Title
Urban Political Ecology of Global Urban Climate Change Mitigation

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Publication Date
2020

Peer reviewed|Thesis/dissertation

UNIVERSITY OF CALIFORNIA,

IRVINE

Urban Political Ecology of Global Urban Climate Change Mitigation

DISSERTATION

submitted in partial satisfaction of the requirements

for the degree of

DOCTOR OF PHILOSOPHY

in Sociology

by

Benjamin Leffel

Dissertation Committee:
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Professor David J. Frank
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2020

DEDICATION

To

Richard V. Knight

Whose mentorship, vision of world cities and words inspire inquiry and action

Cities, having been eclipsed by nationalization, and now, globalization, have an opportunity to reassert themselves.

(Richard V. Knight, *Cities in a Global Society*, 1989: 25)

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGEMENTS

I am grateful to my committee chair, Professor David A. Smith, whose scholarship on global cities brought me to UC Irvine, and whose persistent critique has allowed own inquiry on this subject to realize its fullest potential.

I am also thankful for my committee members. The interdisciplinary expertise on institutions, global climate change governance and urban planning of Professors David Frank, Wang Feng, Michael Prather and Scott Bollens granted my dissertation the clarity to advance the state of knowledge on global urban climate change mitigation.

I am also grateful for Professor Michele Acuto at the University of Melbourne, with whom my ongoing collaboration made possible the inclusion of rich data on transnational municipal networks in this dissertation. I would further like to thank Annette Buckley of UCI Libraries for helping me ensure that my cross-database search of firm-level data was as comprehensive in coverage as is presently possible.

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ABSTRACT OF THE DISSERTATION

Urban political ecology of global urban climate change mitigation
by
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Doctor of Philosophy in Sociology
University of California, Irvine, 2020
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What explains city-level greenhouse gas emissions reduction on a global-scale, and what lessons does this hold for global climate change governance? This dissertation analyzes emissions change in 330 cities across 49 countries during 2005-2013, and finds through statistical analysis that strongly associated with emissions reductions are the local concentration of environmental management consultancies, city memberships in environmentally-oriented transnational municipal networks and the stringency of national climate change regulation. Qualitative inquiry reveals that the former two city-level mechanisms affect emissions reductions via cost-minimizing energy performance contracts and related climate policy services and expertise. It also finds that the carbon market, specifically the EU emissions trading system and Clean Development Mechanism, does not achieve the emissions reductions for which it was designed.

CHAPTER 1 Introduction

Human activity has caused increases in greenhouse gas emissions that drive global climate change (Santer et al., 1993; IPCC, 2013), and efforts to reduce these anthropogenic emissions is now the defining global governance and human survival challenge of our time. To define the stakes, unmitigated climate change poses major health hazards (IPCC, 2014), including worsening heat waves, threatening access to food, housing and clean water, substantially increased risk of famine, conflict, sociopolitical instability, unemployment (Adger et al., 2014) and extinction across a wide range of species (Foden et al., 2018; Thomas et al., 2004). The present global economic recession and loss of life resulting from the novel coronavirus (COVID-19) pandemic is being called a “dress rehearsal” for the coming effects of climate change if insufficiently mitigated, prompting calls for a major global shift in our economic development approach to support accelerated climate mitigation (Latour, 2020).

As the site of the greatest spatial concentration of human activity driving anthropogenic emissions increases, the modern city holds immense potential to reduce emissions globally. The objective of this project, then, is to identify urban-level factors and socio-technical processes that are associated with urban emission reduction, and in so doing achieve progress toward a systemic, global understanding of urban climate change mitigation. With local authorities recognized as key actors for implementing post-pandemic “green recovery” policy interventions to shift economic development toward long-term low-carbon growth (Bozuwa et al., 2020), this project can also yield actionable insights for the urban role in achieving green recovery.

Most research identifies economic development factors as driving increasing emissions and describes institutional environmental reform efforts, income-related factors and civil society mechanisms as driving the reduction of emissions (Jorgenson et al., 2019; Jorgenson and Clark, 2012; Schofer and Hironaka, 2005). These bodies of research focus on the national-level of emissions change, partly in order to analyze total global emissions, and partly due to the relatively greater availability of national-level emissions data than at lower scales such as the state/provincial- or city-level. However, the core narrative I argue in this dissertation is that city-level factors matter for global greenhouse gas emissions reduction.

Measures of greenhouse gas emissions in their most precise and granular form are at the point-source or facility level, or the level identifying the specific conveyance(s)—such as pipes and vents—from which emissions are discharged. The city is the geographically-defined jurisdictional unit housing the greatest concentration of point-source emissions, as most energy resources are consumed in cities (Dodman, 2009; Prather et al., 2001; Van der Heijden, 2019). Cities are also the largest contributor to national greenhouse gas emissions driving global climate change (Kennedy et al., 2009; Kennedy et al., 2012). That is, in any given country, urban areas contribute the majority of greenhouse gas emissions comprising the aggregate national emissions, the contribution by suburban and rural areas being smaller by comparison.

