering algorithm to identify K. The explanation for this approach can be found in Wilkerson and Casas’s study of United States Congressional floor speeches (Wilkerson and Casas 2017).

Similar to the BoW assumption, LDA makes an assumption that the order of documents in a corpus is irrelevant and all documents are independent from one another and non-hierarchical (Blei, Ng, and Jordan 2003). For simpler research questions this assumption may be appropriate, but in other cases it may not hold, for instance in longitudinal research where we would like to know how topic prevalence changes over time (Grubert 2018). For these cases, LDA has been adapted into various other algorithms that can perform different functions, such as taking into account sequences of distributions over topics. Dynamic topic models, for example, allow the researcher to identify documents by increments of time (e.g. years) and look longitudinally at how topics change over time (Blei and Lafferty 2006b). Correlated topic models examine the relationship between topics to show where the existence of one topic is correlated with the existence of another (Blei and Lafferty 2006a; Roberts et al. 2014). The appropriateness

of these models will vary depending on research questions of interest and document characteristics.

In preparing a corpus for analysis, the researcher must also deal with the various idiosyncrasies of document sets. Dissection of documents into document-term-matrices requires simplification of text, such as translation into the same language, removal of numbers, punctuation, and symbols, elimination of very common words (stopwords) with little substantive meaning (e.g. ‘it’, ‘and’, ‘or’, ‘he’, ‘she’) or very rare words, and stemming of similar words (e.g. stemming ‘adaptation’, ‘adaptive’, ‘adapting’ to ‘adapt’). These pre-processing steps aim to balance simplification of the complexity inherent to textual data with interpretability, and have implications for the results generated from a topic model (de Vries, Schoonvelde, and Schumacher 2018; Denny and Spirling 2018). As such it is critical that the researcher be aware of how the pre-processing stage can affect their results. The following section details the pre-processing steps taken in the two examples presented here.

6.3 Implementing an LDA model

Language is highly complex and requires simplification for algorithmic analysis. Generating an output from a topic model requires several steps, including i) data collection, ii) document pre-processing, iii) corpus processing, and iv) interpretation (see Table 6.1 for a summary of steps). Here we provide an overview of these steps (see Appendix C for additional details).

Table 6.1 Summary of approach

Stage	Steps	Case 1: COP speeches	Case 2: Canadian local government records
1. Model selection	<i>1. Specify research question</i>	How do country leaders talk about adaptation within the UNFCCC process?	How is adaptation being approached among local governments in Canada?
2. Data collection	<i>2. Select algorithm</i>	LDA	Robust LDA
	<i>3. Identify data source</i>	UNFCCC website	City Council online archives
	<i>4. Document type</i>	Speech	Council minutes, staff reports, strategic planning documents, by-laws
3. Pre-processing	<i>5. Format</i>	Machine-readable PDFs, scanned text	Machine-readable PDFs, scanned text
	<i>6. Language</i>	English, Spanish, French, Arabic, Russian	English, French
	<i>7. Translation (to English)</i>	Tesseract engine and Google Translate	Google Translate
	<i>8. Text extraction</i>	Selection of thirty words surrounding any mention of ‘adapt*’	200-word window surrounding terms inductively identified as relevant to adaptation
	<i>9. Stemming</i>	Yes	No
	<i>10. Stopwords removal</i>	SMART stopwords, plus additional corpus-specific words identified by reviewing top features	SMART stopwords, plus additional corpus-specific words identified by reviewing top features
	<i>11. Additional character removal</i>	Punctuation, separators, numbers and symbols were removed	Punctuation, separators, numbers and symbols were removed
4. Processing	<i>11. Method of selecting K</i>	Perplexity used to guide selection of categories with most semantic coherence; K= 25	Spectral Clustering; K=20-40
5. Interpretation	<i>12. Meta-topic aggregation</i>	Not applicable	Based on Wilkerson and Casas 2017
	<i>13. Topic labels</i>	Based on discussion by research team	Based on discussion by research team

6.3.1 Data collection

A topic model requires a large corpus of documentation to produce robust results, often on the order of thousands or even millions of texts; where documents are very short or very few in number then LDA will often not perform well (Tang et al. 2014). Where there are many very small documents (e.g. tweets), documents can be grouped by author (Hong and Davison 2010) or conversation (Alvarez-Melis and Saveski 2016) to generate larger documents. A variety of tools, such as application programming interfaces (APIs) or pre-existing databases like digitized parliamentary records, can support researchers in identifying and downloading large volumes of data. Web-scraping tools can also be implemented to construct unique databases of texts. With adaptation policy now widely being adopted into climate change policy agendas, there has been a rapid growth in text available through online archives that may be appropriate for thematic analysis via topic modelling.

In this Focus Article, two types of data are used: i) speeches made by country representatives to the Conference of Parties (COP) of the United Nations Framework Convention on Climate Change (UNFCCC) covering the period from 2010 (COP16 in Cancun) to 2016 (COP22 in Marrakech) (document number=1,315); and ii) city council meeting records with containing references to climate change in Canada's largest 25 cities for the period from January 2010 to May 2017 (document number=1,814). Once these documents were manually collected from online archives, they were streamlined into identical formatting that can be read by a computer (text file format).

6.3.2 Data pre-processing

The texts used in both the examples here include multiple languages and both machine-readable and not machine-readable documents (i.e. non-searchable PDFs). Here, we processed the documents into a readable format using R.

Data pre-processing: COP speeches

In the case of the COP speeches example, translation of non-English texts was completed at this stage using built-in translation capabilities for French and Spanish in the *Tesseract* package in R, and manual translation using Google's Neural Machine Translation for other languages (e.g. Arabic, Russian). COP speeches include both mitigation and adaptation content, so to isolate adaptation content for the topic modelling analysis only the 30 words surrounding each reference to 'adapt*' were extracted from the speeches to create the COP speech corpus.

Data pre-processing: Canadian local government records

The Canadian local government documents contained two added layers of pre-processing complexity. First, it became apparent that the in-text language was more varied than in the COP speeches. Second, in addition to climate change, these documents contained references to a whole range of issues and policies being considered by local governments, resulting in sometimes enormous documents (e.g. pages $\geq$ 200). We therefore had to isolate adaptation-relevant text from a highly diverse range of content. To address these issues, two of the authors manually identified a list of all adaptation-relevant keywords from within the texts and selected the 400 words surrounding each of these terms to generate the corpus (keywords: adapt*, risk*, protect*, vulnerab*, emergenc*, security, resilien*, recover*, prevent*, hazard*, prepar*, disaster*, impact*, mitigate).

Data pre-processing: Final corpus preparation (both datasets)

The final step was cleaning both corpuses of stopwords. This involves removing words and punctuation symbols with no substantive information (e.g. 'the', 'and', and 'or') to improve topic coherence and reduce computational time (Hoffmann, Bach, and Blei 2010; Boyd-Graber

and Blei 2009). The most frequently occurring features of the remaining corpuses were then inspected, and additional stopwords specific to that corpus were identified and removed (e.g. formalities such as ‘madame’, ‘gentlemen’, place names, boilerplate terms, procedural terms) (Benoit, Muhr, and Watanabe 2017; Lewis et al. 2004). We observed fewer cases of multiple tenses in the local government corpus as compared to the COP corpus, and so opted not to stem the vocabulary in this model. It is worth noting that there is an ongoing debate regarding the impacts of stemming on model results, with some studies suggesting that stemming can negatively impact topic coherence (Schofield and Mimno 2016). The final size of each corpus was 3,069 unique words for the COP speeches, and 21,243 words for the local government documents.

6.3.3 Processing

After pre-processing the texts but before running the models, the researcher must still provide instructions to the algorithm with regards to one key feature: the number of topics (referred to as ‘ k ’) to be generated. To some extent the choice of how to determine k reflects the aim of the research question itself, whether it is to classify documents into known categories or to conduct exploratory research. A purely inductive approach to selecting k relies on statistical estimates (perplexity) of topic stability to tell the researcher which model output is most stable. Recall, however, that LDA does not associate semantic meanings with words, so the number of topics chosen by purely quantitative methods may not always generate the most coherent output from perspective of the researcher (Chang et al. 2009). Social scientists therefore tend to follow a ‘middle-ground’ approach to k -selection that combines statistical estimates of topic stability with expert judgement about the interpretability of results with regards to the cohesiveness and distinctiveness of topics (Blei, 2012; Roberts et al., 2014). In the case of adaptation, where debate about the relationships between different concepts like resilience, adaptive capacity, and

vulnerability is ongoing, this middle-ground approach also seems likely to provide the greatest likelihood of generating meaningful results. K -selection has important implications for establishing the conceptual validity of topic model outputs, an issue we return to later in the discussion.

K -selection: COP speeches

In the case of the COP speeches example, perplexity was measured at a range of k -values between $k = \{5, 100\}$ to determine an initial range of suitable k -values. The final selection of model parameters followed an inductive analysis of the coherence of the outputs generated from each k value; $k = 25$ was identified as having the most coherent model output. This approach reflects the exploratory nature of this example, wherein the model is intended to provide an overview of major themes that emerge in COP speeches. Subsequently, the research team calculated the most commonly occurring topics by country and by year using posterior probabilities for each topic in a document.

K -selection: Canadian local government records

For the Canadian local government example, the robust LDA model was used (rlda) (Wilkerson and Casas 2017). Using the Python package *rlda*, a set of topic models was generated for $k = \{20, 21, \dots, 40\}$, for a total of 21 models containing 630 topics. Model stability was then approximated using pairwise cosine similarity, which uses a clustering algorithm to group the 630 topics generated across all models by similarity. This process identified a stable model output of approximately 30 topics.

6.3.4 Interpretation

Even exploratory analyses require the researcher to examine model output and interpret meaning from the word clusters identified. Robust interpretation of topic model results therefore

requires familiarity with the subject matter, and a strong understanding of texts used to create the corpus. Here, two researchers independently examined the model outputs from each example and assigned topic titles based on expert interpretation of the word clusters; together their interpretations were compared and discussed to resolve any differences.

6.4 Applying LDA topic models to climate change adaptation

6.4.1 Case 1: COP speeches (2010-2016)

The United Nations Framework Convention on Climate Change (UNFCCC) is a key site for the debate, establishment, and harmonization of global and national climate change policy (Gupta 2010). At the start of each annual UNFCCC Conference of Parties (COP), heads of state and government gather to make brief statements regarding their positions before negotiations begin. With almost all countries submitting a statement each year, these brief speeches give insight into national priorities and overarching discursive trends around climate change (Bagozzi, 2015; Ford & Maillet, 2016). This example looks at Party statements concerning adaptation from COP16 in 2010 to COP22 in 2016, with an interest in identifying trends by country and over time. We apply an LDA model to the corpus and analyze the overall results, probabilities of topic occurrence by year, and differences in topic occurrence between high-income countries (Annex I Parties) and medium- and low-income countries (non-Annex I Parties). It is worth noting that this approach differs from that taken by correlated topic models (e.g. structural topic models), which uses regression models to estimate the relationship between topic prevalence and specified co-variables (Roberts et al. 2014).

Twenty-five topics were generated by the model that represent five broad themes (see Table 6.2). The first theme is an emphasis on the governance architecture for adaptation (topics 1-9), including efforts under the UNFCCC process and national planning processes. Second is the urgent need to take action given the negative consequences of climate change (topics 10-12).

The third theme consists of intersections between adaptation and other policy goals, including sustainable development and mitigation (topics 13-18). Two additional themes are detected around implementation procedures, including support for capacity-building and project implementation (topics 19-22), and climate financing, including financing for African countries, payment into the Green Climate Fund, and addressing the issue of loss and damage (topics 22-25).

Table 6.2 Topics in COP speeches

Number	Topic	Terms
1	Paris Agreement	agreement, must, new, balac, element, pari, comprehens, legal, essenti, natur
2	Cooperation	climat, chang, impact, strengthen, import, cooper, ensur, activ, inform, becom
3	Adaptation framework	framework, committee, mechan, establish, cancun, institute, convent, work, made, durban
4	Global governance	chang, climat, govern, world, assist, ambit, just, promot, current, holistic
5	Leadership	prioriti, presid, remain, like, equal, given, import, resourc, already, impact
6	Party commitments	mitig, commit, financ, pari, order, period, presid, protocol, continu, activ
7	Enhanced action	action, includ, enhanc, implement, mean, program, provis, appropri, nation, assist
8	National planning	nation, plan, strategi, program, process, prepar, polici, adopt, integr, communic
9	Least developed countries	Countri, developedcountri, developingcountri, least, small, ldc, island, african, continu, espec
10	Negative climate change impacts	climat, chang, effect, impact, advers, limit, negat, approach, resourc, convent
11	Need to act	need, mitig, urgent, countri, strong, already, financi, cooper, futur, appropri
12	Risk and vulnerability	vulner, particular, challeng, level, increas, risk, requir, high, extrem, take
13	Sustainable development	develop, sustain, low, econom, achiev, economi, goal, carbon, includ, object
14	Mitigation action	mitig, action, climate, key, intern, achiev, balanc, unfccc, govern, carbon

15	Mitigation effort	global, effort, mitig, contribut, necessari, activ, part, implement, climat, relat
16	Emissions reduction	Emiss, climat, measur, reduc, reduct, effort, greenhous, help, includ, aim
17	Community resilience	mitig, respons, increas, resili, ensur, address, communiti, common, need, capabl
18	Food-water-energy	sector, agricultur, measur, energi, water, initi, secur, food, manag, strengthen
19	Technical and financial support	support, financi, resourc, adequ, mitig, access, call, technic, direct, area
20	Technical capacity	technolog, capac, build, financ, transfer, transpar, enabl, share, forward, join
21	Project implementation	implement, project, import, term, long, mean, ensur, programm, mitig, includ
22	Developing country support	countri, support, developingcountri, provid, enabl, project, clean, first, major, requir
23	Climate finance for Africa	financ, year, africa, addit, billion, cost, toward, million, alloc, start
24	Loss and damage	loss, address, damag, issu, intern, work, time, target, mani, critic
25	Green Climate Fund	fund, green, mechan, contribut, decis, howev, predict, one, special, must

Mean topic probabilities were analyzed by year and by country development status. The yearly results provide intuitive validation of the coherence of the categories (Table 6.3). Overall, we detect a shift between 2010 and 2016 from an emphasis on technical and financial support for least developed countries, to an emphasis on the governance of adaptation at global and national levels. Indeed, COP16-18 were important for the elaboration of the Cancun Adaptation Framework, including enhanced action and cooperation on adaptation and the set-up of the Green Climate Fund, and the establishment of a process for supporting national adaptation planning in least developed country Parties (Schipper 2006; Hall and Persson 2018). In the run-up to the adoption of the Paris Agreement at COP21 we see a move towards emphasizing governance aspects of the UNFCCC process, including intersections with other issue areas like

mitigation and sustainable development. A focus on technical capacity is still apparent but is no longer a dominant topic emerging from the model.

Table 6.3 Probability of topic occurrence by COP event

	COP16 (2010)	COP17 (2011)	COP18 (2012)	COP19 (2013)	COP20 (2014)	COP21 (2015)	COP22 (2016)
1	Adaptation framework (.044)	Adaptation framework (.045)	National planning (.043)	National planning (.043)	National planning (.046)	Paris Agreement (.043)	National planning (.046)
2	Technical capacity (.043)	National planning (.043)	Negative climate change impacts (.043)	Global governance (.042)	Technical capacity (.043)	Negative climate change impacts (.043)	Food-water-energy (.044)
3	Technical and financial support (.041)	Technical capacity (.042)	Developing country support (.042)	Cooperation (.041)	Paris Agreement (.043)	Mitigation (.042)	Sustainable development (.042)
4	Developing country support (.041)	Developing country support (.042)	Technical capacity (.042)	Climate finance for Africa (.041)	Mitigation (.041)	Sustainable development (.042)	Global governance (.042)
5	Enhanced action (.04)	Least developed countries (.041)	Least developed countries (.041)	Adaptation framework (.041)	Global governance (.041)	Least developed countries (.041)	Technical capacity (.042)

Separate examination of the most commonly occurring topic per country for the middle and low-income country block (non-Annex I Parties, n = 155) and the high-income country block (Annex I Parties, n = 42) reveal further insights into these patterns that broadly echo themes found in hand-coded analyses of UNFCCC decision texts (Figure 6.2) (Ford et al. 2016). While non-Annex I Parties tend to focus on national adaptation planning and technical capacity in COP speeches, Annex I Parties are emphasizing climate financing and intersections with mitigation efforts. This is consistent with the polluter pays principle underlying the UNFCCC's approach to adaptation, with developing countries prioritizing national adaptation planning and

Annex I Parties (who carry greater mitigation responsibilities) providing the technical and financial support for those efforts.

Figure 6.2 Topics by country development status

Figure 6.2a Most likely topic (Non-Annex I Parties)

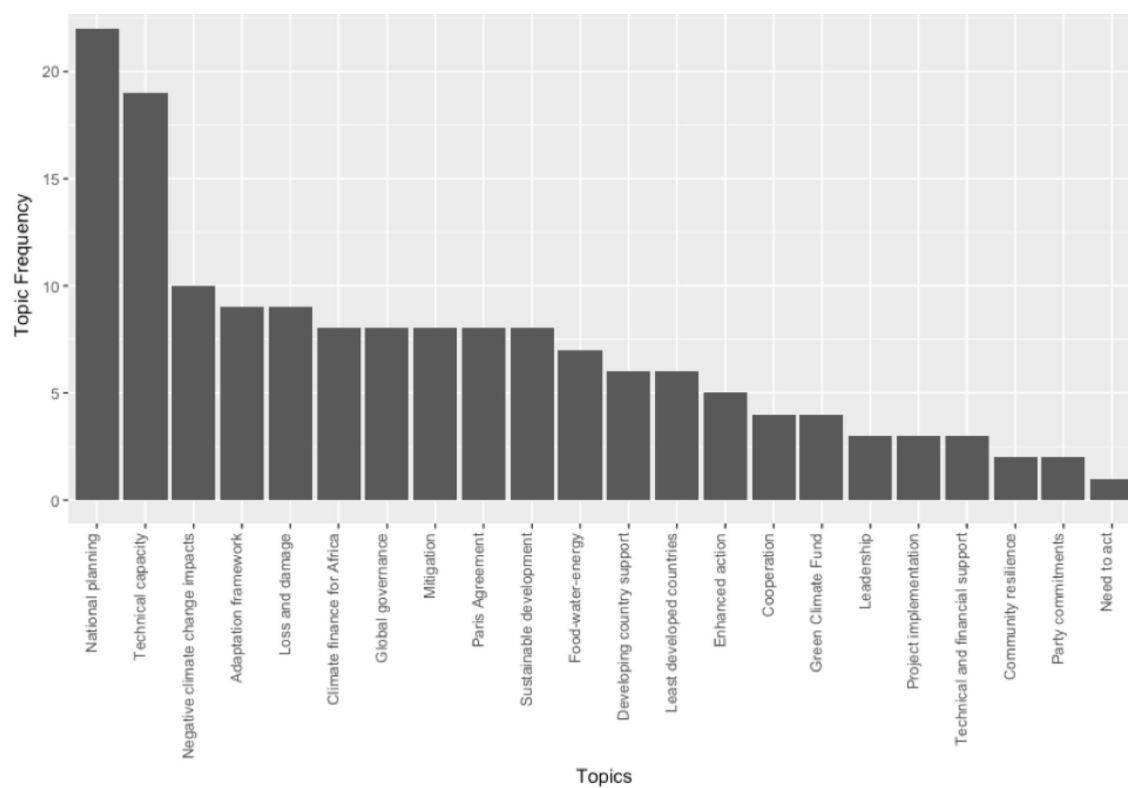
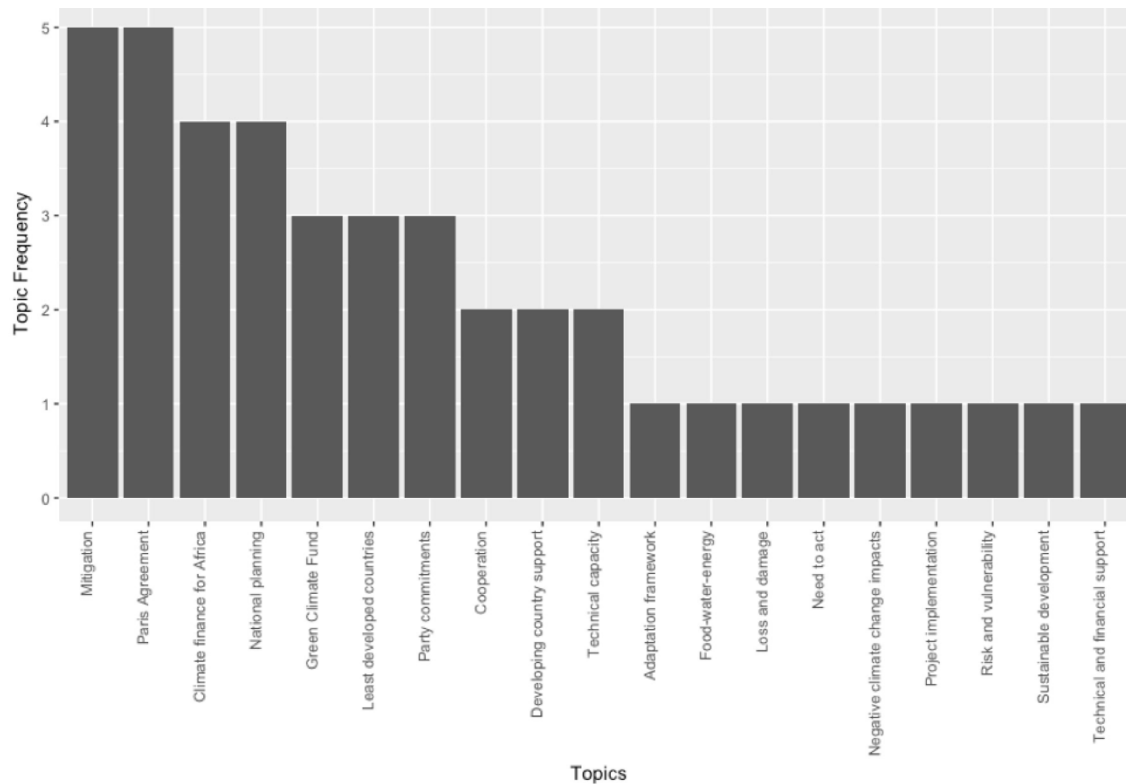


Figure 6.2b Most likely topic (Annex I Parties)



6.4.2 Case 2: Adaptation policy in 25 Canadian cities (2010-2017)

Local governments are considered key sites for adaptation policy development and implementation (Nalau, Preston, and Maloney 2015). A growing body of research is focusing on emerging patterns of policy adoption among local governments with the goal of understanding how decision-makers are integrating adaptation considerations in local operations, plans, and services (Castán Broto & Bulkeley, 2013; Hughes, 2015; Mees, 2017; Shi, Chu, & Debats, 2015; Swart et al., 2014). This case examines topics pertaining to adaptation in 25 Canadian local governments using records from city council meetings between 2010 and May 2017. It demonstrates how topic modelling can be used to get a sense of key adaptation issues facing governments, and broadly how local governments are approaching adaptation as policy issue. We apply a robust LDA model to the corpus to identify a suitable K.