Increasing recognition of this reality motivates growing calls across social science disciplines for more research at the city-level of climate mitigation outcomes (Bulkeley et al., 2014; Jorgenson, 2016), which I seek to fulfill in this study. This means that most existing theory, and the national-level emissions change analysis it is based on, miss important mechanisms associated with and potentially causal mechanisms for emissions reduction.

Given the evident necessity for understanding urban emissions change, I ask, what drives emissions reduction at the city-level on a global-scale? In Chapter 2, I discuss extant literature and theory on the determinants of national-level greenhouse gas emissions change and identify gaps in these bodies of theory. I then establish the theoretical and empirical need to study city-level emissions change on a global-scale, and hypothesize factors explaining global urban climate mitigation outcomes that serve to fill gaps in existing bodies of theory while charting new theoretical pathways for understanding this phenomenon. In Chapter 3, I perform a statistical analysis to quantitatively test these hypotheses, revealing factors associated with urban emissions reduction on a global-scale. In Chapter 4, I pinpoint the ground-level processes represented by these processes through qualitative analysis of individual cases of urban climate change mitigation, and in Chapter 5, I synthesize and summarize findings, discuss empirical and theoretical implications and chart pathways forward for future researchers.

CHAPTER 2: Toward a subnational theory of global environmental change

Existing theory on emissions change

While some existing research on greenhouse gas emissions change focuses on the collective global-level, including global population growth and land use intensification as drivers of emissions increases (Knapp and Mookerjee, 1996; Suh et al., 2020), the world is traditionally thought of as a sum of its national parts. Hence most research on global climate change governance focuses on national-level greenhouse gas emissions and corresponding national-level factors explaining the emissions change. Broadly, this research highlights economic conditions and governance institutions of both the governmental and non-governmental sort as important drivers of emissions change (Jorgenson et al., 2019; Zehr, 2015). In the sections below, I outline these bodies of theory, identify gaps and offer pathways toward a subnational theory of global environmental governance.

A longstanding division in social science theory is that of materialism versus idealism. Materialism most attributes social outcomes to technical-economic forces while idealism attributes social outcomes to cultural-symbolic forces (Adler and Borys, 1993). Materialist thought assumes that actors and the processes they carry out are motivated by the pursuit of economic well-being and value, political power and perpetuating ongoing cycles of capitalist exploitation for growth and profit (Hornborg, 2014; Kilbourne et al., 2017).

Outcomes of interest also include differential anthropogenic environmental change, for which materialist and idealist theories investigate the coevolution of nature and society (Burkett and Foster, 2006). In environmental sociology, materialist approaches place organizational actions and their environmental outcomes within political-economic contexts, including the power relations inherent in capitalist systems (Shwom, 2009). Idealist approaches stress the developmental impact of cultural models, or beliefs and values, such that these models identify specific goals for development and means for achieving them (Thornton et al., 2015).

The materialist and idealist division continues to define social science theory of global environmental change. A materialist approach explaining the global political-economic context of environmental change is ecologically unequal exchange theory. Following from Bunker's work on extractive patterns in global trade affecting local environmental outcomes (1985), ecologically unequal exchange argues that cross-national environmental outcomes are dependent in part on a nation's structural position in international trade flows (Ciccantell, 2019). Structural position and the resultant unequal environmental outcomes are defined by power relations in the world economy, where those occupying the more advantageous positions exploit labor and natural resources for profit while undermining sustainability (Foster, 2000; Gellert, 2019; Hornborg, 2014; Moore, 2015).

Specifically, developed countries extract natural resources from and control the export activity of less developed countries, the result being that the more developed and less developed country parties experience relatively less and more environmental degradation, respectively, including greenhouse gas emissions. Pollution increases are particularly pronounced in less developed countries exporting more manufactured, pollution-intensive, primary sector commodities (Jorgenson, 2016). Less developed countries also experience greater emissions increases due to firms in developed countries externalizing high-polluting operations to less developed countries, or off-shoring carbon-intensive production (Thombs, 2018).

Ecologically unequal exchange explains cross-national variation in greenhouse gas emissions patterns between 1960 and 2005, where the flow of exports from low-income to high-income nations affects markedly stronger emissions increases in the former than the latter (Jorgenson, 2012; Jorgenson and Rice, 2012). These processes perpetuate the causal cycle whereby the capitalist proclivity toward infinite economic growth leads to environmental degradation (Foster, 2000; Gellert, 2019; Hornborg, 2014; Moore, 2015).