We interpret five overarching themes from the topics generated by the model, which indicate that adaptation in Canadian cities is largely being considered from the perspective of the built environment (see Table 6.4). The largest discernible theme in topics is around land use management (topics 1-8), which concerns zoning, area planning, and project development, strategic planning around key sectors, and neighbourhood conservation. Several topics are also concerned with public works, including freshwater and wastewater management, waste management, and grey infrastructure (topics 13-16). While about half of the topics identified by the model center around hard infrastructure, several other topics are related to urban greening, including ecological areas, environmental assessment, and the urban forest (topics 23-25). The remaining topics capture a series of substantive issues for local governments that intersect with adaptation, including local resources, transportation, flood protection, mitigation, and local food systems (topics 17-20, 22).

Figure 6.3 Topics by Canadian local government records

Number	Topic	Terms
1	Subdivision	plan, owner, subdivision, satisfaction, draft, engineer, road, lands, development, design, construction, sanitary, prior, lots, required
2	Site development	residential, site, development, street, density, building, zoning, plan, area, zone, planning, lands, commercial, planner, design
3	Project planning	project, planning, development, street, building, company, district, plan, area, amount, services, construction, integration, prepared, site
4	Land use planning	plan, area, lands, development, land, uses, planning, industrial, site, areas, official, growth, planner, natural, commercial
5	Re-zoning	development, site, rezoning, building, district, housing, plan, community, application, zoning, street, residential, planning, centre, engineering
6	Urban growth planning	plan, community, development, strategy, management, growth, environmental, transportation, land, infrastructure, planning, economic, sustainability, sustainable, services
7	Strategic planning	energy, water, food, river, waste, climate, community, flood, services, downtown, transit, plan, risk, health, street
8	Heritage protection	heritage, conservation, district, building, plan, street, property, guidelines, original, cultural, village, south, old, wortley, buildings

9	Legal and records services	law, services, street, community, information, road, planning, development, file, plan, avenue, solicitor, part, act, property
10	Community services	services, corporate, community, management, environmental, law, service, 'business, risk, fire, safety, back, protective, parks, park
11	Financial resources	budget, capital, million, services, funding, service, year, management, cost, operating, financial, asset, fund, water, infrastructure
12	Health and safety	health, services, prevention, unit, planning, community, care, safety, fire, team, housing, middlesex, healthy, ace, lake
13	Freshwater management	water, drinking, system, stormwater, wastewater, sewer, management, quality, treatment, lake, systems, act, infrastructure, environment, response
14	Waste management	waste, landfill, resource, recovery, diversion, recycling, environmental, solid, gas, management, collection, garbage, disposal, environment, materials
15	Wastewater management	stormwater, water, sewer, management, storm, system, treatment, wastewater, infrastructure, flooding, sanitary, green, control, engineering, property
16	Grey infrastructure	dike, area, road, protection, management, island, phase, river, existing, ecological, land, strategy, lands, infrastructure, park municipalities, infrastructure, funding, communities, housing, national, standing, development, provincial, forum, local, safety, provided, update, issues
17	Local resources	transit, downtown, transportation, street, cycling, design, parking, pedestrian, road, rapid, project, plan, service, traffic, bridge
18	Transportation	river, flood, thames, dike, mitigation, dam, assessment, protection, area, lake, flooding, measures, property, level, project
19	Flood protection	energy, emissions, climate, community, gas, carbon, ghg, greenhouse, plan, corporate, change, reduction, local, green, sustainability
20	Mitigation	climate, change, adaptation, risk, weather, impacts, flood, heat, extreme, dike, events, mitigation, strategy, health, increased food, local, system, community, agriculture, agricultural, urban, production, health, security, farm, strategy, land, flood, governments
21	Impacts and adaptation	natural, areas, ecological, river, species, eis, dike, area, habitat, study, environmental, management, heritage, features, flood environmental, study, project, river, engineering, stormwater, thames, creek, works, assessment, plan, process, water, flood, design
22	Local food systems	trees, tree, urban, forest, species, strategy, planting, 'canopy', 'invasive', 'cover', 'forests', 'management', 'green', 'ace', 'forestry']
23	Ecological areas	
24	Environmental assessment	
25	Urban forest	

The topics reflect the high visibility of flood risk management in local Canadian adaptation planning (Thistlethwaite and Henstra 2017; Henstra et al. 2019); ‘flood’ appears in topics 7, 15, 19, and 21-24. Topics 13 (‘freshwater management’) and 16 (‘grey infrastructure’) can also be interpreted as related to flood risk management. Topic 21 (‘impacts and adaptation’) suggests that municipalities are concerned about heat risk in a changing climate, but this seems disconnected from the ‘health and safety’ topic that is composed of words relating to community health services and emergency services.

We draw four observations from these topic interpretations. First, climate change adaptation approaches among local governments seem to be embedded in local regulatory tools related to land use decision-making and public works projects. Second, Canadian municipalities seem to be primarily concerned about risks from extreme events, particularly flooding but also extreme heat. Third, the relative balance of topics indicate that adaptation is more often linked with ‘hard’ aspects of the built environment like infrastructure, buildings, and public works (topics 1-5, 7-8, 11, 13-19, 21, 24), with only two topics composed of terms related to green infrastructure (topics 23 and 25). Finally, these topics suggest that local adaptation in Canada is being framed as an issue of vulnerability to climate change risks, and a planning issue connected to activities like land use management, services provision, and environmental assessment (Juhola, Keskitalo, and Westerhoff 2011). It is worth noting that the presence of mitigation and transportation categories suggests that the decision to take a larger selection of words around the adaptation keywords that were used to generate the corpus (see section 3.2.2 for detailed description) also captured mitigation content; further narrowing of the text might have generate somewhat different topic outputs.

6.5 What does topic modelling offer adaptation governance research?

The aim of this Focus Article is to provide an overview of topic modelling and its uses, and discuss potential applications for the study of adaptation governance. The two cases illustrated here are intended to be interpreted only in an exploratory light, and demonstrate the range of document sources that can be used in topic models and how different types of insights can be drawn from these various sources. The examples demonstrate two approaches to dealing with a key methodological debate in topic modelling, namely how to optimize model performance by selecting an appropriate number of topics around which the algorithm builds its output: a partial inductive approach typical of LDA applications in the social sciences (COP speeches), and a spectral clustering technique for grouping topics of a similar nature used in the robust LDA model (Canadian local government documents).

There are several important takeaways for adaptation governance researchers considering the use of topic models in their research. First, topic models are never an entirely automated affair. Model outputs require interpretation by researchers, and validity of results must be assessed based on clear criteria. Chuang et al., for example, offer several suggestions as a general guideline for establishing model validity, including use of multiple models to determine model consistency and measuring topic similarity (Chuang et al. 2015). Several existing topic modelling packages include features for estimating model robustness, such as the *stm* package in R for structural topic modelling, which helps to simplify this interpretive process (Roberts et al. 2014).

Second, decisions made in pre-processing are critical to the interpretability of model results (Denny and Spirling 2018). Determining whether removal of stopwords, stemming, and language translation will impact the validity of results are important steps in the process of implementing topic modelling. Here we provide only a limited introduction to pre-processing

considerations, but there is a growing empirical literature testing the implications of various pre-processing decisions for model robustness.

Third, topic modelling can be used alone as an exploratory or hypothesis-testing technique, but it can also be used to strengthen the validity of manual coding protocols, and to inform the identification of future research questions (Potter and Levine-Donnerstein 1999). For example, the model results discussed here offer several interesting directions for qualitative research projects: 1) How are issues around technical capacity and financial support for non-Annex I States being treated under the emerging global governance framework emerging from the Paris Agreement? Are we seeing a shift in how States are addressing these gaps in light of this emphasis on global climate change governance? 2) To what extent is there coherence between national adaptation planning efforts in non-Annex I Parties and emerging climate finance plans from Annex I Parties? 3) How do regulatory powers around land use and development affect the scope of adaptation responses to key vulnerabilities in Canadian municipalities? 4) To what extent are local governments in Canada adopting ‘soft’ approaches to flood risk management, or do they continue to rely on more traditional grey infrastructure approaches?

We suggest four key ways that topic modelling might inform adaptation governance research in the future. First, topic modelling can be used to analyze framing and issue salience. Frames are key components of decision-making processes because problem detection and definition shape how actors think about adaptation and what kind of responses they propose (Dewulf 2013). These frames are often implicit, however, and not easy to identify. Topic modelling can be used for inductively detecting frames embedded within the latent structure of policy documents, with the added advantage of reducing potential bias from the application of *a priori* frame definitions that may not translate easily across contexts. This type of frame analysis

can also be triangulated with more fine-grained studies of policy adoption to advance understandings of how framing is related to motivations behind policy and financing decisions. Incorporation of a longitudinal perspective using dynamic topic models can also shed light on how the framing of adaptation is changing over time.

Second, expanding our ability to parse latent adaptation content across larger volumes of text also offers a new approach to the study of adaptation policy integration (Candel and Biesbroek 2016; Massey et al. 2015; Schmidt and Fleig 2018). Identifying keyword similarities in policy documents across jurisdictions, administrative units, or organizations can be used to examine the climate change concerns of politicians and decision-makers and shed light on coherence of ideas, issues, and approaches across sectors and scales. Similarly, it can also inform our understanding of how adaptation is distinct from related policy areas (Runhaar et al. 2017; Roeck, Orbie, and Delputte 2018).

Third, policy document analyses can be used for evaluative research by connecting thematic patterns generated by topic models with global climate model projections or climate impact assessments that identify key vulnerable sectors or regions. This type of analysis can inform us about the extent to which there is alignment between the projected environmental risk and the focus or concerns of decision-makers. These evaluative questions are highly pertinent in more applied areas of adaptation governance research, which aim to determine whether current adaptation efforts are aligned with priorities for vulnerability reduction.

Finally, here we presented exploratory examples of the LDA model, but application of correlated topic models that look for covariance between topics can be used for hypothesis testing studies. In the absence of large data-sets on adaptation policies and processes, descriptive and causal research has been largely limited to case studies or small-n comparisons. Topic

modelling would enable larger hypothesis testing studies that use document identifiers determined by the researcher to test relationships between the content of texts and variables like institutional structure, development status, political culture, or environmental exposure.

6.6 Conclusion

The efficiency gains that come with topic modelling represent an opportunity for adaptation governance research to engage with large-n comparative research. With rapid technical progress being made in the social sciences around the application of topic models, this approach will be an important tool for making sense of the growing volume of qualitative information available for research and policy purposes. Harnessing opportunities to use quantitative text approaches like topic modelling for adaptation research will require competency-building among researchers in the adaptation community, and deeper collaboration with quantitative social scientists already applying these techniques in their research. We argue that the chance to scale-up text-based analysis is well-worth the effort and will open new methodological horizons for adaptation research that have been previously underexplored.

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Preface to Chapter 7

This chapter addresses the third research question of the thesis: how is adaptation being framed as a policy issue by local governments and what does this indicate about emerging policy approaches? It examines how adaptation is being formalized within local policy agendas by using Structural Topic Modelling to identify adaptation policy frames, and discusses what these frames signal about underlying beliefs and perceptions about adaptation as a local policy issue. Building on Chapters 4 and 5, this chapter finds variation across country context in emerging local approaches to climate change adaptation.

This chapter is currently being prepared for submission to *Nature Climate Change*.

Chapter 7: Climate change adaptation policy framing among local governments

Abstract

Adaptation policy research suggests that differences in policy framing have implications for how adaptation policy goals are articulated, the strategies that local governments adopt to achieve these goals, and challenges that arise in policy implementing. Divergence in policy framing and issue prioritization reflect disagreements over the nature of adaptation as a societal and policy problem, and are regarded as key challenges for the design of coherent adaptation policy approaches. Conversely, the literature proposes that convergence in framing and issue prioritization are more likely to lead to coherent policy adoption. This study examines how adaptation is being formalized within local policy agendas by identifying adaptation policy frames and interpreting what they signal about underlying beliefs and perceptions about the nature of climate change vulnerability as a public policy issue. It uses Structural Topic Modelling to examine 1,820 policy documents retrieved from the city council archives of 125 local governments across five countries (Canada, France, Germany, Netherlands, the United Kingdom) in what is one of the first large comparative studies about policy framing to use computational text analysis techniques. We observe variations in policy framing across countries, which suggests that local governments are taking different approaches to adaptation across countries.

7.1 Introduction

Evidence that our climate is changing due to rising greenhouse gas emissions has significantly increased the importance and visibility of adaptation over the past decade. Governments are committing to develop adaptation policy frameworks, and are beginning to implement various measures to achieve targets and policy goals (Reckien et al. 2018; Hsu, Weinfurter, and Xu 2017). Much of this empirical work is concerned with policy changes taking place among local governments, which are commonly perceived to be primary drivers of policy innovation around adaptation (Nalau, Preston, and Maloney 2015). A growing body of research is focused on explaining the policy outputs of local adaptation decision-making processes, including how different ideas about the nature of adaptation as a policy problem shape policy design and implementation (Vogel and Henstra 2015).

Here we examine the overarching ideas held by policy-makers about the nature of adaptation as a policy problem and its possible solutions, and what these ideas indicate about how adaptation is being formalized in local policy agendas. Empirical adaptation research suggests that the acceptance by decision-makers of particular ideas about the causes and solutions of adaptation as a policy problem shapes how policy goals are articulated and has implications for policy implementation (Dupuis and Knoepfel 2013; Fünfgeld and McEvoy 2014; Romsdahl et al. 2017). Understanding how policy-makers define adaptation as a policy issue, including their interpretation of its causes and ideas about desirable solutions, is thus key to interpreting emerging policy approaches to climate change adaptation (Vink et al. 2013).

We aim to address two research questions. First, how is the idea of adaptation as a policy problem represented in local government policy documents? Second, is there variation in how adaptation is being represented across contexts? We employ topic modelling to examine 1,820 policy documents retrieved from the city council archives of 125 local governments in five

countries (Canada, France, Germany, Netherlands, and the United Kingdom). We first identify how adaptation is being described as a policy problem and the scope of its desired solutions, and then examine what variations in these ideas across country contexts signal about similarities and differences in the assumptions and underlying principles shaping the institutionalization of adaptation among these local governments. The following sections describe the theoretical framework and methodological approach guiding this research. Following this, we describe the findings from this study and their implications for how we understand the local policy approaches emerging across country contexts.

7.2 Ideas and policy frames in the context of climate change adaptation policy

The role of ideas in shaping climate change adaptation policy processes and outcomes has been widely considered from different perspectives in the climate change literature, including the relationship between and privileging of different forms of knowledge in decision-making processes (e.g. scientific knowledge and traditional Indigenous knowledge) (Casey and Thomas 2018; Ford, Maillet, et al. 2016), new forms of knowledge production such as co-production (Olazabal et al. 2018), and the interplay between knowledge and power in the negotiation of policy priorities and goals (Vink, Dewulf, and Termeer 2013). Within the adaptation policy literature more specifically, however, theoretical linkages between ideas and adaptation policy processes have largely been made through the lens of policy framing. A number of empirical papers that examine barriers in processes of local policy change note the influence of policy framing, particularly its role in building public support for policies by legitimating particularly approaches to adaptation policy design (Measham et al. 2011; Baker et al. 2012; Picketts, Déry, and Curry 2013; Wood, Hultquist, and Romsdahl 2014; Hoppe, van der Vegt, and Stegmaier 2016; Bahadur and Tanner 2014). The types of frames identified in this literature range from problem categories that are closely related to scientific debates on climate

change impacts, resilience, and vulnerability (Dupuis and Knoepfel 2013; Juhola, Keskitalo, and Westerhoff 2011; McEvoy, Fünfgeld, and Bosomworth 2013; Vogel and Henstra 2015; Fünfgeld and McEvoy 2014; Crabbé, Wiering, and Liefferink 2015; Romsdahl et al. 2017), to those that are concerned with how policy problems are structured with regards to time scale and uncertainty (Bisaro, Wolf, and Hinkel 2010; Hurlbert and Gupta 2016; Vink et al. 2013), and those that represent adaptation as a more general governance dilemma (Bosomworth 2015).

This literature has made an important contribution to the adaptation literature by emphasizing the importance of ideas and discursive processes in explaining the outcomes of policy decision-making processes. It shares a basic notion that frames represent substantive, overarching ideas about ‘what is and what ought to be,’ and influence how issues are talked about and understood (Bosomworth 2015). Within public policy processes, frames focus attention on certain issues and steer debate towards particular action strategies and away from others. They require the construction and representation of facts and events as actors try to make sense of policy problems from the perspective of particular ideational and organizational contexts or political agendas (McEvoy, Fünfgeld, and Bosomworth 2013; van Hulst and Yanow 2016). Frames are therefore fundamentally normative in nature because they imply subjective decisions about what constitutes the nature of an issue, and require actors to draw boundaries around a given policy problem in relation to other policy problems (Dewulf 2013; Hurlbert and Gupta 2016).

Under conditions of high uncertainty, such as that which characterizes climate change adaptation planning, framing processes are shown to play a critical role in encouraging collective action through the creation of shared norms, values, and meanings (Dewulf 2013; Duijn and van Buuren 2017; Dewulf and Biesbroek 2018). Dominant frames can become so institutionalized in organizational structures and routines that they acquire a ‘taken-for-granted’ status and shape

new ways of talking about and understanding issues (Schmidt 2008). These frames thus come to influence the specification of policy goals and the types of policy instruments that are used to achieve those goals (Hall 1993; Howlett and Cashore 2009). On the other hand, frames can also undermine efforts at policy change as they can become increasingly difficult to change over time “...where actors feel it costly to change knowledge, skills, past decisions, or relinquish hard-won outcomes” (Bosomworth 2015). Tensions or contradictions between frames can become a source of intractability in resolving policy problems (Schon and Rein 1994; Biesbroek, Termeer, et al. 2013); the addition of further information is not a solution in these situations, because frames imply no objective reality and actors can attribute different meanings to the same facts or observations (Dewulf 2013).

While the adaptation framing literature places ideas front and centre to theoretical explanations about the dynamics of policy change, the ability of this literature to deliver broader insights on the relationship between ideas, the institutional context from which they emerge, and the decisions that policy-makers take on how to deal with adaptation is limited on both theoretical and epistemological grounds. This limitation reflects two difficulties in the literature. First is a tendency to assume a linear relationship between policy frames and alternative adaptation approaches *a priori* based on scientific theories of resilience, vulnerability, transformative change, etc. Examples of this are found in linkages made between vulnerability-centred adaptation framing and structural approaches to addressing climate change risk, and resilience framing that emphasizes incremental risk management strategies, as well as more broadly in the literature on transformative change (Dupuis and Knoepfel 2013; O’Brien 2012). The assumption that particular conceptualizations of adaptation are associated with particular policy approaches, however, does not account for how institutional or political contexts filter the interpretation of these ideas in policy decisions. Furthermore, in an emerging policy area like

adaptation where conceptual meanings are vigorously debated and the terminology used by policy-makers is sometimes arbitrary and often influenced by political expediency (Keenan, King, and Willis 2016), the assumption that scientific understandings of what resilience or social vulnerability framing indicates for desirable policy responses parallel those found in policy discourses is problematic. Defining the relationship between conceptual ideas and policy approaches *a priori* may lead to bias in how frames are uncovered and interpreted, a challenge that goes largely uninterrogated in the adaptation framing literature. The interpretive challenge for analysis of the ideas underpinning adaptation policy changes is therefore to identify and attribute meaning to discourses within a conceptually unstructured field in which the language of policy-makers may not always be consistent with the language of science.

Second, the empirical study of adaptation policy framing primarily draws from the interpretive tradition in policy research that emphasizes case study and small-n comparative research designs over quantitative, comparative research designs. Recent work in the area of discursive institutionalism has argued that progress on understanding interactions between institutional context and ideational processes requires the systematic comparison of discourses across contexts through quantitative methods for text analysis (Wueest and Fossati 2015). Topic modelling has been proposed as a promising technique for frame detection in political research (Boräng et al. 2014; Nowlin 2016; Quinn et al. 2010; DiMaggio, Nag, and Blei 2013), and there is growing use of it to analyze framing in public debates about climate change denialism (Boussalis and Coan 2016), public opinion and preferences on climate change (Jiang et al. 2018; Tvinnereim et al. 2017; Cody et al. 2015; Lynam 2016; Tvinnereim and Fløttum 2015), climate change representation in the media (Büchi 2017; Cody et al. 2017; Elgesem, Steskal, and Diakopoulos 2015), and elite discourses around climate change (Bagozzi 2015; Benites-Lazaro, Giatti, and Giarolla 2018; Jun Hyun Ryoo and Bendle 2017). Here we apply this technique to

analyze how ideas about adaptation as a policy problem are represented in local government policy documents.

There are several advantages to using topic modelling for the analysis of ideas underpinning the logic of different approaches to adaptation policy design. First, it provides a middle ground between deductive and inductive approaches to identifying policy ideas. Topic modelling is inductive in nature but assumes that the ideas underlying texts are objectively identifiable using quantitative analysis of word frequencies and co-occurrences across texts. It thus does not call for *a priori* definition of frame categories, but still provides a systematic approach to analyzing the content of texts. In applying topic modelling to the study of policy ideas, we assume that the language of policy texts reflects how actors understand the urgency, nature, and boundaries of adaptation as a societal problem. Second, the rapid increase in volume of textual data available online is providing novel opportunities to expand methodological approaches to discursive analyses. Topic modelling dramatically increases the analytical capacity of discursive research when compared to manual analysis of textual data, therefore supporting comparative research on policy ideas at a much larger scale than what has been done to-date in the adaptation literature (Lesnikowski et al. 2019).

While topic modelling is typically classified as an automatic content analysis technique (Grimmer and Stewart 2013), the topics that are generated by the model still require careful interpretation by the researcher based on clearly defined research questions (Grubert and Siders 2016). The analytical approach used here draws on the adaptation policy framing literature to interpret topics as the underlying ideas about adaptation policy that represent normative and cognitive beliefs about adaptation (Campbell 2002; Wueest and Fossati 2015; Kangas, Niemela, and Varjonen 2014). Specifically, we understand policy frames as “diagnostic/prescriptive stories that tell, within a given issue terrain, what needs fixing and how it might be fixed” (Rein

and Schon 1996, p 89). Schon and Rein's approach to policy-making sees frames as narrative devices that help actors make sense of complex and often vague situations, and imply certain types of solutions (Rein and Schon 1996). This perspective is also prevalent in the literature on framing and social movements, where Benford and Snow argue that all frames can be characterized by three functions: diagnosis, prognosis, and action mobilization (Benford and Snow 2000). These functions speak to how frames influence perceptions about who and what bears responsibility for a policy issue (diagnosis), propose solutions for resolving issues (prognosis), and formulate a call to action for change (mobilization). Our analysis differs from frame analysis in one important way, however. Given our use of automated quantitative text analysis in this study, we focus on understanding only the substantive content of the ideas that underlie adaptation policy discourses, and set aside questions about the interactive processes by which ideas emerge, succeed, or fail for future research (V. A. Schmidt 2008; Dewulf et al. 2009).

We interpret the topics that emerge from our model based on two fundamental 'tasks' that frames perform: i) problem diagnosis, and ii) problem prognosis (Benford and Snow 2000). Our interpretation of problem prognosis pays particular attention to two attributes of adaptation policies: i) openness, meaning the extent to which adaptation is framed as a distinctive, stand-alone issue or as an inter-sectoral issue, and ii) geographical scale, meaning whether adaptation is framed as a challenge for local, regional, national, or global governance.

7.3 Methods

Data were collected from web searches of city council meeting archives held between January 2010 and May 2017 for the largest 25 local governments in Canada, France, Germany, Netherlands, and the United Kingdom (n = 125 local governments). Using the key term 'climate change,' we identified policy documents with explicit mentions of climate change and selected

those documents with adaptation-relevant content. A total of 1,820 policy documents were retrieved from 125 local governments, including council meeting minutes, policy strategies, local bylaws and regulations, and background reports. These policy documents pertain to all council business conducted at each meeting and so have content relating to a wide variety of local issues; to eliminate irrelevant content to the research questions at hand we selected only text surrounding the term ‘adapt*’ for analysis. Non-English documents were translated into English using Google’s Cloud Translator API, which has been found to be robust in translating texts for topic modelling uses (de Vries, Schoonvelde, and Schumacher 2018; Reber 2018). All documents were then combined into a single corpus of documents (see Appendix D for additional information).

To conduct the analysis, we use structural topic modelling (STM), a mixed-membership topic modelling technique that allows researchers to discover latent topics in texts based on word co-occurrences across a bundle of documents called a ‘corpus’ (Roberts et al. 2014). In mixed-membership models each document is assumed to be composed of some mix of topics, and individual words can belong to multiple topics (Blei, Ng, and Jordan 2003). Each topic has a set of words most strongly associated with that topic, which are identified based on probability of co-occurrence. STM was selected because it permits the introduction of meta-data at the document level to better understanding patterns in topic prevalence across document attributes. Here we introduce one meta variable, country, to examine whether local policy frames vary between country contexts. All analyses are conducted in RStudio using the *stm* package (Roberts, Stewart, and Tingley 2018).

The STM algorithm makes several important assumptions that have implications for how models are run and interpreted. First, it assumes that the order of words in a document is irrelevant, such that grammar and syntax are ignored. Meaning is ascribed from the frequency of

word appearance in a document and relative to other words in a document. Second, the algorithm assumes that the number of topics is fixed (denoted with k) and requires that this number be specified *a priori*. Following Roberts et al., we determine this number based on evaluation of the *exclusivity* and *semantic coherence* of possible model configurations (Roberts, Stewart, and Airol di 2016). Exclusivity refers to models where words that are highly associated with one topic have low probability of being highly associated with another topic. Semantic coherence refers to the interpretability of a topics, meaning the ease with which researchers can make sense of each topic.

We run a series of models with $k = 10, 20, 30 \dots 100$ and determine that $k = 60$ gives the most robust model result based on exclusivity and semantic coherence (Appendix D).

Interpretations about the meaning of each topic are done by the researchers. These interpretations are drawn from two groups of words associated with each topic: the seven highest probability words associated with that topic, and the seven words most exclusively associated with that topic (called FREX words).

We analyze the models output based on topic prevalence to assess the relative importance of topics across all local governments and examine variations in topic prevalence by country.

Topic prevalence refers to how much of a document is associated with a given topic.

Calculations for variation in topic prevalence by country are conducted in the *stm* package.

Country identification is applied as a document-level covariate; by using generalized linear regression, document-topic proportions are allowed to vary based on these covariates (Roberts, Stewart, and Airol di 2016).

7.4 Results

7.4.1 Topic prevalence

We first examine the distribution of topics across the local policy documents contained in our corpus (Table 7.1). This is measured by the mean proportion of all documents that are composed of a particular topic. The distribution of topics is relatively flat across the corpus, with most topic proportions being between one and two percent. Topics were interpreted based on the highest seven most probable and FREX words, and topic titles were assigned based on this interpretation. For example, the most prevalent topic is interpreted as ‘Regional mitigation planning’ (Topic 3) and contains words such as ‘energy,’ ‘plan,’ ‘change,’ ‘emissions,’ and ‘territorial.’ This topic indicates that adaptation is frequently associated with greenhouse gas mitigation planning in our corpus. The second most prevalent topic is interpreted as ‘Climate change impacts’ (Topic 13), and contains words such as ‘effects,’ ‘increase,’ ‘temperature,’ and ‘vulnerability.’ Table 7.1 summarizes all relevant topics by their prevalence within the corpus.⁴

Table 7.1 Topic prevalence across corpus, interpretation, highly associated words, and words weighted by probability and exclusivity to each topic (FREX)

Topic	Prevalence	Interpretation	High probability words	FREX
3	3.20%	Regional mitigation planning	climate, energy, plan, change, emissions, territory, territorial	greenhouse, gas, territorial, ghg, angers, loire, métropole
13	2.70%	Climate change impacts	climate, change, adaptation, impacts, effects, will, increase	impacts, temperature, vulnerability, effects, mean, ipcc, ability
26	2.40%	Adaptation plan adoption	adaptation, plan, matter, printed, city, also, development	cdu, fairway, printed, hamburg, bonn, matter, applause

⁴ It is worth noting that because our corpus was built around references to adapt* within texts containing climate change content, our search strategy captured some content concerning adaptability of the built environment to the needs of particular population segments such as seniors and persons with disabilities (e.g. adaptable home design, adaptations to affordable housing units, funding for disability programs, elder care). We excluded these topics from Table 7.1 (n = 8).

39	2.40%	Urban adaptation measures	climate, adaptation, nuremberg, urban, measures, change, city	nuremberg, german, roadmap, weststadt, exwost, bavarian, nürnberg
41	2.30%	Carbon emissions reduction	climate, change, emissions, carbon, reduction, strategy, greenhouse	emissions, greenhouse, carbon, fife, gas, reducing, targets
31	2.30%	Local adaptation plans	action, plan, adaptation, climate, change, edinburgh, city	edinburgh, birmingham, croydon, scotland, scottish, adapts, organisations
10	2.00%	Traffic planning	transport, public, network, parking, traffic, modes, adapted	modes, parking, traffic, soft, pedestrian, bus, car
19	2.00%	Sustainable energy technology	development, energy, sustainable, carbon, renewable, low, change	coventry, low, carbon, technologies, core, renewable, resource
21	2.00%	Local procurement	amount, contract, adapted, procedure, market, contracts, public	contracts, procedure, contract, amount, lot, vat, excluding
49	2.00%	Preserving urban biodiversity	urban, spaces, biodiversity, development, green, change, natural	preservation, islands, spaces, biodiversity, fight, preserving, peri
33	2.00%	Future climate change outlook	climate, change, will, territory, adaptation, must, city	clermont, warming, ferrand, anticipate, phenomenon, tomorrow, summer
37	1.90%	Neighbourhood development projects	bordeaux, city, development, new, adapted, will, project	bordeaux, neighborhoods, wuhan, marseille, territories, inhabitants, amateur
42	1.90%	Strategic climate change framework	framework, change, climate, strategic, will, policy, impact	framework, equality, liverpool, strategic, implications, attached, budget
14	1.90%	Renewable energy	energy, renewable, mitigation, energies, action, consumption, adaptation	energies, renewable, airbus, consumption, energy, sobriety, mans
23	1.90%	Carbon-based energy	will, county, durham, climate, change, energy, carbon	county, durham, dcc, north, prepared, organisations, fuel
9	1.90%	Building adaptations	policy, change, climate, planning, development, adaptation, use	materials, policy, shading, nppf, cooling, guidance, reflect

52	1.80%	Climate protection concept	climate, protection, change, adaptation, concept, city, energy change, biodiversity, climate, historic, development, will, landscape	berlin, concept, step, protection, ruhr, topics, content
45	1.80%	Urban habitats	council, report, committee, city, adaptation, climate, meeting	historic, wildlife, aonb, habitats, landscape, assets, landscapes
2	1.80%	Council proceedings	climate, adaptation, change, territory, actions, plan, city	committee, councillor, board, item, approved, report, iclei
50	1.70%	Climate change vulnerability diagnosis	adaptation, climate, cities, can, change, strategy, page change, council, climate, environmental, adaptation, glasgow, coastal	ademe, direction, diagnosis, marseille, vulnerabilities, cpa, tourist
51	1.70%	Adaptation strategy	risk, flood, management, water, flooding, plan, plans	remscheid, solingen, figure, topic, cities, sense, thomas
57	1.70%	Coastal adaptation	green, economic, health, food, provide, social, growth	glasgow, riding, coastal, east, yorkshire, cabinet, clyde
12	1.70%	Coastal flood risk management	climate, change, london, adaptation, strategy, environmental, city	risk, flood, erosion, coastal, surface, flooding, smp
7	1.70%	Green growth	action, city, development, adaptation, public, eco, sustainable	growing, bristol, food, growth, physical, allotments, economic
29	1.70%	Adaptation planning input	climate, adaptation, planning, measures, change, areas, settlement	london, advisory, update, york, fcm, advocacy, engineering
56	1.70%	Sustainable urban development	project, adapted, will, account, urban, plu, site	animation, eco, realized, deadlines, sober, calendar, nîmes
55	1.70%	Adaptation area planning	mitigation, target, action, toulouse,	settlement, documentation, relations, cold, competitions, bergische, determination
32	1.70%	Development site regulation		zac, dijon, plu, regulatory, brest, scot, zoning
46	1.70%	Mitigation targets		coherence, transversality, sobriety,

25	1.60%	Heavy storms	adaptation, impacts, sobriety climate, adaptation, heat, wind, heavy, rain, description	toulouse, attenuation, summary, articulation wind, heavy, rain, description, storm, sensitive, waves
5	1.60%	Water management	water, adaptation, management, area, use, systems, adapted	drinking, water, groundwater, sewerage, solution, dry, pools
30	1.60%	Local climate leadership	local, mayors, actions, adaptation, cities, city, initiative	mayors, covenant, pact, initiative, villeurbanne, commitments, signatories
27	1.60%	Local economic investment	business, local, opportunities, adaptation, businesses, climate, communities	business, businesses, innovation, opportunities, investment, skills, economy
48	1.60%	Home energy retrofits	adaptation, renovation, energy, housing, adapted, private, will	condominiums, dwellings, device, renovation, aging, difficulty, precariousness
40	1.50%	Agricultural production	air, energy, production, quality, development, agricultural, climate	production, orientations, agricultural, orientation, pollutants, agriculture, industry
47	1.50%	Stormwater diversion	city, adaptation, climate, rotterdam, actions, change, win	rotterdam, sewer, win, windsor, basement, downspout, sewers
34	1.50%	Green development	will, development, new, green, infrastructure, buildings, city	sites, centre, significance, connectivity, rail, brownfield, harm
20	1.50%	Adaptive management	management, monitoring, adaptive, implementation, actions, plan, years	vancouver, metro, adaptive, coves, lake, percent, monitoring
11	1.50%	Facility improvements	adapted, will, lighting, new, adapt, time, better	lighting, said, club, positions, furniture, digital, know
58	1.50%	Adaptation and Canadian jurisdictions	city, climate, change, adaptation, toronto, health, actions	toronto, vaughan, ontario, canada, saskatoon, http, resiliency
36	1.40%	Extreme weather events	weather, events, extreme, climate, paris, city, adaptation	weather, extreme, paris, events, severe, storms, parisians

4	1.30%	Tree planting	species, trees, tree, will, planting, urban, conditions	species, planting, tree, trees, plant, invasive, planted
22	1.30%	Transportation networks	transport, travel, cornwall, change, local, climate, network	cornwall, transport, travel, connecting, cheshire, walking, cornwall's
44	1.30%	Community planning	city, development, community, use, plan, heritage, adaptive	richmond, reuse, downtown, transit, whereas, transportation, edmonton's
28	1.20%	Time horizons	term, long, medium, strategy, short, adaptation, community	htl, nai, term, long, medium, epoch, short
35	1.20%	Adaptation programming	lyon, operation, deliberation, city, see, adaptation, program	lyon, deliberation, nantes, saint, etienne, operation, debate
59	1.20%	Sustainable environmental promotion	environment, promote, sustainable, natural, change, enhance, climate	durham's, altogether, greener, maximise, enhance, conserve, promote
15	1.10%	Regional climate change protection	climate, change, adaptation, measures, protection, wuppertal, environment	wuppertal, westphalia, alliance, ministry, rhine, bmu, nrw
53	1.10%	Tools and sensitization	will, adapted, association, city, article, terms, year	association, article, undertakes, sensitized, tool, edd, validated
43	1.00%	Flood mitigation infrastructure	flood, mitigation, measures, level, infrastructure, sea, river	lfrms, sea, river, calgary, watershed, barriers, resiliency
18	0.80%	Local services	provision, work, adapted, recycling, car, offices, new	offices, rights, badge, recycling, garbage, whereas, church

We observe that twenty-one topics are composed of words exclusive to climate change policy. Fourteen of these topics concern adaptation, including impacts and extreme weather effects (Topics 13, 25, 36, and 50), local leadership (Topic 30), and processual aspects of policy planning and implementation (Topics 2, 15, 20, 28, 30, 31, 35, 39, and 51). Several additional topics were either exclusively focused on climate change mitigation and/or renewable energy

technology (Topics 3, 23, and 41), or indicated an integrated focus on mitigation and adaptation (Topics 14, 42, 46, and 52). Three additional topics concern various aspects of transportation planning (Topics 10, 22, and 40), which we suspect are likely to be associated with mitigation policy goals rather than adaptation goals.

Nine topics contain words that link adaptation with other closely associated concepts in the scientific literature, namely sustainability, resilience, climate protection, vulnerability, and risk management. Our results suggest that the use of these concepts has a sectoral dimension, with risk management and resilience associated with flood risk management and flood mitigation infrastructure, respectively (Topics 12 and 43), and sustainability associated with environmental protection (Topic 59), energy technology (Topic 19), and urban development (Topic 56). Vulnerability, on the other hand, is linked to the science of climate change, specifically climate change impacts and assessments (Topics 13 and 50), and climate protection is linked to action around adaptation, specifically adaptation measures (Topic 15) and strategic planning efforts (Topic 52).

We further analyze topics for cross-sectoral linkages and geographical scope. Sectoral integration of adaptation considerations appears to be largely considered within urban development and environment, with development carrying a slightly higher average prevalence among topics (0.018) compared to environment (0.016). Nine topics make reference to urban planning and building with terms like ‘development,’ ‘buildings,’ ‘site,’ and ‘zoning’ (Topics 9, 19, 26, 32, 34, 37, 44, 55, and 56). Along with Topics 7 and 27, which concern green growth and local economic investment, this suggests a narrative linking climate change adaptation and urban growth. We observe fewer topics related to the natural environment ($n = 6$). One of these topics contains a general reference to the environment in strategic adaptation planning (Topic 29), while another reference to the environment is made in relation to coastal adaptation (Topic 57).

Only four topics are therefore interpreted as being primarily about preserving or promoting natural habitats and biodiversity in urban areas (4, 45, 49, and 59). Several additional sectoral topics are identified as relating to water management. Topics 5 and 47 link adaptation with drinking water and sewerage management, while Topic 12 links adaptation with flood management. These two aspects of water management appear to be framed differently within our corpus, with Topics 5 and 47 interpreted as focusing on urban systems management and Topic 12 focusing more on risk management.

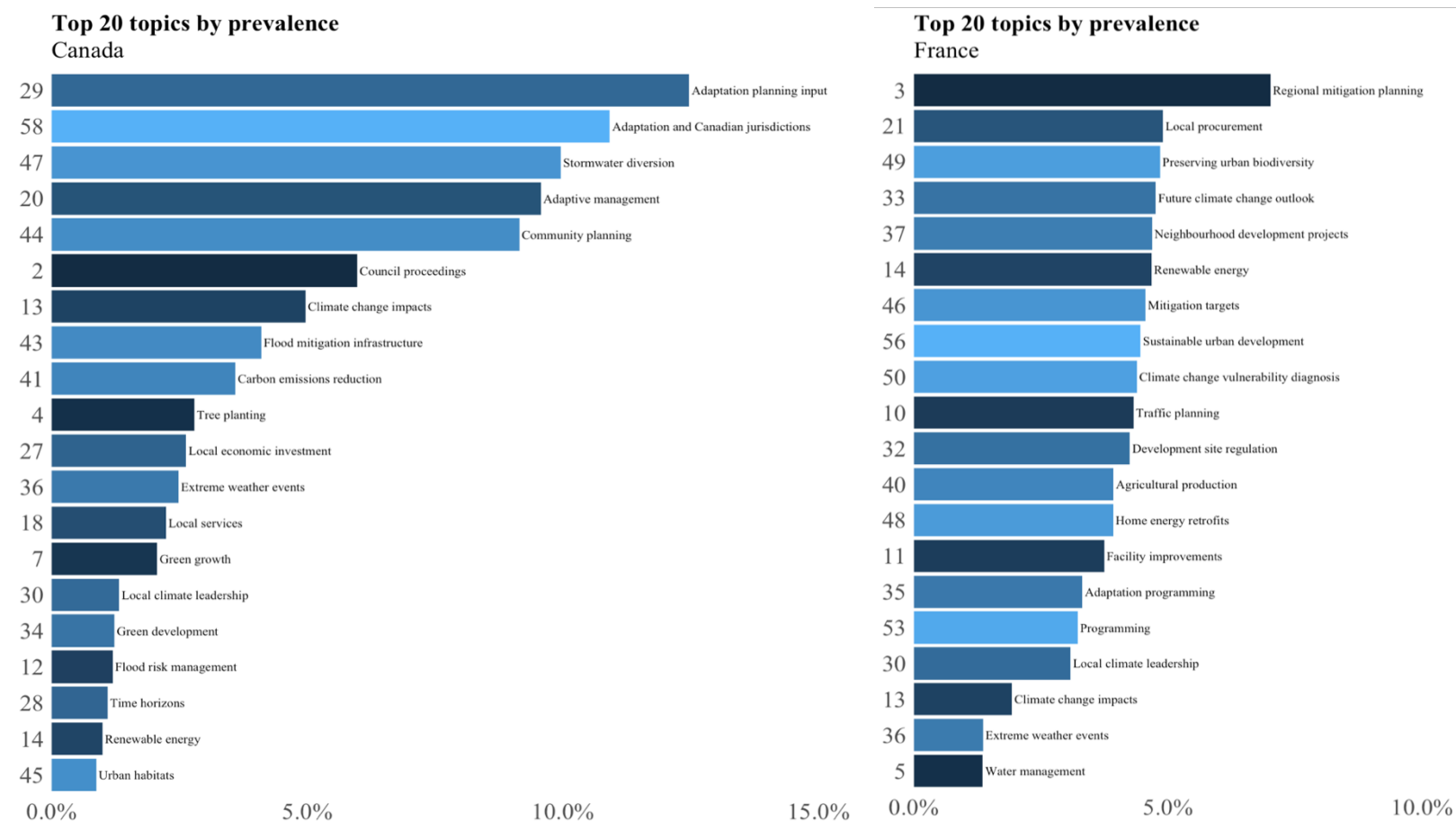
Unsurprisingly the geographic scope of the topics is strongly local, with 41 topics using terms such as ‘urban,’ ‘community,’ ‘city,’ or ‘neighbourhood,’ or including references to specific local governments. Some linkages are observed between local-scale words and regional/territorial-scale words within seven topics that concern strategic planning (Topics 3, 15, 50, and 52) and adaptation measures (Topics 20, 39, 50, and 58), but there seems to be a disassociation between local policy framing and national and global scales of adaptation governance. Only topics 9 and 50 make reference to national-level policies. Topic 9 is concerned with adaptations to building infrastructure and includes a mention of ‘nppf’ (National Planning Policy Framework of the UK) in the list of FREX words. Topic 50 refers to ‘ademe’ in the list of FREX words, the acronym for the Agence de l’environnement et de la maîtrise de l’énergie, which is tasked with coordination environmental protection efforts in France. Only one topic references a global-scale word, though unlike Topics 9 and 50 this topic is specific to the climate change field: Topic 13 links the IPCC with increasing climate change impacts and vulnerability. This reflects a view in the literature that adaptation has emerged as a largely bottom-up policy issue, characteristic of polycentric governance environments (Jordan et al. 2015; Biesbroek and Lesnikowski 2018).