Knox-Hayes (2015) notes that more effective climate change governance requires recognition of how norms play a role in decision-making, rather than just the value of profitability. Addressing this gap is world society theory, an idealist approach explaining the discursive and normative factors driving global environmental change, which stresses the prevalence of normative governance models as causally efficacious. This tradition emphasizes the role of norms and institutions, specifically by explaining the conditions in which institutions affect policy outcomes by way of globally-diffused norms, models or scripts. This includes norms of an environmental sort and the associated policy outcomes. World society theory is an idealist tradition because the diffusion process involves the convergence of definitions of environmental problems and solutions, definitions that otherwise vary significantly across cultural, historical and economic divides (Sonnenfeld and Mol, 2002).

Environmental governance norms are argued to diffuse globally and reach national governments via national participation in intergovernmental organizations such as the UN, or via domestic "receptor sites" such as scientific institutes that receive, decode and transmit norms to national government actors (Frank et al., 2000a). In either case, national government then implements world society norms via domestic policy, which takes the form of environmental treaty ratification or other policy measures (Longhofer and Schofer, 2010; Shorette, 2012). This national policy implementation leads to implementation at the subnational level, which ultimately results in improved environmental conditions (Shorette et al., 2017; Swiss, 2018), including the reduction of greenhouse gas emissions (Schofer and Hironaka, 2005). World society theorists characterize this principally as a national government-driven process, where global norm-driven environmental improvements occurring at the subnational-level result only from national policy implementation (Frank et al., 2000a, 2000b; Schofer et al., 2012).

With regard to economic forces, world society theorists recognize that institutional capacity for environmental reform implementation is delimited by level of economic development (Drori, et al., 2003; Schofer et al., 2012), but they do not assume that economic development necessarily leads to environmental degradation (Hironaka, 2014).

Gaps in existing theory

Ecologically unequal exchange and world society theory each contribute unique explanations for cross-national variation in emissions change, the former specifying structural position in international trade and the latter specifying normative governance model diffusion. As macro-scale theories, these traditions are not calibrated to address drivers of environmental outcomes at the city-level. However, subnational components form the national environmental outcomes observed by these theories, of which cities doubtless are a consequential part, particularly given the increasing actorhood of cities in global climate change governance. Specifically, city governments are implementing detailed climate action plans to reduce emissions, some independently of national governments as a response to environmental and economic threats posed by climate change, and others as a response to state/provincial and national government climate policy. These involve the inventorying of urban emissions, identification of high-emitting sectors, and the design and implementation of emissions-reducing measures targeting those sectors (Rice, 2014; Tzaninis et al., 2020).

This points to the necessity to integrate the urban into the macro-scale, national-level theories of global environmental change. This multi-level integration must involve addressing organizational rescaling of global climate change governance to the city-level, and both the political-economic forces and the discursive, or normative, flows affecting urban environmental outcomes. Below I discuss these gaps and argue that urban political ecology and the concept of polycentric systems provide immediate pathways for addressing them.

Ecologically unequal exchange is argued to allow for inference on the local environmental impacts of macro-scale trade patterns, such that it addresses "political ecology of global economic processes and their local repercussions" (Hornborg and Martinez-Alier, 2016: 331) and allows for "analyses from the global to the local of environmental and social harms and the underlying mechanisms that drive these outcomes" (Givens et al., 2019: 2). However, the definition of "local" in all cases are national-level trade flows and their associated environmental outcomes (Jorgenson, 2016), as national-level emissions are comparable and longitudinal.

Given that the national-level is the spatial aggregation of subnational components, subnational units such as cities may nevertheless be assumed as sites that are meaningfully affected by and affect the economic-environmental phenomena posited by ecologically unequal exchange. Bunker's (1985) early work on global extractive forces and environmental outcomes in the Amazon, on which ecologically unequal exchange is in part based, was itself focused on the regional-level, observing community-level environmental outcomes.

The world society tradition assumes that national governments are the key intermediaries between globally-legitimated environmental policy norms and the subnational authorities directly responsible for implementing them (Frank et al., 2000a, 2000b; Schofer et al., 2012). Hence, world society theorists have heretofore studied environmental outcomes only on the national-level (Henderson, 2019; Schofer and Hironaka, 2005). This leaves an important gap, as global environmental norms reach subnational authorities through channels independent of national government-driven processes.

In the following, I first define the subnational gap in these theories and the need to address the organizational rescaling of global climate change governance to the subnational-level, and both the political-economic forces and the normative forces affecting urban environmental outcomes. Second, I introduce urban political ecology as a means of filling these gaps. Both ecologically unequal exchange and world society theory are macro-level in vantage point, observing collective global outcomes via national-level phenomena. However, the governance of greenhouse gas emissions that drive climate change has experienced a significant rescaling over the past three decades. Environmental reforms of global consequence are no longer managed solely by national governments, but also by city governments that are increasingly designing and implementing their own environmental policies independently. Cities are also obtaining the requisite knowledge, financial and other resources needed for climate change mitigation from sources other than higher tiers of their domestic government, from other cities, universities, international organizations and private consultancies. Global climate change governance thus exists in a multi-level context and must be studied as such (Kern and Bulkeley, 2009; Peterson, 2017).