Finally, we observe several references to network governance environments. The urban networks ICLEI and the Federation of Canadian Municipalities (FCM) are associated with local planning procedures (Topics 2 and 29, respectively), and the Global Covenant of Mayors, which is associated with local climate leadership (Topic 30).

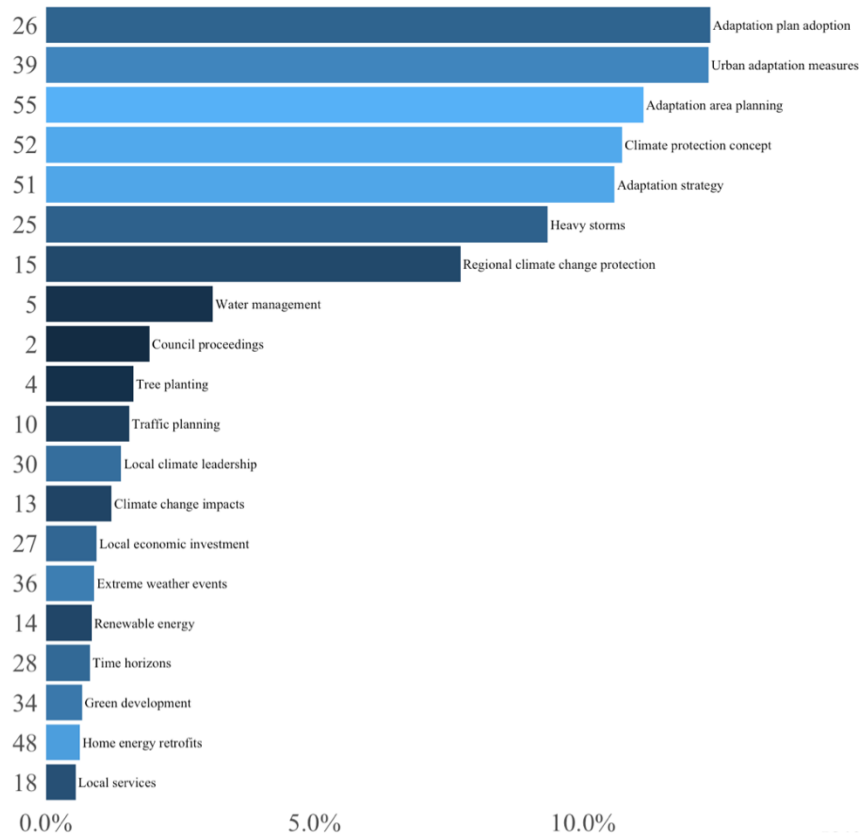
7.4.2 Topic prevalence by country

To examine linkages between institutional contexts and the ideas shaping local adaptation policy development we analyze the top 20 topics per country to make inferences about the diagnostic and prognostic dimensions of policy frames (Figure 7.1). This is implemented by introducing the country location of each local government as a document-level covariate in our corpus. Overall, we observe considerable variation in the framing that characterizes local policy documents across these contexts.

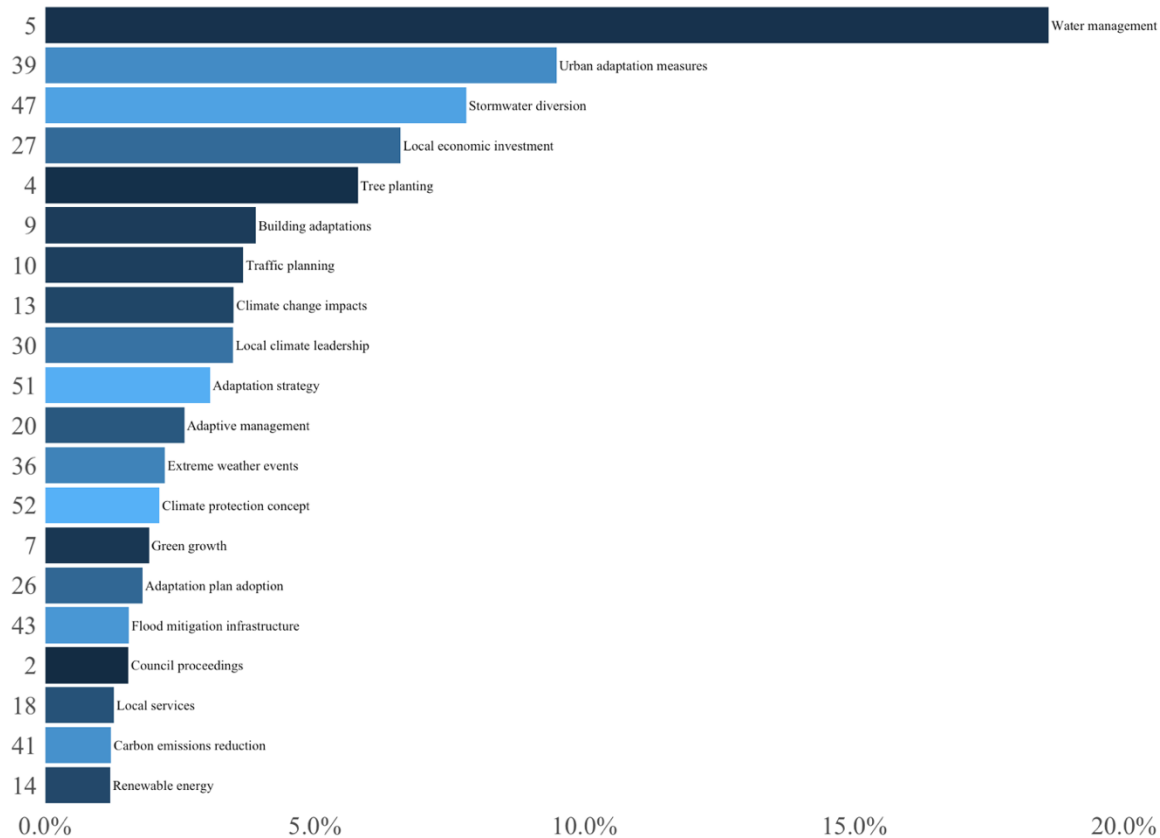
Figure 7.1 Topic prevalence by country



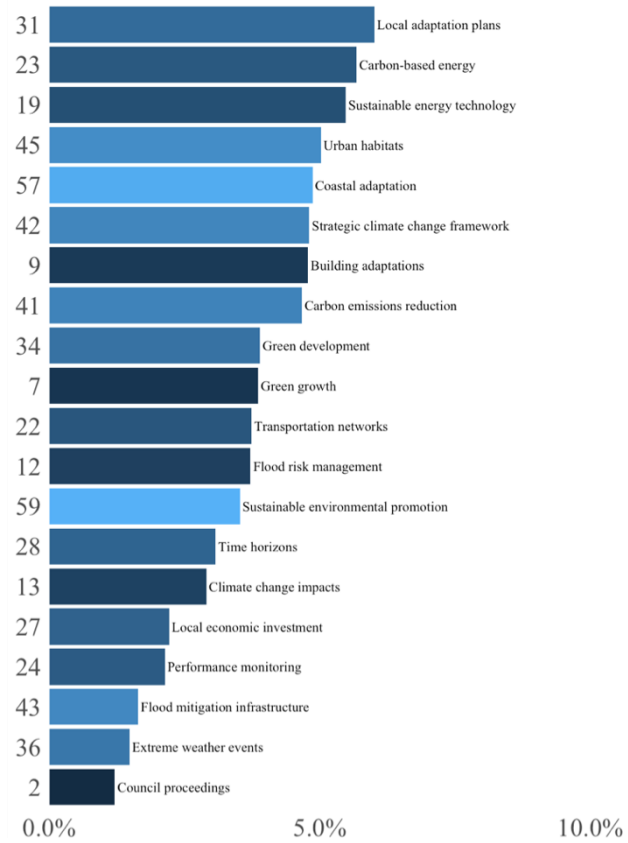
Top 20 topics by prevalence
Germany



Top 20 topics by prevalence
Netherlands



Top 20 topics by prevalence **United Kingdom**



Analysis of topic prevalences by country indicate that all local governments have problem framings that encompass the scientific language of climate change impacts (Topic 13) and extreme weather events (Topic 36). These topics include words like ‘ipcc,’ ‘impacts,’ ‘temperature,’ ‘vulnerability,’ ‘increase,’ ‘weather,’ and ‘extreme.’ Nonetheless there are notable differences in the influence of this frame relative to other problem frames. The strongest climate science-based problem framing is observed among policy documents collected from German and Dutch local governments. ‘Climate change impacts’ and ‘extreme weather events’ are prevalent within both countries, with ‘heavy storms’ also carrying a high level of influence within German policy documents. The concept of climate protection is also represented in two German topics (15 and 52), a common phrase that has conventionally been associated with mitigating greenhouse gas emissions (Bulkeley and Betsill 2003). No references to resilience or sustainability are found among German topics, but reference to resilience is observed among Dutch policy documents under the topic ‘flood mitigation infrastructure (Topic 43).

The emphasis on climate change science-based problem framing among the German policy documents is mirrored in solutions-oriented topics, where we observe a very high prevalence of adaptation-specific topics. Indeed, all seven of the most prevalent topics are climate change-focused and relate to strategic planning and targeted implementation measures (Topics 26, 39, 55, 52, 51, 25, and 15). Overall this suggests policy framing that establishes adaptation as a distinct issue within the work of local governments. By comparison, a stronger sectoral viewpoint on adaptation solutions appears in the case of Dutch policy documents, with high prevalence of water management (Topic 5) and stormwater diversion (Topic 47), and to a lesser extent flood mitigation infrastructure (Topic 43). These topics describe a systems-approach to managing sewerage and drinking water systems that reflect infrastructure-based approaches to adaptation. Other substantive topics also focus on modifications to the built

environment, including building adaptations and tree planting (Topics 9 and 4). Interestingly, Topic 27 on ‘local economic investment’ emerges with high prevalence among Dutch local policy documents. This appears to be a unique aspect of adaptation policy framing in the Dutch context, as this topic has a much lower prevalence among other country clusters. It is possible that the Dutch political tradition of neo-corporatism, which emphasizes cooperation among government, business, and labour, is being reflected in this topic, suggesting a more explicit role for local businesses in managing climate change impacts in Dutch local policy environments.

Among Canadian policy documents ‘climate change impacts’ and ‘extreme weather events’ also have relatively high prevalence levels, but we observe a stronger focus on resilience framing in Topics 58 (‘adaptation and Canadian jurisdictions’) and 43 (‘flood mitigation infrastructure’). The association of resilience with a specifically Canadian topic (58) and its very high prevalence among these documents suggests that the language of resilience is more commonly used to frame problem of adaptation within local Canadian policy environments than in other policy environments. Solutions-oriented topics are more diverse than those in German and Dutch policy documents, constituting a mix of adaptation planning and implementation (Topics 29, and 58), adaptive management (Topic 20), community planning and urban habitat protection (Topics 4, 44, and 45), local economic development (7, 27, and 34), flood risk management systems (Topics 12, 43, and 47), and health (Topic 58). Overall this gives the impression of a heterogeneous landscape around adaptation policy framing and suggests that adaptation policy approaches in the Canadian local government context are highly multisectoral.

In contrast to the contexts described above, the problem framing around adaptation in French and UK local policy documents does not appear to centre strongly around the science of climate change or extreme events. In the case of the UK, we see a broad mix of topics with no clearly dominant problem framing emerging. References are made to climate change impacts and

extreme weather events, but also to sustainability, resilience, and risk management (Topics 19, 59, 13, 43, 36), with no adaptation-related problem framing clearly more prevalent than another.⁵ This heterogeneity is suggestive of an adaptation policy landscape composed of multiple policy sectors, including dedicated adaptation planning, urban planning and development, flood management, economic growth, and the environment.

Among French local policy documents, we observe problem framing that emphasizes sustainability and vulnerability (Topics 56 and 50). The latter is distinct from references to vulnerability made under Topic 13 on ‘climate change impacts’ as it concerns processes relating to vulnerability assessment in the context of strategic planning processes, rather than vulnerability in relation to physical impacts of climate change. It also appears that local problem framing around vulnerability is emerging due to central government leadership on adaptation, with Topic 50 (‘climate change vulnerability diagnosis’) specifically referencing the French national environmental protection agency, which is tasked with assisting local governments to identify relevant climate change impacts and developing adaptation strategies. Solutions-oriented topics among French local policy documents have a stronger urbanism perspective compared to other country contexts, with four topics emerging around (sustainable) urban development in the built environment (Topics 32, 37, and 56) and preservation of urban biodiversity (Topic 49). Notably, only one prognostic topic is identified on adaptation-specific measures (Topic 35), though four mitigation-specific topics emerge (Topics 3, 14, 10, and 48). Taken together this suggests that adaptation may still be in the shadow of mitigation, and is being framed around a sustainable urbanism agenda rather than as a distinct policy issue.

⁵ Topic 19 (‘sustainable energy technology’) emerges as a highly prevalent, but concerns climate change mitigation and not adaptation.

Finally, we also consider differences in framing around who has responsibility for adaptation based on how different scales of governance are referenced within topics. While overall topics are primarily local in scale, notable distinctions arise across country contexts in regard to regional and national levels of government. None of the 20 topics most associated with Dutch local policy documents make reference to a higher level of government. Topics associated with local policy documents from Canada, France, Germany, and the United Kingdom, however, make reference to both regional and national levels of government.

References to higher levels of government in the Canadian context are limited, appearing only in Topic 58 as a general topic on ‘Adaptation and Canadian jurisdictions’ and not linked to specific sectors or policy topics. In French, German, and UK local policy documents jurisdictional references are more specific. Among French local policy documents, Topic 50 indicates a vertical intergovernmental dimension to adaptation planning processes by specifically referencing the French national environmental protection agency in relation to vulnerability assessments. ‘Territory’ is also mentioned in three topics (3, 33, and 50) within the context of strategic planning processes, which reflects national mandates on local government adaptation action that require local climate change plans and town planning regulations to consider goals and policy provisions in Territorial Climate and Energy Plans. Similarly, topics concerning strategic planning for climate protection that are highly associated with German policy documents reference both regional governments and the national government, reflecting close intergovernmental cooperation on knowledge creation, communication, and policy planning for adaptation between government levels in Germany’s federal system.

Finally, references to different levels of government in the UK context are representative of the UK’s system of devolved unitary government. Topic 30 on ‘local climate leadership’ is notably absent from the list of most prevalent topics in the UK, in contrast to every other

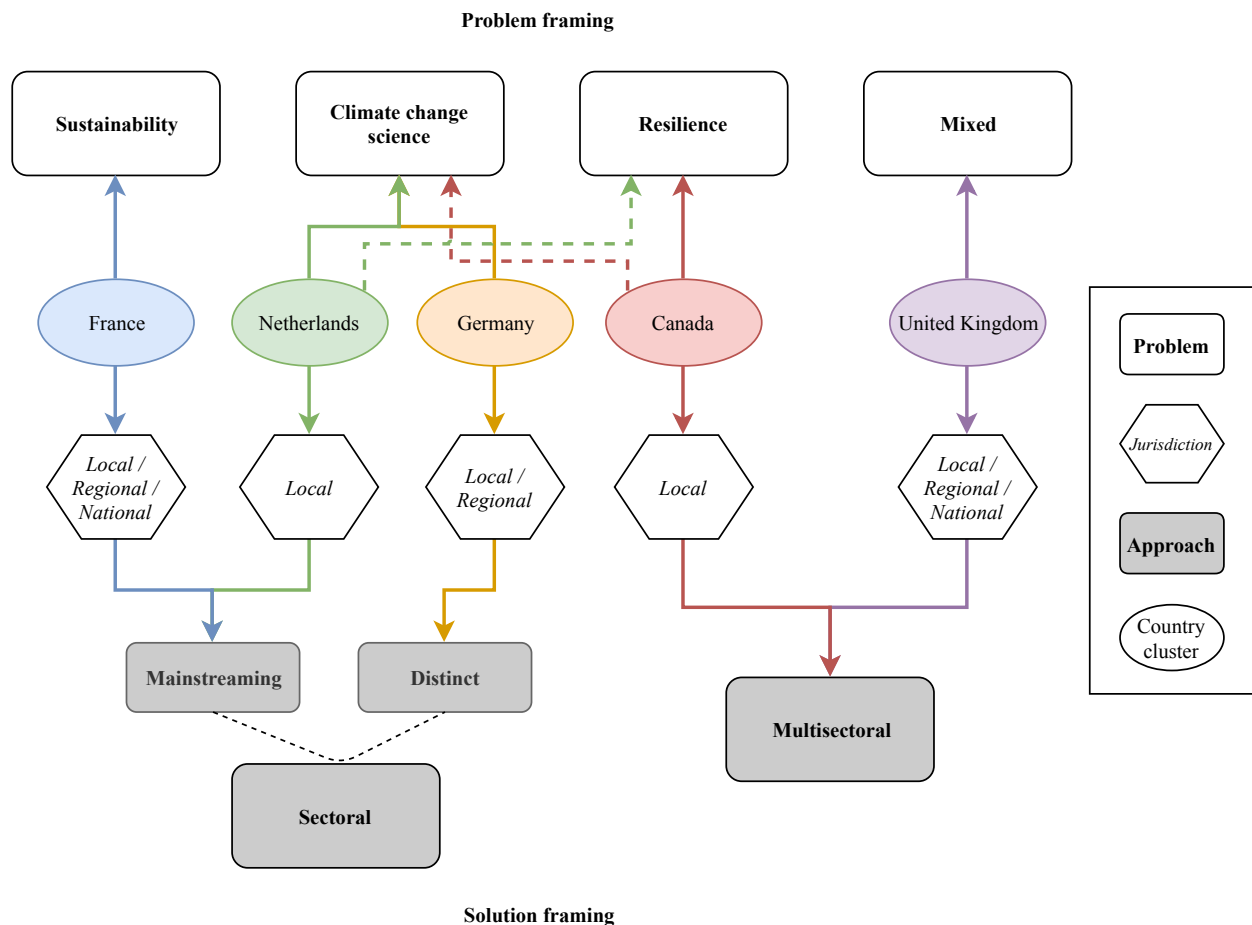
country. The absence of any emphasis on local political leadership may reflect local institutional arrangements in the UK, which typically have no directly elected mayor and no separation between executive and legislative functions in city councils. We also observe specific references to the National Planning Policy Framework and national guidance on building materials and siting (Topic 9), which set general planning priorities for all of England that are implemented by local governments, including those pertaining to adaptation. In the context of Scotland, these priorities are determined regionally by authority devolved to the Scottish Parliament, which is reflected in Topic 31 ('local adaptation plans'), which references 'scotland' and 'scottish.'

7.5 Discussion

This study applies an unstructured machine learning approach, structural topic modelling, to identify emerging ideas about the nature of climate change adaptation as a local policy issue and understand what the substance of these ideas indicates about how adaptation is being formalized in local policy agendas. We interpret 'ideas' as policy frames that represent normative and cognitive beliefs about the nature of climate change impacts as a policy problem, its solutions, and the role of local governments in addressing it. Drawing from the emerging literature on discursive institutionalism, we make the relationship between policy frames and institutional environments explicit by systematically comparing policy frames across country contexts.

Our results indicate that while there are some shared features in local policy frames, for example a focus on extreme weather events, there are key distinctions between country clusters in the content of policy ideas that link policy documents collected from the local governments analyzed here. These differences are captured in Figure 7.2, which illustrates observed relationships between four types of problem frames, the responsibilities of different jurisdictions, and two distinct approaches to addressing adaptation in local government policies.

Figure 7.2 Distinctions in adaptation policy framing



Based on these findings we propose that overarching conceptual distinctions within problem framing are associated with different sectoral perspectives on adaptation, for example with sustainability linked to integrating climate change adaptation into urban development planning and the urban environment, and resilience linked to infrastructure-based flood risk mitigation measures. Sectoral approaches to adaptation were observed in topics highly prevalent among French, Dutch, and German local governments, but emerging approaches to institutionalizing adaptation differ between a *sectoral mainstreaming* approach, observed in France and the Netherlands, and what appears to be the treatment of adaptation as a stand-alone policy issue in Germany, suggesting that in this context adaptation is evolving as a *distinct* policy

sector. The exception to this pattern appears in the case of local Canadian policy, where resilience is observed to be highly prevalent in framing adaptation as a jurisdictional issue, in addition to framing flood mitigation efforts.