While national governments organized by the UN and other frameworks continue to be a prominent force in the modern structure of global climate change governance, this structure also includes a parallel system populated by sub- and non-state actors. The latter refers to polycentric systems, a decentralized landscape where multiple centers of power, including organizations of cities and companies, work toward climate change governance goals (Ostrom, 2010). These organizations horizontally cooperate independently of national governments, and often integrate sub-state efforts into supranational bodies such as the UN to achieve global climate governance goals (Carlisle and Gruby, 2017; Hsu et al., 2017; Van der Heijden, 2019). Neither a substitute nor competition for the traditional, nation-state-centric system of top-down global governance (Borja and Castells, 1997), the initiatives of polycentric systems help fill a distinct governance gap, or the gap between the traditional multilateral system and public goods needed (Hale et al., 2013).

These polycentric systems house the cities and other sub- and non-state actors whose emissions reduction commitments can fill the national "emissions gap" if said commitments are achieved (Kuramochi et al., 2019), hence a greater understanding of environmental outcomes in these systems can elucidate new pathways for the achievement of climate mitigation goals. The organizational rescaling of global climate change governance to the city level, as well as the political-economic and normative forces affecting urban environmental outcomes, may all be addressed by urban political ecology.

Political ecology itself is a political-economy approach to understanding the relation between society and the natural world, or more specifically the relationships between environmental change, economic growth and political processes (Bryant, 1992; Keil et al., 1998). *Urban* political ecology follows from this logic, and specifically explains the codetermination of urban political-economic change and urban environmental change (Heynen, 2013). Urban political ecology situates the city in globalization, where the relationship between society and nature is determined by both economic forces and ideational flows of a global sort. In other words, urban political ecology explains the process by which "the city both facilitates and regulates global to local flows of capital and resources, people and ideas" (Rice, 2014: 382). Urban political ecology thus affords an analytical lens combining multi-scalar approaches, materialist political-economic forces and discursive flows to better understand urban environmental outcomes (Hodson and Marvin, 2009).

I use the multi-scalar lens of urban political ecology to analyze political-economic and normative forces affecting urban environmental change unique to the local-scale and to the macro-scale, the latter allowing for initial conceptual linkages to be made to macrosociological theory of global environmental change, namely ecologically unequal exchange and world society theory. In addition to the theoretical impetus of this study, there also exists a methodological need for better understanding urban emissions change, as I explain in the next section.

Precision & granularity in analyzing climate change governance

An additional impetus for developing subnational theory for global climate change governance is the need to explain variation in emission change otherwise obscured by national-level change. It is possible that the causal mechanisms of emissions change identified by existing, nation-level-focused research on emissions change are accurate, as patterns of political-economic activity measured at the national-scale may ultimately explain patterns of emissions change measured at the national-scale. However, since measuring emissions change at the national-level obscures variation occurring at the city-level, greater explanatory value in the causes of emissions reduction may be achieved by accounting for city-level emissions change.

Sociologists have long stressed cities as crucial units of analysis beyond the nation-state needed to better ascertain change in global economic power and inequality (Friedmann, 1986;

Sassen, 2006; Smith, 1996). As global decentralization of social processes continues, so too have calls in sociology for "scaling down" analysis to the city-level, emphasizing that doing so will allow for more accurate understanding of transformations within and across countries (Sybblis and Centeno, 2017).

This also holds for achieving a better understanding of global environmental change. Annual change in greenhouse gas emissions measured at the national-level obscures urban reductions over time that may otherwise be observed, which creates important analytical obstacles that my city-level focus may overcome. This is due to national-level emissions measures representing the combined emissions change of all urban and non-urban sub-units of the national territory in a given time period, producing a national metric that mixes emissions increasing *and* reducing jurisdictions together.

A direct example of this is shown in Table 1 below, by way of the U.S. and China, the world's largest two national contributors of greenhouse gas emissions. At the national-level, per capita greenhouse gas emissions in China increased by 64% in 2012 from a base year of 2005. While emissions increases are observed at the provincial-level for Hebei, Jiangsu and Shandong provinces, reductions are observed in Baoding, Nanjing and Yantai. Table 1 also includes the national emissions change for the U.S., three states and three cities within said states, which shows reductions at all levels. In my larger sample of U.S. (56) and Chinese (127) cities, more U.S. cities reduced than increased, and more Chinese cities increased than reduced per capita greenhouse gas emissions during the observed time period.

Table 1. Greenhouse gas emissions changes by provincial versus city scale

Country	GHG % change '05-'12/3	State/ Province	GHG % change '05-'12/3	City	GHG % change '05-'12/3
China	+64%	Hebei	+46%	Baoding	-11%
		Jiangsu	+56%	Nanjing	-28%
		Shandong	+44%	Yantai	-12%
USA	-16%	Colorado	-11%	Denver	-14%
		Ohio	-15%	Columbus	-25%
		Texas	-12%	Houston	-23%

Sources: Shan et al. (2017, 2018a, 2018b, 2019); WRI/CAIT 2.0. (2014); Carbon Disclosure Project; carbon*n* Climate Registry; C40 Greenhouse Gas for Cities Dashboard; U.S. Census Bureau, U.S. Department of Commerce; U.S. Environmental Protection Agency.

More importantly, emissions change trends observed at the higher geographic scales of nation and state/province obscure greater variation in emissions change seen at the city-level. This is due to the boundary problem in spatial analysis, where accurate estimation of the statistical parameters of spatial process depends on the spatial distribution of the process (Barber, 1988; Cressie, 1992). In analyzing environmental processes, while defining boundaries at an aggregate scale may offer a certain completeness, it may also do so at the expense of detail observed at the micro-scale (Weidmann and Minx, 2007). The same is true for observing air pollution emissions at the national rather than local-level, as most point-source and nonpoint source greenhouse gas emissions originate from cities. Estimating with greater precision the factors affecting emissions reduction requires analyzing emissions data of more granular pollution source geometry, necessitating a city-level analysis, where the most meaningful variation in emissions change can be observed.

A city-focused analysis therefore allows for a more accurate estimation of factors associated with and isolation of mechanisms associated with emissions reduction. A critical caveat is that emissions reductions occurring within the urban boundary are often attributable to emissions increases occurring beyond the urban boundary, or the externalization of emissions. Analysis of urban emissions change must address the entire "carbon footprint" of cities, covering the emissions occurring both within (direct) and beyond (indirect) the urban boundary (Lombardi et al., 2017; Pang et al., 2019).

Theorizing urban emissions reduction

In this section, I formulate hypotheses on city-level factors associated with urban greenhouse gas emissions reduction, organized as follows. In *Global political-economy of urban emissions change,* I use urban political ecology literature to conceptualize political-economic forces associated with urban emissions change both at the local-scale and at the macro-scale, in the latter formulating initial linkages with ecologically unequal exchange. In *Normative forces in global urban emissions change,* I define normative forces associated with urban emissions change as technical expertise on urban climate mitigation, both at the local-scale and at the macro-scale, in the latter formulating linkages with world society theory, and arguing that polycentric systems act as a global-scale delivery system for these effects.

In *Polycentric systems of urban climate mitigation*, I hypothesize that the local presence of environmental management consultancies and city government memberships in environmental transnational municipal networks are specific mechanisms associated with urban emissions reduction, involving both political-economic and normative forces. Last, in *Financialization & urban climate change governance,* I hypothesize that the carbon market, or market-oriented climate change governance mechanisms will not be associated with urban emissions reduction, and that city government credit rating, as a proxy for access to climate mitigation loan financing, will be associated with urban emissions reduction.

Global political-economy of urban emissions change

By the end of the 1980s, urban governance became defined increasingly by entrepreneurship, where attracting more investment than other cities became a mark of success (Harvey 1989). The neoliberal era accelerated this urban entrepreneurialism, incorporating urban environmental governance into its logic (Hodson and Marvin, 2017; While et al., 2004). In this vein, urban political ecology grants primary causal efficacy to political-economic forces in urban environmental change, and assumes that urban governance follows a neoliberal, pro-growth and free market-oriented logic (Keil, 2018). While urban political ecology does acknowledge the influence of normative, ideational forces, these are ultimately subject to political-economic forces in determining outcomes (Hodson and Marvin, 2009; Rice, 2014).

This is in keeping with the concept of the urban growth machine, where economic growth and cost-minimization become the primary goal of urban governance, normally via commiseration between local officials and private sector elites (Adua and Lobao, 2019; Logan and Molotch, 2007; Molotch, 1976). In these conditions, government dependence on local business profits for tax revenue (Gould et al., 2016) as well as avoidance of unemployment and other problems that may affect tax revenues (Bargaoui and Nouri, 2017) lead to environmental governance decisions being superseded by the pro-growth interests of local businesses (Schnaiberg, 1980). The expected result from these processes is increased urban environmental degradation (Bridges, 2016; Buttel, 2004; Catton and Dunlap, 1978). This reflects the broader developmentalist imperative in environmental studies which assume that economic development leads to negative environmental outcomes.

Urban political ecology also recognizes that urban environmental change exists in a larger global political-economic context. Beyond local-scale political-economic forces, urban environmental outcomes are also understood as influenced by uneven resource and capital flows within globally constituted networks (Swyngedouw and Kaika 2014). This bears an important similarity with ecologically unequal exchange, which shows that emissions change follows from unequal trade flows among nations (Jorgenson, 2016). While the macro-scale processes of ecologically unequal exchange cannot be directly tested at the urban-level, initial conceptual linkages may be made.