Importantly, we do not observe that similarity in problem framing across contexts implies similarity in adaptation policy responses. Local governments in Germany and the Netherlands share a focus on climate change impacts and extreme events (and to a lesser extent resilience in the Netherlands), but those in Germany have a stand-alone policy approach to adaptation that emphasizes strategic planning and implementation of adaptation measures, while local governments in the Netherlands have developed a dual emphasis on water management and adaptation measures that suggests a focus on adaptation from a sectoral perspective. This is also the case from the adaptation solutions perspective, where we observe that in both the Canadian and UK contexts prognostic topics are highly multi-sectoral, but problem framing in Canada has a strong resilience emphasis (and to a lesser extent climate change impacts and extreme events) while in the UK problem framing is heterogeneous with no clearly dominant conceptual focus.

Considerable debate has occurred within the climate change literature on the implications of different policy frames for shaping policy approaches to adaptation, with particular concern that the emergence of resilience framing signifies an over-emphasis on technocratic and incremental changes that avoids deeper structural change and social learning (O'Brien et al. 2007; Mcevoy, Fünfgeld, and Bosomworth 2013; K. Brown 2014; Pelling 2011; Whitehead 2013). Our results do not necessarily contradict this view, but they nuance the debate by showing that regardless of whether local governments adopt a dominant problem framing around resilience, climate change impacts and vulnerability, or sustainability, the policy solutions they gravitate towards represent established routines. More specifically, despite the differences emphasized here in problem and solution framing across these contexts, there is a shared

tendency to treat adaptation as a problem that exists in the physical environment, rather than as a problem of equity, exclusion, or environmental and social justice that originates from and exists within social spaces. Indeed, only one topic (Topic 42) indicates an explicit view on adaptation as a moral issue, referencing ‘equality’ in relation to strategic climate change frameworks and highly associated with local governments in the United Kingdom. This suggests that local governments are generally pursuing adaptation based on standard policies and procedures, and underlines the difficulties of gaining traction around an innovative policy agenda that focuses on the broader social dimensions of climate change risk given institutional inertia (Biesbroek, Peters, and Tosun 2018).

The patterns that we detect mirror empirical research on the relationship between adaptation policy decisions and underlying dimensions of governing traditions and reinforce our argument that the substance and influence of policy ideas must be considered within the context of institutional logics, even at the local level (Painter and Peters 2010b; Loughlin et al. 2011; Klein and Juhola 2018). Biesbroek et al. elaborate several dimensions of public administration that influence how issues and ideas are adopted into policy and practice, including the perceived role of public administration, state-society linkages, the importance of policy uniformity in public administration, and the interface between science and policy in decision-making (Biesbroek, Peters, and Tosun 2018). Shadows of these dimensions are observable across the topics that emerge from our model. The decentralized governing structures and legal formalism of the Germany governing tradition is reflected in the emphasis among German local governments on developing distinct strategic planning frameworks for adaptation and implementing urban adaptation measures. In the Canadian context, decentralization and managerialism in administrative culture seems to foster a more diffused policy landscape, and an experimental focus on innovative policy solutions like adaptive management. The emphasis on

urban development and the urban environment among French local governments and references to assessment procedures informed by national agencies is consistent with the technocratic tradition of French public administration and the role of the French state in facilitating scientific assessment (Rothstein, Borraz, and Huber 2013; Szarka 2006; Nadin and Stead 2013). Neo-corporatism and an established tradition of autonomous and technocratic water management has become the focal point of Dutch adaptation efforts, reflected in the prevalence of water management, stormwater diversion, and local business climates (Vink et al. 2015; Buuren et al. 2018). Finally, the diversity of norms and practices observed across policy sectors in the UK reflects a policy integration approach to climate change policy that resulted from introduction of adaptation as a cross-cutting and decentralized (local and regional) issue, but where strategic objectives are still centrally determined (Vink et al. 2015; Gillard 2016).

Structural dimensions of intergovernmental institutional contexts are also evident within the model, though it is not clear that particular diagnostic or prognostic aspects of frames hinge on specific types of arrangements. We find references to national-level aspects of adaptation governance in contexts with stronger state centralization of adaptation agenda-setting (France and the United Kingdom), and references to local and regional governance environments in contexts where local governments receive less direction from national governments in setting adaptation policy (Canada, Germany, and the Netherlands).

The consistency of these findings with establishing literature on governing styles and administrative traditions speaks to the validity of using automated text analysis to systematically identify the content of policy ideas across contexts. We are able to situate the content of policy ideas within distinct institutional environments by using a correlated topic modelling approach that examines variation in topic proportions across country context, lending analytical nuance to an otherwise unstructured analytical approach (Blei and Lafferty 2006a). Here we focus on

differences in topic content related to the governing traditions of countries, but additionally structural topic modelling could be used to examine differences in policy ideas under different elected governments or between different administrative units, or changes over time.

The findings from this study indicate that the differences in local adaptation policy approaches seems to stem more from the established norms and routines of particular institutional contexts than the substantive nature of the concepts underlying the frames themselves. While distinct local problem frames have emerged across the countries studied here, these appear to be influenced by the governing traditions of different environments, including the dominance of particular policy sectors and the relationships between different levels of government. This suggests that policy framing is not simply a precondition to different governance pathways, but rather that policy actors tend to gravitate towards frames that fit existing norms and routines (Vogel and Henstra 2015; Stone 1989). By adopting a comparative research approach, we are able to demonstrate that understanding the role of ideas in shaping policy pathways requires consideration of path dependencies and inertias embedded within existing structural arrangements, policies, and decision-making procedures. The growing literature on discursive institutionalism emphasizes the importance of institutions as filters for how ideas are received and interpreted, the implication being that similarities in framing in different contexts does not necessarily lead to similarities in policy outcomes. Our findings point to the importance of linking scientific debate about the implications of different policy frames for adaptation policy action to the institutional contexts in which policy ideas are received and processed.

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Chapter 8: Summary, discussion, and conclusion

8.1 Summary of chapters

The previous chapters of this thesis examined how climate change adaptation is being addressed among local governments in Canada, France, Germany, the Netherlands, and the United Kingdom. This research addressed three questions:

1. What policy approaches are local governments taking to deal with climate change adaptation?
2. How do local and national policy environments influence the adaptation policy choices of local decision-makers?
3. How is adaptation being framed as a policy issue by local governments and what does this indicate about emerging policy approaches?

The research is structured around a conceptualization of public policies specified by Howlett and Cashore, who describe two dimensions of policies, goals and means, that exist on three levels of abstraction: i) high-level ideas and preferences, ii) program-level mixes of formal policy goals and policy instruments, and iii) operational-level policy targets and calibrations (Howlett and Cashore 2009). I examined local adaptation policy approaches using a multiple methods research design that includes content analysis, statistical analysis, and topic modelling. Chapter 3 situated the motivation for my empirical focus on local governments within the multilevel landscape of adaptation governance. Chapter 4 addressed the first research question above by examining policy mixes emerging across 125 local governments in the five countries listed above using systematic content analysis of local policy documents. The second research question was addressed in Chapter 5 of the thesis, which uses linear regression analysis and multilevel modeling to test hypotheses about local and national drivers of local adaptation policy

choice. Chapter 6 makes a methodological contribution to the adaptation literature, arguing that topic modelling has potential applications for adaptation policy and governance research that have hitherto been largely untapped. The third question was addressed in Chapter 7 using topic modelling to identify policy frames contained in the policy documents collected during the Chapter 4 stage of research. This final chapter summarizes the overall findings from these chapters and reflects on the contributions of this thesis to theoretical and methodological development in adaptation policy research.

The primary argument of this research is that local governments are addressing climate change impacts using highly complex mixes of policy goals and instruments that are influenced by unique policy frames and multilevel institutional environments. This research contributes to conceptual and methodological advancements in the adaptation policy literature by refining our understanding of adaptation policy choice from the perspective of policy mixes, examining the relationship between institutional environments and local policy choice, and introducing novel methods for measuring policy mixes and policy frames across large sample sizes.

Chapter 3 of the thesis presented an overview of major developments in global adaptation governance over the past decade, with a particular focus on the significance of the Paris Agreement for further institutionalizing adaptation within the climate policy landscape, and formally positioning adaptation as a multilevel governance challenge. This chapter argued that the Paris Agreement signalled a widening of the framing around adaptation to include the broader institutional context of adaptation, but that the extent to which this would result in meaningful policy change was contingent on the ability of international institutions to encourage compliance with nationally-determined adaptation policy goals through procedural mechanisms such as adaptation communications, the global stock-take on progress under the Paris

Agreement, and a transparency framework to tracking progress on policy implementation within countries.

Chapter 4 of the thesis presented a novel approach to conceptualizing adaptation policy through policy mixes, and operationalized this approach using systematic content analysis of policy documents collected from the 125 local governments studied here. The empirical results of this chapter demonstrated that local governments are adopting increasingly complex combinations of policy goals and instruments to address climate change risk, which presents challenges for administrative coordination and successful policy implementation. The chapter argues that this conceptual approach brings clarity to the ‘dependent variable problem’ underlying adaptation policy research, while providing a theoretically-informed pathway forward for evaluating adaptation policies and conducting explanatory analysis on the drivers of policy choice.

Chapter 5 presents the findings from an explanatory study of local adaptation policy choices using linear regression analysis and multilevel modeling. Here I draw on a model of policy implementation styles from the policy instruments literature to analyze the influence of local and national policy environments on adaptation policy choice. I observe that a majority of local governments are adopting policy implementation approaches consistent with public provision and oversight of adaptation and regulatory corporatism, with somewhat lower reliance on voluntary approaches to adaptation and a much lower reliance on market-based governance approaches. This suggests that local governments are often following fairly traditional top-down approaches to policy implementation. The results provide mixed support for the hypotheses developed from the theoretical model of implementation styles. Key findings for the adaptation policy literature include our observation that increased governing capacity is not necessarily related to more substantive policy adoption, and that the degree of complexity in the climate risk

environment and constellation of actors in the policy environment influence local policy choice. We also observe that national engagement with climate change adaptation appears to be associated with more substantive policy formulation at the local level, particularly mandates requiring local adaptation policy engagement. We find that increased devolution of authority is not always associated with more substantive adaptation as is argued in parts of the local adaptation scholarship; rather our findings suggest that greater dependency of local governments on national governments is associated with greater adoption of regulatory policy instruments, but not greater institutional development.

Chapter 6 is the result of a collaborative project on new methods for adaptation policy assessment, and argues that computational text analysis, specifically topic modelling, provides an opportunity to expand our canon of adaptation policy analysis methods and increase the scale of textual analysis beyond what is currently feasible through manual analysis of policy documents. Here the co-authors and myself provide an introduction to topic modelling for lay audiences, and conduct two test cases using different collections of adaptation policy documents. This chapter provides a technical overview to topic modelling, and explanation of the novelty of Chapter 7.

Chapter 7 examines policy framing of local adaptation in the policy documents collected for Chapter 4 of the thesis using Structural Topic Modelling. Here I examine how local decision-makers perceive adaptation as a policy problem and situate adaptation solutions within the policy responsibilities of local governments. I identify variation in policy frames that reflect country clustering of local governments, which suggests that embeddedness in particular country contexts influences local governing approaches on adaptation.

8.2 Theoretical and methodological contributions

A substantial literature around adaptation policy and governance has emerged within the climate change literature over the past decade. Despite evidence that adaptation policy adoption is increasing, the literature has struggled to address the basic ‘dependent variable problem’ of how we conceptualize adaptation policy as an empirical phenomenon and design research that contributes to knowledge accumulation about policy processes across places, governance scales, and policy sectors. In this thesis I proposed to address this challenge through the lens of policy mixes, which conceptualizes adaptation policy as combinations of policy goals and policy instruments that coalesce around climate change adaptation as a substantive policy issue. To my knowledge, this research is the first to explicitly design a cross-country, large-n comparative research protocol around this concept and demonstrate its usefulness for not only identifying and classifying adaptation policies, but also theorizing on adaptation policy choices and governance approaches emerging across contexts. This research will help move the adaptation tracking literature beyond a focus on lists and typologies towards research that is more grounded in the theoretical positioning of adaptation policy outputs within governing approaches for complex policy problems.

This perspective is explicit about the nature of adaptation as a political problem, recognizing that there is no objectively ‘correct’ way to address climate change impacts and reduce social vulnerability in a changing climate, and adaptation cannot be thought of as a technical problem. Instead, explanations of policy change must be interpreted within the context of historical policy legacies and interactions among actors in a policy environment. Policy instruments and policy mixes are never politically neutral, but represent particular norms and expectations about government intervention in society that often reflect institutionalized approaches to policy-making.

This thesis also contributes to growing calls in the adaptation literature to shift our analytical focus away from ‘barriers’ and ‘facilitators’ of adaptation action and towards the explanatory study of how ideas and institutions shape policy choices. It emphasizes the importance of comparative methods for examining how contextual differences influence decision-making processes and outcomes, and demonstrates that correlational analysis can complement case study and small-n explanatory studies to this end.

This thesis is novel in its methodological approach, which integrates systematic content analysis, statistical analysis, and computational text analysis to examine local adaptation policy choices. Chapters 6 and 7 are the first in the adaptation field to apply topic modelling to the study of adaptation policy. They provide test cases for the use of computational methods to scale up the analysis of adaptation policy and governance. To my knowledge the use of factor analysis and multilevel modelling in Chapter 5 is also the first attempt to explicitly incorporate the nested structure of vertical governance arrangements into the statistical modelling of local adaptation policy choice. My results demonstrate the need for future statistical analyses of local adaptation policy change to account for variations in inter-governmental arrangements across country context and develop clearer metrics for operationalizing local institutional arrangements in explanatory statistical analysis. Finally, while the content analysis method used in Chapter 4 builds on well-established approaches in the adaptation literature, linking this technique with the policy mixes concept has demonstrated how to more explicitly integrate the empirical side of systematic data collection with a nuanced conceptual understanding of public policies and policy formulation.

8.3 Policy implications

The key implication of Chapters 4, 5, and 7 was that adaptation policy recommendations must be sensitive to the diversity of policy goals and instruments that are emerging within

specific decision-making contexts. One-size-fits all recommendations about the resource capacity of local governments or desirability of particular policy instruments disregard this complexity and are unlikely to provide useful advice to decision-makers operating within different normative and institutional constraints. My advice to the adaptation community therefore centres around the way that we *do* policy analysis and make policy recommendations, rather than specific prescriptions.

Instead of developing policy recommendations based on normative visions of what we think adaptation policy ought to look like, we need to begin from the question of what the adoption of particular combinations of policy goals and instruments indicates about the normative and institutional foundations of policy choice. From this empirical foundation we can make more insightful arguments about whether we as a society are pursuing the right adaptation goals, or whether the manner in which policy portfolios are designed is likely to move us closer to achieving those goals (Berrang-Ford et al. 2019).

Linking adaptation policy research to theories of policy change is thus important not just for the scientific study of adaptation, but also for how we understand the nature of normative and social change occurring in response to the pressures of climate change. For example, I have observed that despite high-level political rhetoric in international agreements like the Paris Agreement or the Sustainable Development Goals around the intersections between climate change risk, inequality, and social vulnerability, policy frame analysis among local governments indicates minimal attention to equity and justice dimensions of adaptation policy. A key question for future policy analysis will be whether shifts in policy framing occur over time among local governments that mirror the broadening discourse on climate change adaptation, and how this influences policy choice.

8.4 Future research

This thesis slices off and examines one area of the policy instruments scholarship, policy mixes and policy choice, and leaves many questions open for future research. First is the issue of assessing the design of adaptation policy mixes. The policy design literature contains well-developed thinking about the assessment of policy mixes and policy integration processes that the adaptation policy assessment literature can draw from (Candel and Biesbroek 2016; Nilsson et al. 2012; Rogge and Reichardt 2016; Tosun and Lang 2017; Cejudo and Michel 2017). Conceptualizing adaptation within the policy mixes literature creates a stronger theoretical foundation for how we think about challenges to effective policy design and stands to make valuable contributions to the debate on how we define successful adaptation.

Second is re-visiting the question of how we conceptualize and measure the content of adaptation policy goals. Chapter 4 discussed challenges around adopting the policy strictness perspective common in comparative policy research to defining and evaluating adaptation policy goals, which tend to be highly qualitative and diffused across multiple diverse policy sectors. Here I used proxy measurements for capturing the substantive content of policy goals, risk prioritization and diversity, but future work should return to this question and develop more nuanced measures of adaptation policy goals for use in comparative analysis and policy evaluation. This work should take into account not only the prioritization of climate risks, but also the relative ambition and specificity of different adaptation policy goals.

The third avenue for future research is conducting longitudinal analysis of adaptation policy change among the local governments studied here in order to examine the nature and pace of change within local policy mixes. Though the data collection period here covers 2010 to 2017, I consider the study to be cross-sectional in nature as it does not account for policy termination

or examine changes in how specific policy targets or calibrations of policy instruments are designed and re-designed over time.

8.5 Conclusion

Over the last few decades, growing social movements have pressured governments at all levels to more seriously confront challenges facing society as a result of anthropogenic climate change. The policy responses of governments reflect core values and choices around who and what we should protect and how we should go about protection, which will become increasingly evident as impacts of climate change manifest with greater frequency and severity. While climate change adaptation is still largely being treated from an incremental perspective by policy actors, an important question for adaptation research will be whether the changing ways that we experience our environment shift societal expectations around the role of governments in managing environmental risks over the long-term. Examining adaptation from the perspective of policy instruments and mixes can reveal these implicit assumptions and expectations, and support more robust inferences about the nature of policy choice and policy change across contexts. Making progress on the fundamental question of how we conceptualize adaptation as an empirical phenomenon is central to this effort.

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APPENDIX A

Supplemental materials for Chapter 4

PHASE 1: Document search

The objective of the first phase of analysis is to collect all meeting minute records for city councils that include references to climate change. The assumption underlying the selection of meeting minutes as the document source is that any policy instrument that has moved past the brainstorming and proposal stage (i.e. existing as aspirational statements or commitments) will need to be formally accepted and voted on by the legislative body of a local government, typically in the form of a city council. Meeting minutes will provide records of all debates around adaptation policy instruments, and any subsequent votes. The following steps will be used to identify the relevant documents:

1. If meeting minute database is *non-searchable* then all documentation was opened and searched for references to “climate change” or climate (where search function didn’t allow for phrase searches). Some cities will provide all documentation for a meeting in a single file while others will provide these documents separately. Where documentation is posted as separate files, each file must be opened and searched using “climate change” or climate.
2. If meeting minute database was *searchable by keyword* then the date range Jan 1 2010-May 1 2017 was searched for documents referencing “climate change” or climate (where search function didn’t allow for phrase searches).
3. Save copies of all meeting minutes with keyword hits (including those where mitigation is the subject).
4. If minutes are unavailable online then contact the municipal records office to request the minutes for gaps years.

5. If step 4 is unsuccessful then perform a full search of the municipal website using the search strategy below.
6. Where background reports or presentation files are also provided for the relevant meetings, these documents should also be saved to a separate folder titled “[City] Background Documents.”

Search strategy:

Download all relevant policy documents (e.g. strategies and plans), bylaws, meeting minutes, and screenshots of webpages that have program/initiative information that describe what that municipality is doing to increase resilience/adapt to climate change. Exclude anything that is strictly emissions reduction and/or doesn’t explicitly make a linkage with resilience or adaptation.

Search strings: Municipal websites (e.g. policy documents, strategies, bylaws, meeting minutes, department webpages- screenshots)

- “climate change” AND adaptation
- “climate change” AND resilience
- “climate protection” AND adaptation
- “climate protection” AND resilience

Save all documents to Dropbox under folder names for each city, divided into subfolders for each year (2010-2017).

The following table provides a list of all cities included in this data collection process.