Further, urban political ecologists recognize that embeddedness in global capital flows place urban phenomena in contact with natural processes beyond the immediate reach of urban authorities (Keil, 2003; Swyngedouw, 1997). For instance, urban environmental outcomes themselves often involve spillover beyond urban boundaries (Wilson and Jonas, 2018), including adjacent suburban landscapes (Tzaninis et al., 2020). A more global articulation of this process would involve urban firms and processes externalizing high-polluting operations to less developed countries, in much the same way that ecologically unequal exchange theorists show occurs at the collective national-level (Ciccantell, 2019; Thombs, 2018).

Empirically, this externalization is captured in the third of the three "scopes" in which spatially-bound greenhouse gas emissions are measured, which together constitute the full "urban carbon footprint" (Jones and Kammen, 2014; Lombardi et al., 2017). The three scopes include direct emissions discharged within the city by sources owned or controlled by actors within the city (Scope 1), emissions from the generation of purchased energy (Scope 2) and emissions occurring beyond the boundary of the city but as a result of activities within the city (Scope 3). The full urban carbon footprint thus accounts for the local-, regional- and global-scale emissions resulting from the activity of actors in a given city (Moran et al., 2018; Pang et al., 2019).

The third scope includes emissions caused by the production, transportation, sale and use of materials, goods, and services consumed by actors in the city (Fong et al., 2014), meaning that the externalized emissions described by ecologically unequal exchange are captured by Scope 3. The mapping of 13,000 carbon footprints in urban areas by Moran et al. (2018) shows that a large number of cities globally, including those with relatively higher levels of GDP, often have Scope 3 emissions that are higher than their direct Scope 1 emissions. It is therefore plausible that many of these externalized emissions by world cities are embodied in the industrial, export-based and/or off-shored production activity described by ecologically unequal exchange.

While the extent to which this is the case cannot yet be directly tested for over time in a global sample of cities, it may be in any case assumed that urban actors similarly externalize emissions increases. This phenomenon has been observed in Chinese cities, where emissions reductions in some cities were attributable to high-emitting industries simply moving to other cities (Ang 2018; Leffel, 2018). This means that observable urban-level emissions reductions may involve urban actors externalizing emissions increases beyond the urban boundary, be it via off-shoring high-polluting operations or otherwise. Some urban emissions reductions may nevertheless also be a spatially isolated outcome, resulting from climate mitigation efforts making substantive, permanent adjustments to pollution sources, and thus without necessarily involving affecting emissions increases in other areas.

In sum, I draw from the above common threads a global political-economic context that recognizes urban environmental outcomes as to some extent interdependent, such that international economic flows to which the city is connected directly influence environmental change, and within a distinct structural context. Ecologically unequal exchange specifies a cross-national structure defined by commodity-specific trade patterns that affect environmental outcomes, but urban political ecology does not yet define an urban-level political-economic structure.

I posit that a general political economic structure of urban emissions change may be defined by the city-level ranking in what is known as the “world city hierarchy,” which is associated with emissions reduction, and the number of firms belonging to high-polluting industries per city, which is associated with emissions increases. Ecologically unequal exchange literature argues that countries reducing emissions tend to occupy a structurally advantageous trade position relative to other countries, defined by controlling the exports of structurally disadvantaged countries (Givens et al., 2019; Jorgenson, 2016).

A conceptual translation of this dynamic at the city-level might be expected to involve cities occupying a structurally advantaged position defined by greater control/power in the global economy, and those occupying a disadvantaged position. An economically powerful position in this sense may be most closely represented using the world city hierarchy, a metric which represents relative centrality of each urban economy within transnational private capital flows (Friedmann 1986; Taylor, 2001). Specifically, a higher ranking in the hierarchy represents the command and control functionality of a given city economy within the larger the global economy (Sassen, 2006). This is functionality is reflected in particular through the number of corporate headquarters located within a city and how many branches belong to it globally, measurable by the inter-city ties formed by corporate headquarter-branch office locations (Alderson and Beckfield, 2004).

I would expect cities with a higher rank in the hierarchy to house either the finance needed for infrastructural upgrades sufficient to achieve permanent emissions reductions and/or the wherewithal to off-shore high-polluting operations. In this way, higher rank in the world city hierarchy would be associated with urban emissions reductions. This is not taken as a direct city-level approximation of the extent to which one economy controls the exports of another economy, per ecologically unequal exchange. Rather, this translates to the city-level the concept that a structurally advantageous position in the global economy can allow for environmental benefits. In this case, cities in the advantaged position are more likely than the disadvantaged cities to either reduce their total carbon footprint or reduce direct emissions within the urban boundary by externalizing indirect emissions increases beyond the urban boundary.

Conversely, cities housing more high-polluting manufacturing firms may be taken to represent a structurally disadvantaged position in the world economy, and the emissions increases thought to accompany it. This similarly is a conceptual translation of ecologically unequal exchange literature emphasizing that greater manufacturing intensity embodies emissions increases (Ciccantell, 2019; Jorgenson and Rice, 2012; Marquart-Pyatt et al., 2015). Together, ranking in the world city hierarchy and the presence of high-polluting manufacturing firms provide a general global political-economic structure for urban emissions change.

Beyond this presumed structure, there are further mechanisms discussed in the next section that are expected to have a more pronounced impact on urban emissions reduction, specifically, environmental management consultancies and city government memberships in environmentally-oriented transnational municipal networks. Functionally, these mechanisms enable deliberate climate mitigation by city actors, and structurally, these mechanisms constitute polycentric systems of global governance, where urban environmental outcomes are influenced by political-economic and normative forces in a multi-scalar governance context.

While co-existing with the previously posited structure of the world city hierarchy and manufacturing firms, I theorize environmental consultancies and networks as having a distinct relationship with urban emissions reduction by way of the targeted climate mitigation action processes that they facilitate. These mechanisms and processes should allow meaningful emissions reductions that are isolated within the urban boundary, or that do not externalize emissions increases. While such emissions reductions may be attributed to environmental consultancy- and network-related processes, they constitute only part of a wide range of forces that reductions of the total carbon footprint, and do not negate the possibility that other observed reductions may be attributable to externalization or to other forces.

Normative forces in global urban emissions change

Urban political ecologists endeavor to reconcile materialist and idealist tensions (Angelo and Wachsmuth, 2015), and in so doing, acknowledge that in addition to political-economic forces, there exist global-to-local discursive or ideational flows that are also consequential for environmental change (Hodson and Marvin, 2009; Rice, 2014). Particular attention is paid to social power relations that allow access to resources that affect the environment, which includes discursive meanings and ideologies (Heynen, 2017; Swyngedouw et al., 2002). Beyond political-economic forces at play, cities also become sites of normative contestation, which can directly influence all manner of urban environmental management approaches (Zimmer et al., 2020).

Urban political ecology research in this normative vein explores how identity politics affect land use planning in the fisheries of less developed nations (Kadfak and Oskarsson, 2020), how normative conceptions of scale affect the organization of water systems (Swyngedouw and Heynen, 2003) and how discourse on viable food production systems affects the use of urban gardens (Classens, 2015). While urban political ecology acknowledges that environmental change is influenced by norms, it does not invoke a normative notion of environmental justice, but rather highlights the political decision-making processes that influence environmental management outcomes (Swyngedouw and Kaika, 2014).

In this way, urban political ecology frames normative, ideational flows as one of the factors influencing the local political decision-making processes that ultimately lead to urban environmental change. The effect which urban political ecology suggests normative forces have on urban environmental outcomes should not be thought of as isolated from political-economic forces. That is, urban political ecology recognizes cost- and growth-conscious political-economic interests as a ubiquitous force in the city (Keil, 2018), hence, normative flows should be thought of as intermingling with political-economic forces during the process of urban environmental governance. Urban political ecology does not yet, however, define a macro-scale structure by which normative flows affect urban environmental change. To conceptualize such a structure, I synthesize the norm diffusion processes of world society theory, the horizontal structure of polycentric systems of climate change governance and the multi-level governance purview of urban political ecology.

World society theorists posit that national governments obtain globally-legitimated normative governance models, implement these norms in the form of environmental policy which policy reaches local authorities, where emissions reductions are ultimately affected (Henderson, 2019; Schofer and Hironaka, 2005). Traditionally ignored by world society theorists, this vertical structure of nation state governance processes also co-exists with emergent horizontal, decentralized structures called polycentric systems (Carlisle and Gruby, 2017; Ostrom, 2010; Van der Heijden, 2019). Together, they form a full picture of modern climate change governance, which is structurally multi-level (Peterson, 2017). Urban political ecologists acknowledge this complex structure, arguing that "urban ecological conditions and the configurations of their governance are never just local," but are embedded in multi-level governance arrangements (Swyngedouw and Kaika, 2014: 471). This involves urban environmental policy outcomes resulting both via vertical, national governance processes and via horizontal governance processes among locales within polycentric systems. I argue that polycentric systems facilitate the horizontal transmission of globally-legitimated climate governance norms directly to cities, which through policy implementation can influence urban emissions reduction.

Normative governance models may more precisely be defined as the technical expertise of urban climate governance necessary for reducing emissions, which can be as valuable a resource for policy implementation as financial resources. Local government actors tend not to possess in-house all necessary knowledge for formulating and implementing effective policy (Toikka, 2010), necessitating external sourcing of the required policy expertise and knowledge.