Table 1 Dataset coverage

Canada (Municipality)	Toronto (2,731,571), Montreal (1,704,694), Calgary (1,239,220), Ottawa (934,243), Edmonton (932,546), Mississauga (721,599), Winnipeg (705,244), Vancouver (631,486), Brampton (593,638), Hamilton (536,917), Quebec City (531,902), Surrey (517,887), Laval (422,993), Halifax (403,131), London (383,822), Markham (328,966), Vaughan (306,233), Gatineau (276,245), Saskatoon (246,376), Longueuil (239,700), Kitchener (233,222), Burnaby (232,755), Windsor (217,188), Regina (215,106), Richmond (198,309)
France (Commun)	Paris (2,229,621), Marseille (855,393), Lyon (500,715), Toulouse (458,298), Nice (342,295), Nantes (292,718), Strasbourg (275,718), Montpellier (272,084), Bordeaux (243,626), Lille (231,491), Rennes (211,373), Reims (182,592), Le Havre (172,074), Saint-Etienne (172,023), Toulon (163,760), Grenoble (160,215), Dijon (153,003), Nimes (150,564), Angers (150,125), Villeurbanne (147,192), Le Mans (144,244), Aix-en-Provence (141,545), Clermont-Ferrand (141,463), Brest (139,386), Limoges (135,098)
Germany (Municipality)	Berlin (3,520,031), Hamburg (1,787,408), Munich (1,450,381), Cologne (1,060,582), Frankfurt (732,688), Stuttgart (623,738), Düsseldorf (612,178), Dortmund (586,181), Essen (582,624), Leipzig (560,472), Bremen (557,464), Dresden (543,825), Hannover (532,163), Nuremberg (509,975), Duisberg (491,231), Bochum (364,742), Wuppertal (350,046), Bielefeld (333,090), Bonn (318,809), Munster (310,039), Karlsruhe (307,755), Mannheim (305,780), Augsburg (286,374), Wiesbaden (276,218), Gelsenkirchen (260,368)
Netherlands (Municipality)	Amsterdam (844,947); Rotterdam (634,660); Den Haag (524,882); Utrecht (343,038); Eindhoven (226,868); Tilburg (213,804); Groningen (202,636); Almere (200,914); Breda (182,304); Nijmegen (173,556); Apeldoorn (160,047); Haarlem (159,229); Enschede (158,140); Arnhem (155,699); Amersfoort (154,337); Zaanstad (153,679); Hertogenbosch (152,411); Haarlemmermeer (146,003); Zwolle (125,548); Zoetermeer (124,763); Leiden (123,661); Maastricht (122,753); Dordrecht (118,731); Ede (113,421); Alphen aan den Rijn (108,915)
United Kingdom (Local authority, metropolitan district)	Birmingham (1,124,569), Leeds (781,743), Glasgow (615,070), Sheffield (575,424), Cornwall (553,687), Manchester (541,263), Bradford (534,279), Durham County Council (522,143), Edinburgh (507,170), Wiltshire (488,409), Liverpool (484,578), Bristol (454,213), Kirklees (437,047), Barnet (386,083), Croydon (382,304), Cheshire East (376,695), Fife (370,330), Cardiff (361,468), Coventry (352,911), Leicester (348,343), Ealing (343,196), Newham (340,978), Belfast (339,579), North Lanarkshire (339,390), East Riding of Yorkshire (337,696)

Note: Population in parentheses

PHASE 2: Inclusion/exclusion evaluation

The objective of the second phase of analysis is to identify adaptation-relevant policy instruments that have been put into action by local governments. Documents identified in Phase 1 of data collection are uploaded to Atlas.ti for sorting. Tests for inclusion are applied to determine whether references to climate change in meeting minute records indicate that an adaptation policy instrument was implemented. Codes for adaptation, mitigation, or not relevant are assigned and all document sections coded “adaptation” are exported for policy instrument coding according to the indicator list below.

Inclusion requirements:

1. *Action constitutes purposeful adaptation.* Adaptation is understood as: “The process leading to the production of outputs in forms of activities and decisions taken by purposeful public and private actors at different administrative levels and in different sectors, which deals intentionally with climate change impacts, and whose outcomes attempt to substantially impact actor groups, sectors, or geographical areas that are vulnerable to climate change” (from Dupuis and Biesbroek 2013).
2. *Action constitutes a policy instrument.* A policy instrument is understood as: “The generic term provided to encompass the myriad techniques at the disposal of governments to implement their public policy objectives” (from Howlett 1991). The list of techniques relevant for adaptation are provided in indicators 11 and 12 below (types of substantial and procedural policy instruments).
3. *Policy instrument has been implemented by a local government authority.* Here implementation means formal adoption through the relevant local legislative body. Where

the legislative body has directed a department to complete some action this can be considered implemented. The exception is where the legislature directs a department to complete a task for later consideration; this will be considered unimplemented as the final decision on acceptance will be made at a later date. Processual steps taken in the implementation of a policy (e.g. status update reports on an adaptation plan) are to be excluded as not constituting a policy instrument.

4. *Policy instrument was implemented or amended between 2010 and 2017.* Policy instruments first implemented prior to 2010 but subsequently changed are eligible for inclusion.

Grounds for exclusion:

1. *Climate change mitigation.* Actions concerned exclusively with the reduction of greenhouse gas emissions are excluded.
2. *Non-adaptation risk reduction.* Environmental risk reduction policies that do not explicitly account for long-term changes resulting from climate change are excluded.
3. *Aspirational policy statements or policies still in the proposal or planning stage.* Policy must have been voted on by the relevant legislative body and approved.
4. *Actions taking place at another level of government.* Local governments sometimes participate in regional or national-level initiatives, but if this action is being led at another level of government then it is to be excluded.

PHASE 3: Coding policy instruments

All text identified in phase 2 as constituting adaptation policy instruments are exported from Atlas.ti and coded in an Excel spreadsheet according to the following indicators. Each row

in the dataset corresponds to a discrete policy instrument and text containing duplicate references to the same policy instrument can be condensed to one entry. Where necessary, relevant reports or documentation provided along with the meeting minute records are consulted for additional detail to populate the list of indicators below. In some cases, this may yield additional policy instruments not captured in the analysis of the meeting minutes.

List of indicators:

1. City name
2. Sub-national region
3. Country
4. Item name
5. Year of adoption
6. Policy aim
7. Policy objective
8. Nature of target problem
9. Policy setting
10. Resource type
11. Type of substantive policy instrument
12. Type of procedural policy instrument
13. Instrument calibration
14. Duration of instrument
15. Instrument target
16. Geographical boundaries of target
17. Administrative responsibility

Table 2 Indicator list

ID	Indicator	Definition	Field Options
1	City name	City name	<i>Open</i>
2	Sub-national region	Province, state, county, region	<i>Open</i>
3	Country	Country	<i>Canada</i> <i>France</i> <i>Germany</i> <i>Spain</i> <i>Netherlands</i> <i>United Kingdom</i>
4	Item name	As named by city	<i>Open</i>
5	Year of adoption [Mutually exclusive]	Year instrument came into force – unless otherwise stated, provide year of meeting	<i>2010</i> <i>2011</i> <i>2012</i> <i>2013</i> <i>2014</i> <i>2015</i> <i>2016</i> <i>2017</i>
6	Policy aim	Refers to how adaptation is framed. May need to be inferred from general documents like an adaptation strategy. (from Dupuis and Knoefel 2013)	<i>1. Climate change adaptation:</i> Adapting to specific impacts of anthropogenic climate change. Example: “In human systems, adaptation is the process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities. Adaptation is a function of Vulnerability and Risk.” (City of Vancouver Climate Change Adaptation Strategy) <i>2. Vulnerability-centred adaptation:</i> Reduction of structural drivers of vulnerability to climate change impacts <i>3. Resilience:</i> Systems-based thinking that emphasizes recovery from sudden shocks; adapting to climate variability as deviation from climate norms regardless of cause <i>4. Sustainability:</i> Adaptation linked to green growth objectives and broad balancing of economic and environmental objectives
7	Policy objective	Specified goal of the policy	<i>Open</i> Example: “Minimize rainfall related flooding and associated consequences”
8	Nature of adaptation problem [Inclusive]	Type of climate change impact addressed.	<i>1. Sea level rise (including storm surges):</i> Coastal inundation, saline intrusion. <i>2. Flooding:</i> Overland flooding, including storm water runoff. Affected by changing conditions for

Table 2 Indicator list

ID	Indicator	Definition	Field Options
			ice, snow, precipitation, drought, or extreme weather events. Linked to public safety hazards, risk of water-borne illness, ecosystem health, infrastructure damage, and population displacement.
			3. <i>Storms</i> : More frequent and/or intense thunderstorms, winter storms, tropical storms (hurricanes, cyclones), high winds, and storm surges. Linked to public safety hazards, population displacement, overland/coastal flooding, and infrastructure damage.
			4. <i>Water security</i> : Affected by changing conditions for ice, snow, precipitation, drought, or extreme weather (e.g. floods, storms). Linked to contamination in drinking and recreational water supply, salt water inundation of fresh water sources, ecosystem health, irrigation issues for crops, and general water management challenges.
			5. <i>Drought</i> : Affected by decrease in precipitation and land-use changes. Linked to food security, water security (irrigation, drinking, and recreation), ecosystem health, infrastructure damage, and flooding risk.
			6. <i>Wildfires</i> : Affected by higher temperatures and dryer conditions (including drought). Linked to public safety hazards, air quality, population displacement, ecosystem health, and infrastructure damage.
			7. <i>Erosion and landslides</i> : Including mudslides, avalanches, rock slides, and debris flows. Affected by sea level rise, storms, changing ice and permafrost conditions, and flooding. Linked to public safety hazards, population displacement, and infrastructure damage.
			8. <i>Desertification</i> : Land degradation in arid, semi-arid, or dry areas. Affected by drought and land use changes. Linked to food security and ecosystem health.
			9. <i>Food security</i> : Affected by changes in precipitation, drought, water security, and extreme events. Linked to increase in food-borne contamination, decrease in food availability. Includes crops, livestock / animal husbandry, and fisheries.
			10. <i>Infectious disease</i> : Changes in transmission patterns of rodent and vector-borne diseases. Linked to public health risks.

Table 2 Indicator list

ID	Indicator	Definition	Field Options
			<i>11. Heat events:</i> Changing frequency and severity heat waves. Affected by air quality conditions. Linked to heat-related illness and deaths, respiratory and cardiovascular disorders. Generally expected to worsen.
			<i>12. Cold events:</i> Changing frequency and severity of cold conditions. Linked to hypothermia and cold-related deaths, respiratory and cardiovascular disorders. Generally expected to improve.
			<i>13. Permafrost:</i> Changes in snow cover and / or permafrost.
			<i>14. Air quality:</i> Air pollution, including higher levels of ground-level ozone, airborne dust, particulates, increased production of pollens and spores by plants. Affected by extreme heat conditions. Linked to eye/nose/throat irritation, exacerbated asthma/allergy symptoms, chronic pulmonary disease/respiratory conditions, and increased risk of certain cancers.
			<i>15. Mental health:</i> Psychological impacts resulting from climate change-induced stress. Linked to extreme events, conflict, displacement, and health impacts.
			<i>16. Biodiversity:</i> Includes marine, freshwater, and terrestrial ecosystem health. For example, loss of species, species migration, pests and diseases, shifting hydrological systems, coral bleaching, etc.
			<i>17. Economic growth:</i> Loss of business profitability or viability, including insurance, tourism, agriculture, forestry, etc. Costs to government of climate impacts, including infrastructure repair or up-grade.
			<i>18. Telecommunications:</i> Stress on communications networks. Affected by extreme weather, including storms and heat/drought. Linked to economic impacts and public safety hazards.
			<i>19. Energy supply:</i> Stress on electrical grids, including loss of power, and delivery of energy resources. Affected by extreme weather, including storms and heat/drought. Linked to economic impacts and public safety hazards.
			<i>20. Heritage:</i> Loss of cultural traditions, including traditional lifestyles and foods and methods of acquiring/using natural resources. Linked to food security, economic impacts, physical and mental health.

Table 2 Indicator list

ID	Indicator	Definition	Field Options
			21. <i>General</i>: Vulnerabilities not captured among the options above. Includes general references to “extreme weather events” and “climate change” in cases where vulnerabilities are not specified. Includes UV radiation.
			23. <i>Other</i>
9	Policy setting	Specific policy target	<i>Open</i> Example: “Complete and implement a citywide Integrated Stormwater Management Plan”
10	Resource type [Mutually exclusive]	Policy instrument categorized according to the nature of the governing resource employed. From Hood (1983) and Henstra (2016).	1. <i>Nodality</i>: Information-based instruments; relies on voluntary compliance. Especially knowledge generation and mobilization. 2. <i>Authority</i>: Use of the power of the state to command, prohibit, permit behaviour. 3. <i>Treasure</i>: Use of public funds to (dis)incentivize, produce and maintain public goods and services, impose costs. 4. <i>Organization</i>: Leveraging physical and human capital of the state through direct delivery of programmes and services and government operations.
11	Type of substantive policy instrument [Mutually exclusive]	Policy instruments that are intended to directly affect the nature, type, quantity, distribution of goods and services in society. Adapted to an adaptation contexts. From Howlett (2000) and Henstra (2016).	1. <i>Not substantive</i> 2. <i>Regulation</i>: Laws defining responsibilities, conferring decision-making authority, defining liabilities, enabling other instruments. [Authority] 3. <i>Inter-governmental mandate</i>: Directives requiring adaptation by other levels of government. [Authority] 5. <i>Spatial planning</i>: Rules for allocating land uses, public space design standards (including tree planting). [Authority] 6. <i>Infrastructure performance standards</i>: Standards for infrastructure performance, including performance assessment requirement (e.g. flood risk assessment). [Authority] 7. <i>Building regulations</i>: Rules for building and construction standards. [Authority] 8. <i>Strategic planning</i>: Adoption of policy guidance documents that integrate adaptation considerations in impacted sectors (including sustainability planning). [Authority] 17. <i>Adaptation planning</i>: Adoption of policy guidance documents for adaptation (including climate or resilience plans that cover adaptation). [Authority]

Table 2 Indicator list

ID	Indicator	Definition	Field Options
12	Type of procedural policy instrument [Mutually exclusive]	Policy instruments that are intended to influence the network relationships among actors in a policy system. Adapted to an adaptation contexts. From Howlett (2000) and Henstra (2016).	9. <i>User charges</i> : Fees paid on the basis of service usage. [Treasure]
			10. <i>Grants or subsidies</i> : Financial transfers awarded on a conditional basis. [Treasure]
			11. <i>Loans</i> : Financial transfers given on the basis of repayment. [Treasure]
			12. <i>Direct expenditures</i> : Capital investments (e.g. road works, parks, tree planting); land acquisition. [Treasure]
			13. <i>Demonstration projects</i> : Use of government-owned facilities to demonstrate new ideas or technologies. [Organization]
			14. <i>Operations</i> : Procurement; (emergency) response procedures; procedures for updating policies and protocols; routine maintenance; best practices implementation; regular inspections of infrastructure, etc. [Organization]
			15. <i>Facilities</i> : Adapting city facilities to different purposes (e.g. cooling centres); upgrading city-owned properties. [Organization]
			16. <i>Other</i>
			1. <i>Not procedural</i>
			2. <i>Exhortation</i> : Normative arguments to persuade actors to engage in adaptation action. Including endorsements of action from other levels of government or non-state actors and feedback to other levels of government on strategic plans. [Nodality]
			3. <i>Advice</i> : Sharing of knowledge and experience with other agencies or departments in government or key stakeholders. [Nodality]
			4. <i>Education and training</i> : Formalized knowledge-sharing aimed at local government staff and/or key stakeholders. [Nodality]
			5. <i>Reports and assessments</i> : Change system modelling, impact and vulnerability assessments, or scenario-based planning tools. [Nodality]
			18. <i>Monitoring and evaluation</i> : Monitoring changes in exposure or adaptive capacity (i.e. environmental and social conditions). [Nodality]
			NOTE: Moved from #4 under ID11.
			6. <i>Knowledge network</i> : Collaborative actor networks for the purpose of sharing ideas, knowledge, and experience on adaptation. [Nodality]
			7. <i>Public outreach</i> :

Table 2 Indicator list

ID	Indicator	Definition	Field Options
			General information campaigns to educate communities or stakeholders about climate change and adaptation. [Nodality]
			8. <i>Conferences and workshops</i> : Participation in or hosting of conferences or workshops with stakeholders outside local government. [Nodality]
			9. <i>Agreements</i> : Agreements between governments and/or non-government actors to common policy objectives (both governments at the same level and different levels). Including urban climate networks. [Authority]
			10. <i>Advisory groups creation</i> : Creation of working groups, committees, or boundary organizations for the purpose of better understanding adaptation challenges and providing advice to government on how to act. [Authority]
			11. <i>Labelling</i> : Forms of measurement intended to make individuals aware of climate change concerns and to contribute to good design or production practices and innovation. [Authority]
			12. <i>Research funding</i> : Funding to non-government actors for knowledge production, including scenarios, assessments, projections. [Treasure]
			13. <i>Interest group funding</i> : Funding for groups that participate in or influence public policy based on a common concern. [Treasure]
			14. <i>Hearings</i> : Formal meeting for receiving information on public record from stakeholders on various sides of an issue. [Organization]
			15. <i>Institutional reforms</i> : Creation of new agencies, departments, working groups, committees, personnel positions. City council positions specific to climate change portfolios. [Organization]
			16. <i>Judicial review</i> : Review of executive or legislative decisions by courts. [Organization]
			17. <i>Other</i>
13	Instrument calibration	Specific application of instrument	<i>Open</i> Example: Provide \$1,000 tax credit to land owners that set aside wetlands for conservation. Note: Where calibration has changed over time use the most recent information.
14	Temporal nature of instrument	Nature of impact on the	1. <i>Single instance</i> : Single action occurring at one point in time.

Table 2 Indicator list

ID	Indicator	Definition	Field Options
	<i>[Mutually exclusive]</i>	short, medium, or long term	Example: Assessments or reports; events. 2. <i>Expected end date determined; episodic; transitory</i>: A policy with a designated timeframe; action taken on a pre-determined or contingent schedule (e.g. annual reports, heatwave response plans); effect permanence uncertain if dismantled (e.g. the termination of a special committee, joining a policy network). Example: A strategic plan; a pilot program; an administrative unit or staff position. 3. <i>Permanent</i>: Implementation has a permanent effect on exposure, adaptive capacity, or vulnerability. Example: Infrastructure projects; land use planning; building codes/standards.
15	Instrument target <i>[Inclusive]</i>	Nature of the group whose behaviour the policy instrument seeks to influence	1. <i>Individuals</i>: Population at large 2. <i>Households</i>: Residents of single-family homes or occupants of multi-unit buildings 3. <i>Private sector (business)</i>: Local businesses, real estate development (including multi-unit buildings under application/consideration or construction) 4. <i>Local government</i>: Municipal operations, agencies, departments 5. <i>Senior government</i>: Regional or national governments, international organizations 6. <i>Other</i>
16	Geographical boundaries of target <i>[Mutually exclusive]</i>	Scale of the policy instrument's target.	1. <i>Neighbourhood</i>: Area-specific 2. <i>City-wide</i>: Not area-specific 3. <i>Metropolitan area</i>: Multiple local governments, regional governments 4. <i>Region</i>: Provincial, state government 5. <i>Country</i>: Country-level government 6. <i>Unclear</i> 7. <i>Other</i>
17	Administrative responsibility <i>[Mutually exclusive]</i>	Local government unit responsible for implementation	1. <i>Sustainability or climate change unit</i>: Departments or offices within departments dedicated to climate change policy planning 2. <i>Executive or legislative bodies</i>: Mayor's office, city manager's office, City Council 3. <i>Planning and development department</i>: Department responsible for land use planning, urban design standards, building standards

Table 2 Indicator list

ID	Indicator	Definition	Field Options
			4. <i>Public works</i> : Including infrastructure, and transportation: water, roads, public transportation
			5. <i>Economic development</i> : Department responsible for jobs and local business support
			6. <i>Emergency services</i> : Public safety services responsible for crime prevention, fires services, emergency medical response
			7. <i>Community and Health</i> : Public health services, community services
			8. <i>Energy and environment</i> : Parks, water and air management, energy production and delivery services
			9. <i>Unclear</i>
			10. <i>Other</i>

Table 3: Linkages between governing resource and policy instrument type

Resource type	Substantial policy instruments	Procedural policy instruments
Nodality	Education, training, advice, creation of boundary organizations, production of scenarios and projections	Exhortation, knowledge-sharing networks, hosting conference and workshops, advertising
Authority	Legislation, inter-governmental mandates, regulation (zoning, standards, building codes)	Labelling, political agreements, advisory group creation
Treasure	Direct spending on infrastructure, direct spending on services, asset purchases, grants, subsidies, tax credits, levies, user charges	Research funding, interest group funding
Organization	Demonstration projects, procurements	Institutional reforms (working group creation, department re-organization or creation), evaluations, hearings, judicial reviews

Table 4: Policy mixes by local government

City	Substantive instrument frequency	Procedural instrument frequency	Total observations	Policy mix type
Canada				
Brampton	1	6	7	Complex policy mix
Burnaby	2	5	7	Complex policy mix
Calgary	17	38	55	Complex policy mix
Edmonton	2	9	11	Complex instrument mix
Gatineau	0	3	3	Complex instrument mix
Halifax	48	46	94	Complex policy mix
Hamilton	0	16	16	Complex policy mix
Kitchener	2	4	6	Complex instrument mix
Laval	1	2	3	Complex policy mix
London	23	30	53	Complex policy mix
Longueuil	0	2	2	Complex instrument mix
Markham	2	5	7	Complex policy mix
Mississauga	6	16	22	Complex policy mix
Montreal	37	12	49	Complex policy mix
Ottawa	27	7	34	Complex policy mix
Quebec	0	2	2	Complex policy mix
Regina	1	3	4	Complex policy mix
Richmond	24	16	40	Complex policy mix
Saskatoon	52	22	74	Complex policy mix
Surrey	60	49	109	Complex policy mix
Toronto	90	121	211	Complex policy mix
Vancouver	41	41	82	Complex policy mix
Vaughn	3	10	13	Complex policy mix
Windsor	15	10	25	Complex policy mix
Winnipeg	1	3	4	Complex instrument mix
France				
Aix-en-Provence	13	7	20	Complex policy mix
Angers	15	23	38	Complex policy mix
Bordeaux	39	42	81	Complex policy mix
Brest	4	7	11	Complex policy mix
Clermont-Ferrand	8	15	23	Complex policy mix
Dijon	4	10	14	Complex policy mix
Grenoble	13	35	48	Complex policy mix
Le Havre	0	2	2	Complex policy mix
Le Mans	5	3	8	Complex policy mix
Lille	3	5	8	Complex instrument mix
Limoges	1	7	8	Complex policy mix
Lyon	33	24	57	Complex policy mix
Marseille	21	27	48	Complex policy mix
Montpellier	11	7	18	Complex policy mix
Nantes	2	5	7	Complex policy mix
Nice	4	7	11	Complex policy mix
Nimes	1	1	2	Complex policy mix

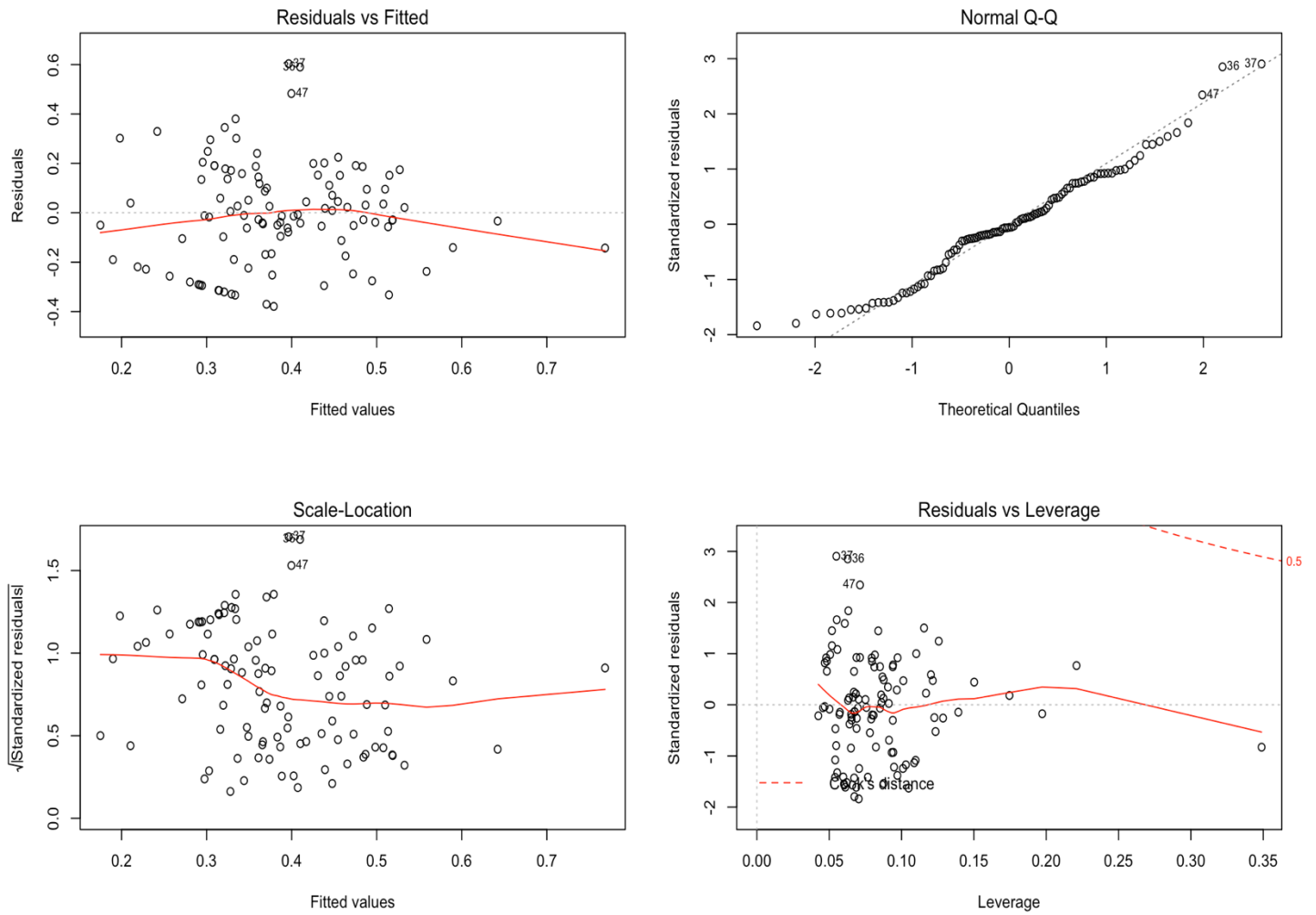
Paris	52	29	81	Complex policy mix
Reims	1	1	2	Complex policy mix
Rennes	5	2	7	Complex policy mix
Saint-Étienne	1	4	5	Complex policy mix
Strasbourg	13	15	28	Complex policy mix
Toulon	2	0	2	Complex policy mix
Toulouse	24	28	52	Complex policy mix
Villeurbanne	20	18	38	Complex policy mix
Germany				
Berlin	35	17	52	Complex policy mix
Bochum	26	18	44	Complex policy mix
Bonn	3	5	8	Complex policy mix
Bremen	19	32	51	Complex policy mix
Cologne	13	1	14	Complex policy mix
Dortmund	0	2	2	Complex policy mix
Dresden	0	1	1	Complex policy mix
Duisburg	1	3	4	Simple instrument mix
Düsseldorf	10	10	20	Complex policy mix
Essen	2	1	3	Complex policy mix
Frankfurt	3	2	5	Complex policy mix
Gelsenkirchen	2	3	5	Complex policy mix
Hamburg	39	39	78	Complex instrument mix
Hannover	22	14	36	Complex policy mix
Karlsruhe	76	40	116	Complex policy mix
Mannheim	0	3	3	Complex policy mix
Munich	17	16	33	Complex instrument mix
Munster	11	8	19	Complex policy mix
Nuremberg	25	7	32	Complex policy mix
Stuttgart	31	10	41	Complex policy mix
Wuppertal	0	2	2	Complex policy mix
Netherlands				
Almere	1	0	1	Simple policy mix
Amersfoort	1	2	3	Complex policy mix
Amsterdam	18	8	26	Complex policy mix
Apeldoorn	6	2	8	Complex policy mix
Arnhem	2	1	3	Complex policy mix
Breda	5	7	12	Complex policy mix
Den Haag	13	7	20	Complex policy mix
Dordrecht	0	1	1	Simple policy mix
Ede	1	0	1	Simple instrument mix
Eindhoven	12	8	20	Complex policy mix
Enschede	17	0	17	Complex policy mix
Groningen	1	1	2	Complex policy mix
Haarlem	3	4	7	Complex policy mix
Haarlemmermeer	3	1	4	Complex policy mix
Hertogenbosch	10	6	16	Complex policy mix
Leiden	6	1	7	Complex policy mix
Maastricht	1	0	1	Simple policy mix

Nijmegen	3	3	6	Complex policy mix
Rotterdam	12	15	27	Complex policy mix
Tilburg	6	7	13	Complex policy mix
Utrecht	9	6	15	Complex policy mix
Zaanstad	1	1	2	Complex policy mix
Zwolle	6	3	9	Complex policy mix
United Kingdom				
Barnet	5	2	7	Complex policy mix
Belfast	1	1	2	Complex policy mix
Birmingham	9	10	19	Complex policy mix
Bradford	5	7	12	Complex policy mix
Bristol	20	15	35	Complex policy mix
Cardiff	17	25	42	Complex policy mix
Cheshire East	10	7	17	Complex policy mix
Cornwall	23	14	37	Complex policy mix
Coventry	16	10	26	Complex policy mix
Croydon	16	29	45	Complex policy mix
Durham County Council	15	28	43	Complex policy mix
Ealing	7	1	8	Complex policy mix
East Riding of Yorkshire	43	27	70	Complex policy mix
Edinburgh	37	52	89	Complex policy mix
Fife	41	44	85	Complex policy mix
Glasgow	18	50	68	Complex policy mix
Kirklees	13	8	21	Complex policy mix
Leeds	36	41	77	Complex policy mix
Leicester	17	21	38	Complex policy mix
Liverpool	29	27	56	Complex policy mix
Manchester	40	25	65	Complex policy mix
Newham	6	1	7	Simple instrument mix
North Lanarkshire	0	1	1	Complex policy mix
Sheffield	29	17	46	Complex policy mix
Wiltshire	32	38	70	Complex policy mix

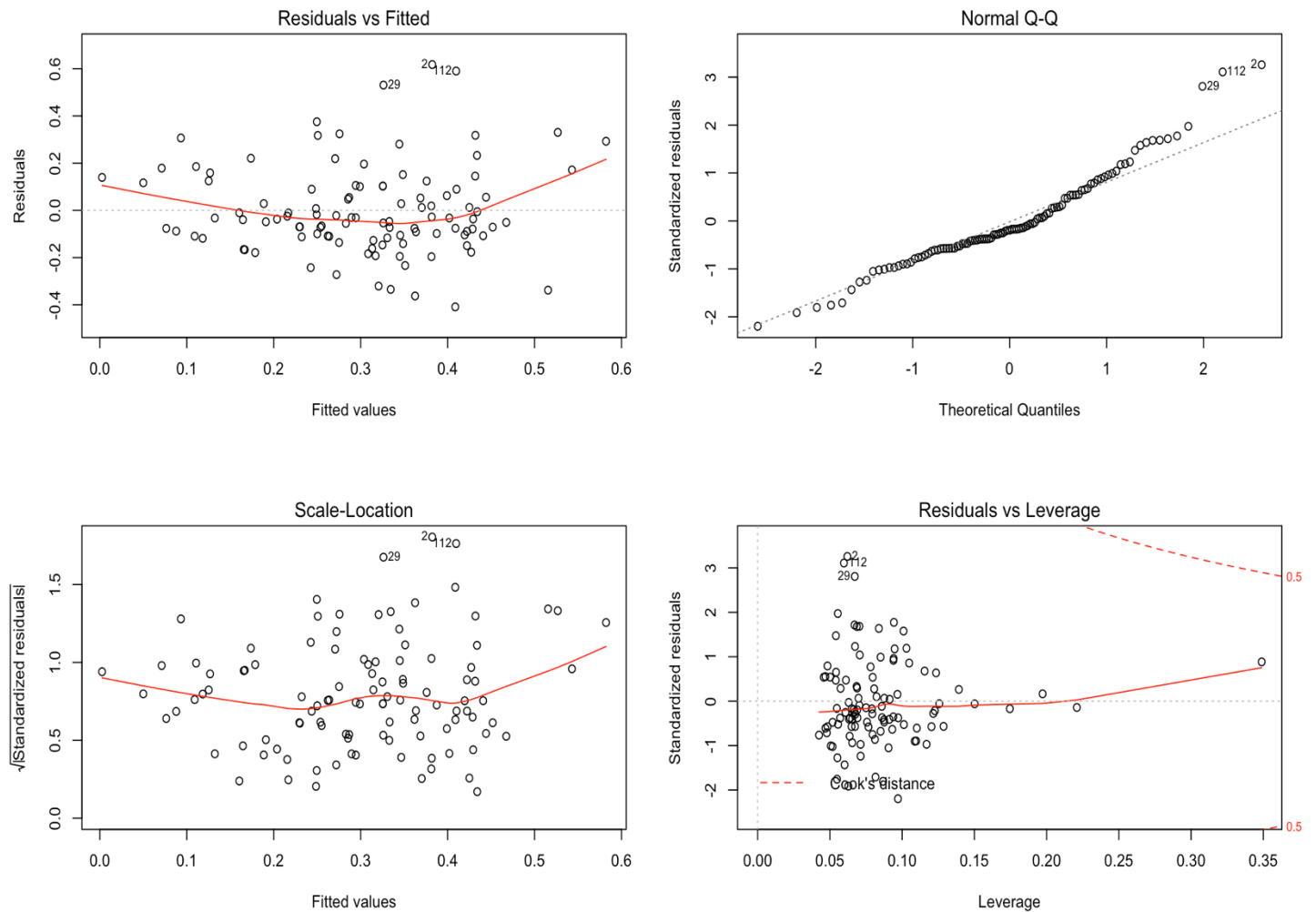
APPENDIX B

Supplemental materials for Chapter 5

1) Linear regression for public provision and oversight



2) Linear regression for regulatory corporatism



Removal of outliers [2, 29, 112]:

	Estimate	Std. Error	t value	Pr(> t)
(Intercept)	0.3519985	0.4178964	0.842	0.401730
pop.log	-0.0106164	0.0312827	-0.339	0.735079
total	-0.0013305	0.0006197	-2.147	0.034341 *
employ_manu	-0.0058422	0.0048763	-1.198	0.233871
simpsons	0.2663418	0.0724686	3.675	0.000393 ***
factor(Country)France	-0.0149265	0.0567438	-0.263	0.793081
factor(Country)Germany	-0.0267165	0.0500840	-0.533	0.594979
factor(Country)Netherlands	0.0254024	0.0674357	0.377	0.707244
factor(Country)UK	0.1568929	0.0620266	2.529	0.013071 *

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

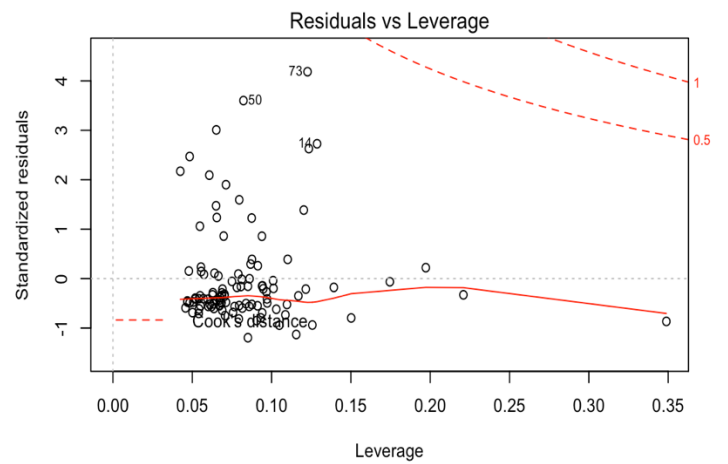
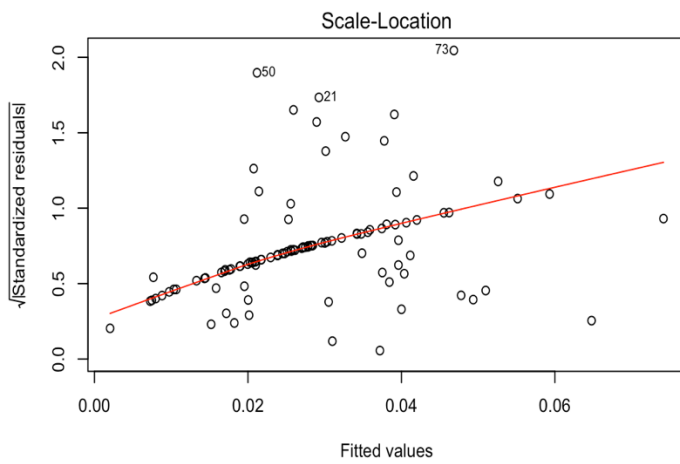
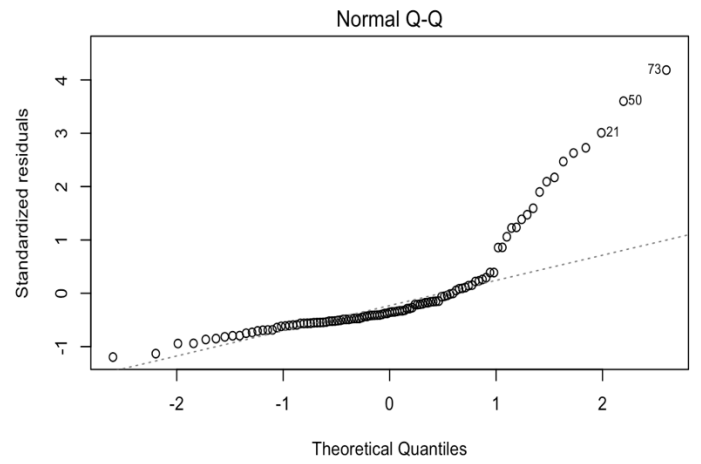
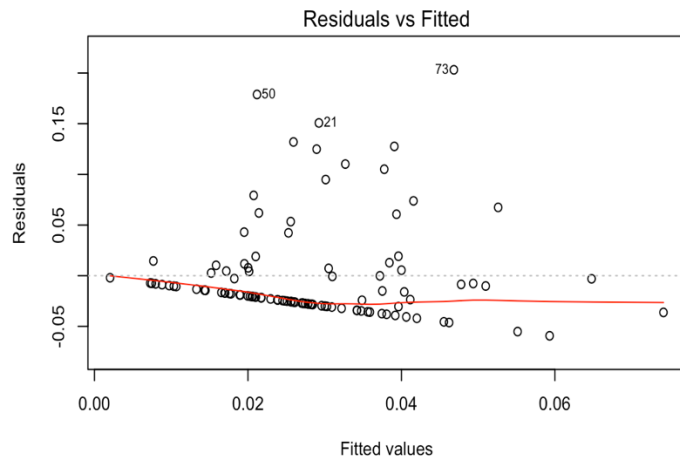
Residual standard error: 0.1677 on 95 degrees of freedom

(18 observations deleted due to missingness)

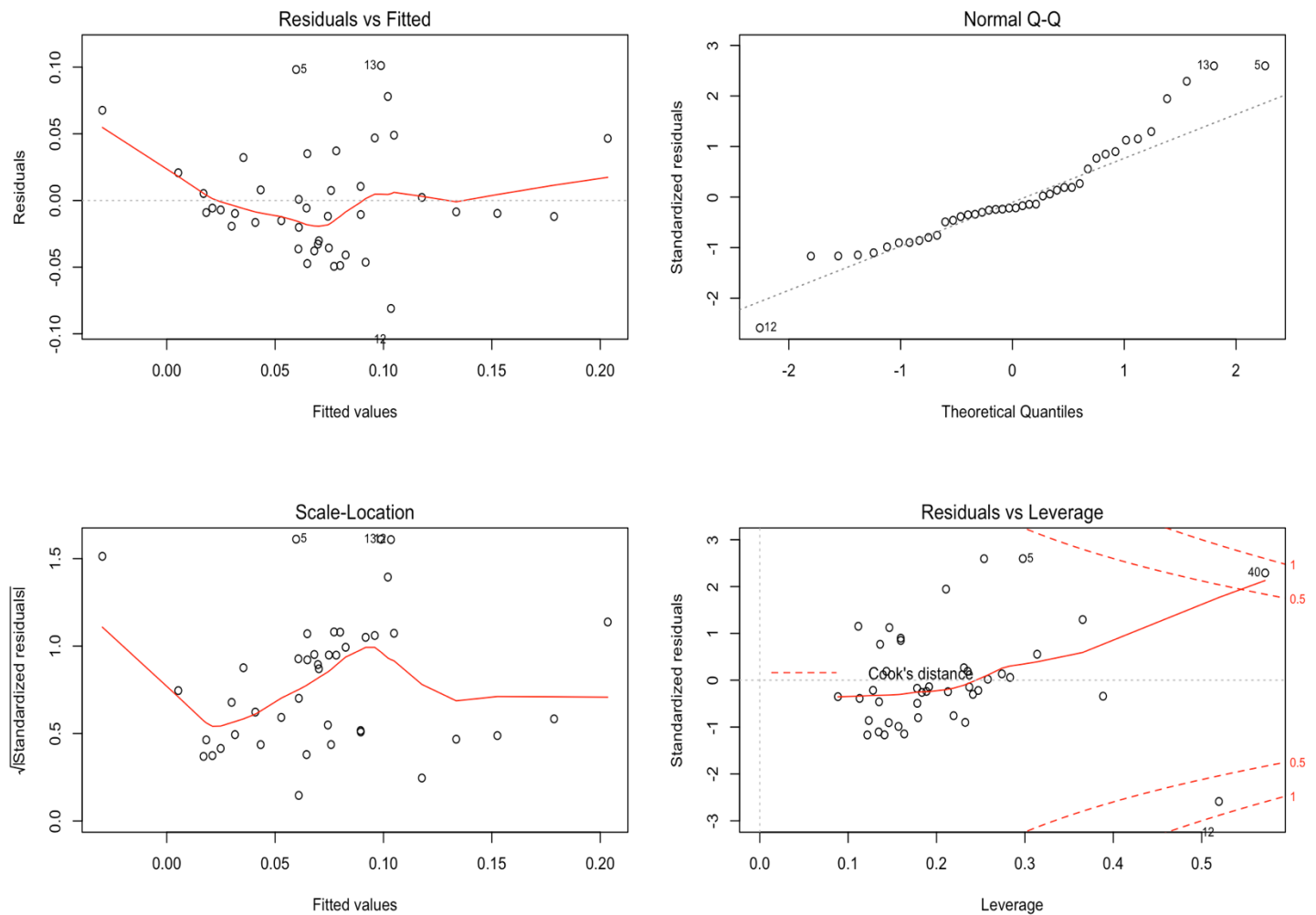
Multiple R-squared: 0.3036, Adjusted R-squared: 0.2449

F-statistic: 5.176 on 8 and 95 DF, p-value: 2.249e-05

3a) Linear regression for directed subsidization (all observations)



3b) Linear regression for directed subsidization (observations with ds = 0 removed)



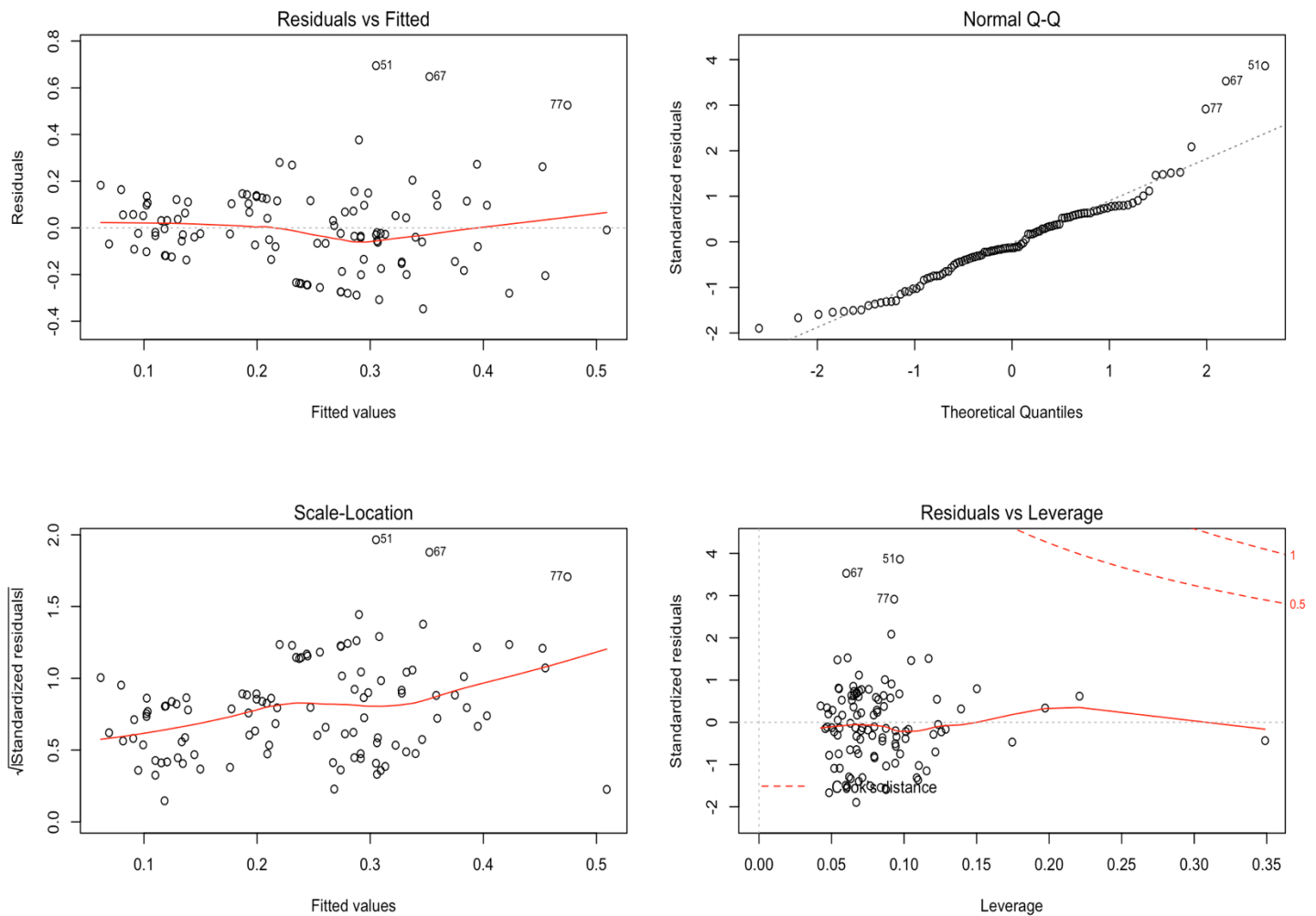
Removal of outliers [5, 12, 13, 40]:

	Estimate	Std. Error	t value	Pr(> t)
(Intercept)	0.1225535	0.1507058	0.813	0.42193
pop.log	0.0061847	0.0109393	0.565	0.57565
total	-0.0005660	0.0002185	-2.591	0.01415 *
employ_manu	-0.0007171	0.0022690	-0.316	0.75394
simpsons	-0.1393232	0.0355272	-3.922	0.00042 ***
factor(Country)France	0.0156871	0.0231713	0.677	0.50312
factor(Country)Germany	-0.0006791	0.0210559	-0.032	0.97446
factor(Country)Netherlands	-0.0048292	0.0330237	-0.146	0.88463
factor(Country)UK	-0.0476554	0.0270673	-1.761	0.08757 .

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.04512 on 33 degrees of freedom
(2 observations deleted due to missingness)
Multiple R-squared: 0.5426, Adjusted R-squared: 0.4317
F-statistic: 4.893 on 8 and 33 DF, p-value: 0.0004835

4) Linear regression for institutionalized volutarism



Removal of outliers [51, 67, 77]:

	Estimate	Std. Error	t value	Pr(> t)
(Intercept)	0.1747669	0.3798837	0.460	0.64653
pop.log	0.0074077	0.0282373	0.262	0.79363
total	0.0002253	0.0005614	0.401	0.68906
employ_manu	0.0069503	0.0044954	1.546	0.12541
simpsons	-0.1358576	0.0668726	-2.032	0.04499 *
factor(Country) France	0.0149686	0.0540066	0.277	0.78226
factor(Country) Germany	-0.1300747	0.0464813	-2.798	0.00622 **
factor(Country) Netherlands	-0.0190547	0.0629755	-0.303	0.76288
factor(Country) UK	-0.1406990	0.0578763	-2.431	0.01693 *

 Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.1521 on 95 degrees of freedom
 (18 observations deleted due to missingness)
 Multiple R-squared: 0.2286, Adjusted R-squared: 0.1636
 F-statistic: 3.518 on 8 and 95 DF, p-value: 0.001325

5) OLS regression models for regulatory corporatism ~ VFI

```
              Estimate Std. Error t value Pr(>|t|)
(Intercept)  0.1950296  0.0382380    5.10 1.25e-06 ***
vfi          0.0030098  0.0008005    3.76 0.000261 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.2235 on 123 degrees of freedom
Multiple R-squared:  0.1031,    Adjusted R-squared:  0.09579
F-statistic: 14.14 on 1 and 123 DF,  p-value: 0.0002615
```

6) OLS regression models for directed subsidization ~ VFI

```
              Estimate Std. Error t value Pr(>|t|)
(Intercept)  0.0353194  0.0082687    4.271 3.85e-05 ***
vfi          -0.0002580  0.0001731   -1.490   0.139
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.04832 on 123 degrees of freedom
Multiple R-squared:  0.01774,    Adjusted R-squared:  0.009753
F-statistic: 2.221 on 1 and 123 DF,  p-value: 0.1387
```

7) OLS regression models for public provision and oversight ~ National portfolio size

```
              Estimate Std. Error t value Pr(>|t|)
(Intercept)  0.225856   0.060435    3.737 0.000284 ***
nat_total    0.002814   0.001072    2.625 0.009758 **
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.2303 on 123 degrees of freedom
Multiple R-squared:  0.05306,    Adjusted R-squared:  0.04536
F-statistic: 6.892 on 1 and 123 DF,  p-value: 0.009758
```

8) OLS regression models for direct subsidization ~ Country size

```
              Estimate Std. Error t value Pr(>|t|)
(Intercept)  2.102e-02  5.000e-03    4.205 4.99e-05 ***
size         1.681e-09  1.116e-09    1.506   0.135
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.04831 on 123 degrees of freedom
Multiple R-squared:  0.01811,    Adjusted R-squared:  0.01012
F-statistic: 2.268 on 1 and 123 DF,  p-value: 0.1346
```

APPENDIX C

Supplemental materials for Chapter 6

The following section describes the steps followed to implement a topic modeling analysis, taking the two cases as examples.

1. MODEL CHOICE

LDA is a probabilistic model, and functions by identifying distributions among topics to predict the probability of document membership in given topics. Here we use two versions of the LDA model as a general introduction to topic modeling applications. These two LDA models use different approaches to determining performance stability in the model output.

1.1 Model choice: COP speeches

Our first example uses the *Topic Models* R package (Grün and Hornik 2011), a LDA model with Gibbs sampling. The underlying statistical basis of the LDA model is explained in Blei et al.'s original paper (Blei, Ng, and Jordan 2003), while the theory behind Gibbs sampling is explained by Darling (Darling 2011) and Resnik (Resnik et al. 2009) among others.

1.2 Model choice: Canadian local government records

The second example uses a robust latent Dirichlet allocation model (*rllda* package in Python) to determine the robustness of topics (see 3.4.2 for a more detailed explanation). The explanation for this approach can be found in Wilkerson and Casas's study of United States Congressional floor speeches (Wilkerson and Casas 2017). This methodology addresses problems of k validation and topic model instability by identifying clusters of similar topics present across a set of topic models within a range of k -values.

2. DATA COLLECTION

2.1 Data collection: COP speeches

Three-minute speeches from the high-level segment of the Conference of Parties (COP) of the United Nations Framework Convention on Climate Change (UNFCCC) were downloaded from the UNFCCC official website, covering speeches made by representations of 197 countries in the period from 2010 (COP16 in Cancun) to 2016 (COP22 in Marrakech) (n=1,315).

2.2 Data collection: Local government meeting minutes

City council meeting records for Canada's largest 25 cities were systematically searched for the period from January 2010 to May 2017 using the keywords "climate change" (English-speaking cities) and "climat" (French-speaking cities). All the local government documents containing references to climate change were then assembled as the preliminary corpus (n=1,644). These documents include meeting minutes, staff reports, by-laws, and strategic planning documents.

3. DATA PRE-PROCESSING

Once documents are acquired, they must be streamlined into identical formatting (typically from PDF or Word documents to text files). Data processing involves dealing with various idiosyncrasies of document sets. The texts used in both the examples here, for example, include multiple languages, and included both machine-readable and not machine-readable documents (i.e. non-searchable PDFs).

3.1 Data pre-processing: COP speeches

We processed the documents into a readable format using R. Where files were not machine-readable, Optical Character Recognition (OCR) was employed using the *Tesseract* package in R.(Ooms 2018) For files in French and Spanish, translation into English was done simultaneously with OCR using Tesseract’s built-in translation capabilities. For miscellaneous documents in other languages (e.g. Arabic, Russian), manual translation was conducted before OCR, using Google Documents’ built-in translation feature, which relies on Google Neural Machine Translation.(Y. Wu et al. 2016) In the second step, the documentation was processed to separate adaptation-relevant content from text concerned with mitigation. The corpus was formed from the 30 words surrounding each reference to “adapt*”.⁶ This narrow word selection reflects the fact that each COP speech is short in nature, and we needed to be conservative in word selection to limit the possibility that segments of the speeches concerned with mitigation would influence the topic results. Using the *Quanteda* package in R,(Benoit et al. 2018) the texts were compiled into the COP speech corpus.

3.2 Data pre-processing: Canadian local government records

As with the COP speeches, the first step with this case was to process the documents into a readable format using OCR. Here we are only interested in the adaptation content of these documents, and needed to isolate these segments of text from those that are not relevant to our research question. To isolate climate change-relevant content from the local government records, we selected a buffer of ten pages surrounding the term “climate change” (or “climat” for French texts), and then exported this text for pre-processing and translation. We manually

⁶ Using GLOB terminology, searches for “adapt*” match any number of characters to the wildcard (e.g. adaptation, adapting), while “adapt?” matches only one character to the wildcard space (e.g. adapt, adapts).

checked for instances where “climate change” or “climat” were not identified due to text-specific features such as table rotation and corrected any errors.

In comparison to the COP speeches, the local government documents were very long and had greater diversity in terminology used to refer to adaptation. We therefore adopted a two-step approach to paring down the text to the final corpus. First, a list was generated of the 1,400 most frequently occurring words within the 400 words surrounding “climate change” in all documents. Second, two of the authors separately identified all adaptation-relevant keywords in this list, and cross-referenced the lists to produce a final list of inductively-generated adaptation-relevant keywords: adapt*, risk*, protect*, vulnerab*, emergenc*, security, resilien*, recover*, prevent*, hazard\$, prepar*, disaster\$, impact\$, mitigate. Within each document, the 400 words surrounding each of these terms was retained for analysis. Using the *Quanteda* package in R (Benoit et al. 2018), this text was compiled into the Canadian local government corpus.

3.3 Final corpus preparation (both datasets)

The final step was cleaning both corpuses of stopwords. This involves removing words and symbols with no substantive information (e.g. “the”, “and”, and “or”) to improve topic coherence and reduce computational time (Hoffmann, Bach, and Blei 2010; Boyd-Graber and Blei 2009). The most frequently occurring features of the remaining corpuses were then inspected, and additional stopwords specific to that corpus were identified and removed (e.g. formalities such as “madame”, “gentlemen”, place names, boilerplate terms, procedural terms). Similarly, punctuation, separators, numbers and symbols were removed from each corpus (Benoit, Muhr, and Watanabe 2017; Lewis et al. 2004). Given a larger overall vocabulary volume in the Canadian local government corpus, extremely rare words (any words occurring <5 times in the corpus) were also removed. The final vocabulary size was 3,069 words for the COP

corpus, and 21,243 words for the municipal corpus. During this process, each corpus was transformed into a term-document matrix, where each document is represented as a row and each column represents the presence/absence of a given term.

4. Processing: Model calibration

While LDA is a type of unstructured machine learning, analysts still must provide instructions to the model with regards to the number of topics (k) to be generated.

4.1 Model calibration: COP speeches

Same-text perplexity was plotted at a range of k -values between $k = \{5, 100\}$, to determine an initial range of suitable k -values. The final selection of model parameters followed an inductive approach, and settled on $k = 25$ following a comparison of several k models. This approach reflects the exploratory nature of this example, wherein the model is intended to provide an overview of major themes that emerge in COP speeches. Subsequently, the research team identified and removed 6 non-substantive topics (i.e. topics composed of words such as “will,” “effort,” “decis,” “take,” etc.), and calculated posterior probabilities for each topic in a document. The means of these posterior probabilities were used to calculate the most commonly occurring topics by country and by year.

4.2 Model calibration: Canadian local government records

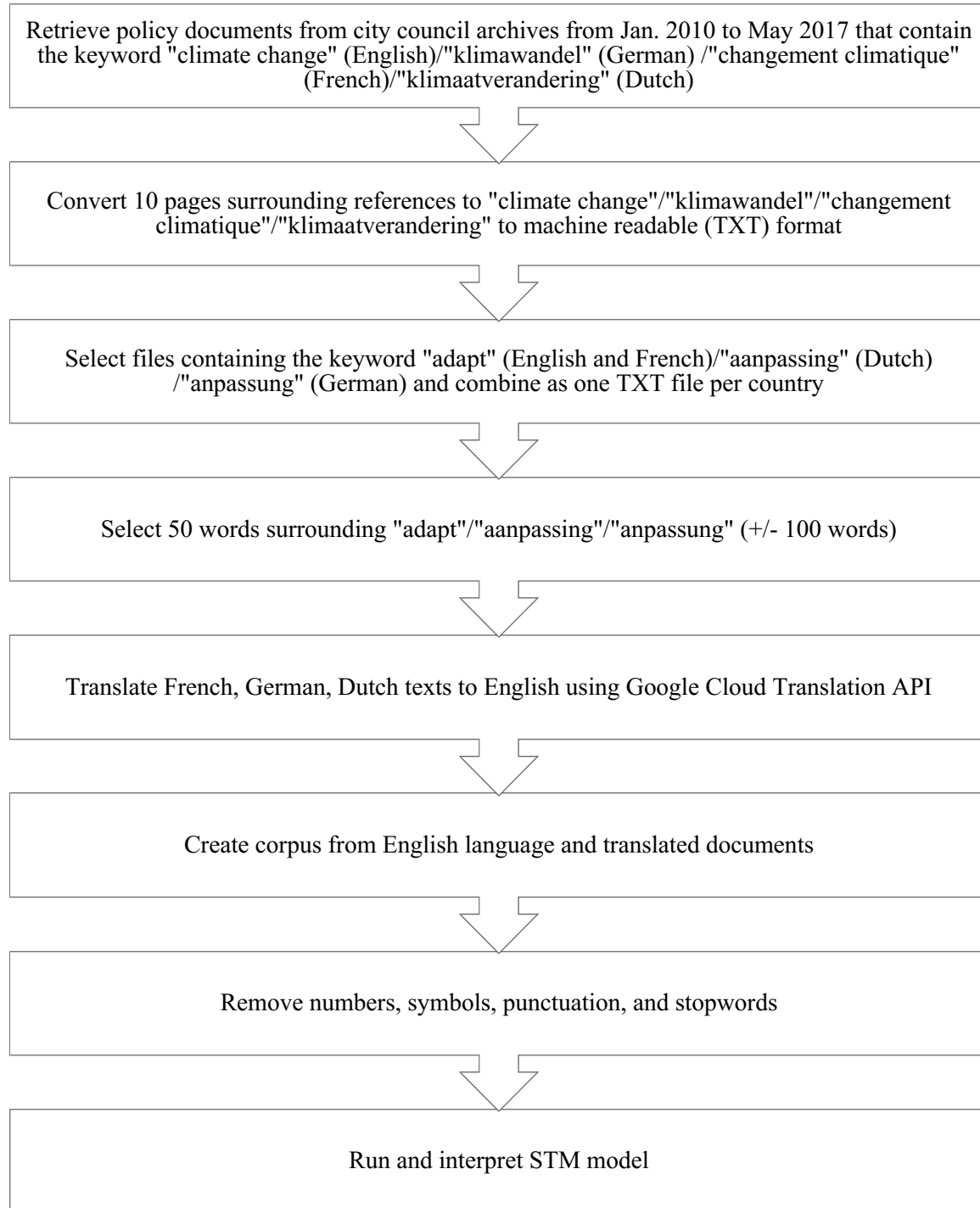
For this case study, the robust LDA model was used, building on the methodology piloted by Wilkerson and Casas (Wilkerson and Casas 2017). Accordingly, our case study aggregates similar topics discussed over differently specified topic models. Using the Python package *rllda*, a set of topic models was generated using Gibbs sampling for $k = \{20, 21, \dots, 40\}$, with 21 models containing 630 topics in total (Wilkerson and Casas 2017). Then, using pairwise cosine

similarity, the spectral clustering algorithm was used to group the 630 topics generated across all 21 models by cosine similarity. The algorithm groups the most alike pairs together by maximizing the average intra-cluster cosine similarity for a given number ($c = \{5, 6, \dots, 100\}$) of clusters c (Wilkerson and Casas 2017), here indicating stabilization at approximately 30 clusters. Finally, non-substantive clusters were eliminated ($n=5$), and where clusters were similar in content, they were grouped into 20 meta-topics by the research team.

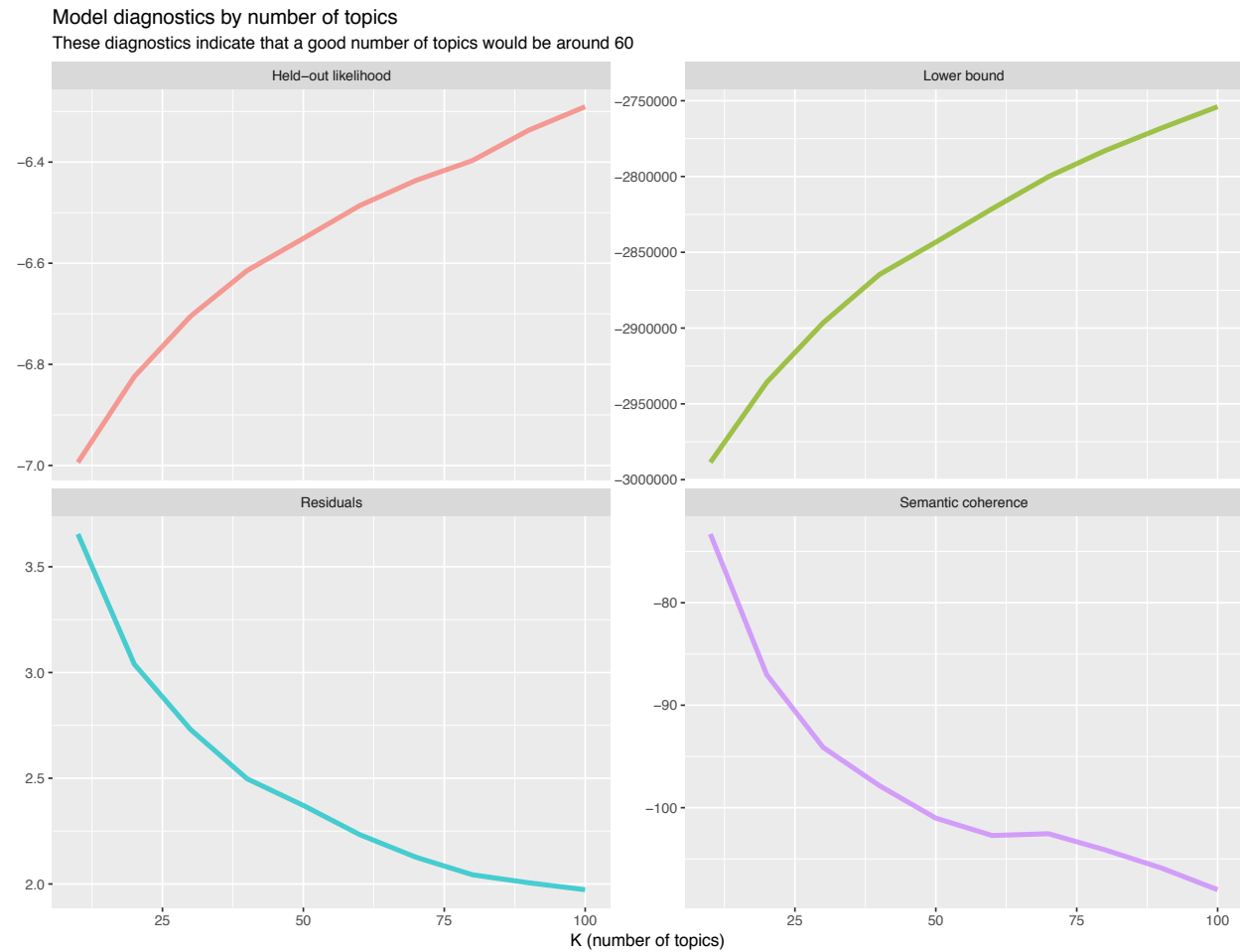
APPENDIX D

Supplemental materials for Chapter 7

Methodological approach:



1. Plotted outputs of model diagnostics for $k = 10, 20, 30 \dots 100$. Determination of k selection is based on held-out likelihood, referring to predictive power of models from training data to test data, exclusivity, and semantic coherence.



Comparing exclusivity and semantic coherence

Models with fewer topics have higher semantic coherence for more topics, but lower exclusivity