This is particularly true for the technical detail-intensive matter of urban-scale climate change mitigation. While environmental commissioners and Chief Sustainability Officers serving in municipal government bring rich environmental management knowledge, they tend not to marshal all necessary technological resources, instrumentation, data and services needed to carry out climate mitigation policy alone. This expertise is highly specialized and is slowly becoming standardized. Urban political ecologists note that the organizational rescaling of climate change governance to the city-level has involved the development and mastery of several practices unique to the urban setting (Tzaninis et al., 2020). This includes detailed municipal climate action plans, urban-scale emissions accounting, the technology and techniques for retrofitting and/or energy system upgrades for building and transportation infrastructure, and the financing mechanisms to fund these endeavors (Jones, 2018; Rice, 2014).

Given that city governments cannot locally generate or synthesize the expert knowledge required to fully design and implement successful climate mitigation policy, local officials must obtain it externally. Hence urban climate change governance begins with city government actors initiating knowledge-seeking behavior to acquire appropriate expertise. City governments have access to a myriad of available sources from which to obtain climate mitigation expertise. These include universities, nonprofits, think tanks, public and private sector organizations both local and non-local. Given the relatively new nature of urban climate mitigation best practices and related services, there exists no centralized source of this knowledge. There are, however, two increasingly common, decentralized mechanisms from which cities obtain urban climate mitigation expertise and services, environmental management consultancies (Baker et al., 2012; Biagini and Miller, 2013; Feser and Runst, 2016; Keele, 2017) and environmentally-oriented transnational municipal networks (Bulkeley et al., 2013; Pichler et al., 2017; Tosun, 2019).

Both mechanisms function by directly providing city governments resources that help facilitate the urban emissions reductions sought by climate change mitigation policy. In structural terms, both are polycentric systems that are global in scale and horizontal in organization, offering direct access to climate policy technical expertise independently of national government. While facilitating normative flows of expertise, these mechanisms also are subject to political-economic forces. I argue further that these mechanisms co-exist with the previously posited structure of the world city hierarchy and manufacturing firms, but have a distinct relationship and a more pronounced association with urban emissions change.

The mechanisms of consultancies and networks are posited to facilitate reductions in the carbon footprint that do not involve externalization or spillover across scopes, such as reduced direct emissions within the city achieved at the expense of increased indirect emissions via offshoring high-emitting facilities. As such, studying these mechanisms allows for isolating instances of meaningful emissions reductions, while also acknowledging that these mechanisms represent just a few of many different forces inducing urban emissions change. Environmental consultancy- and network-related processes are not assumed to account for all observable emissions reductions and again do not negate the possibility of other reductions occurring as a result of externalization. I elaborate in detail on both mechanisms and formulate hypotheses in the next section.

Polycentric systems of urban climate mitigation

Environmental services industry

One of the polycentric systems that I argue facilitates urban emissions reduction is the local presence of the environmental services industry. Environmental management consultancies are the flagships of the environmental services industry and commodify climate mitigation and related expertise and services to be sold explicitly for profit. An increasing number of local governments hire private environmental consultancies to assist in the design and implementation of climate mitigation projects and associated policies (Baker et al., 2012; Biagini and Miller, 2013; Feser and Runst, 2016; Keele, 2019). This reality is further reflected in Engineering News-Record's data on the world's top 200 environmental firms reports that local government clientele comprise roughly 44% of revenue (ENR, 2015, 2016, 2017).

Local government hiring of environmental consultancies to implement greenhouse gas inventories as well as help facilitate local emissions reductions projects include examples spanning more developed and less developed nations of the world.[1] These consultancies range in size from small and middle sized single-location environmental consultancies such as Starcrest Consulting Group with $120,000 in revenue (SCG, 2006) and Brown, Vence & Associates with $640,000 in revenue (City of San Francisco, 2004) to the branches or headquarters of major multinational energy service companies such as Siemens with over $20 billion in revenue (CCI, 2008). The act of contracting to a consultancy for climate policy expertise is assumed to take place after city leadership has committed to some form of climate action, for which the expertise and services sought directly aid in the facilitation and implementation of said climate action.

The process by which expertise provided by environmental management consultancies facilitates emissions reduction involves both the political-economic forces of cost-minimization and the normative flow of globally-legitimated urban climate governance expertise. Research on the political-economy of government contracting to consultants for climate change governance-related services focuses more on the negative externalities of this phenomenon than the process by which it facilitates emissions reduction. The former includes the arguments that government outsourcing to environmental consultants creates market demand for the production, and commodification, of expert climate governance knowledge (Keele, 2017); that this process over time finds firms collecting a rent from government actors seeking the provision of expert knowledge, creating inequalities between cities that can and cannot access it (Barnett, 2020); and that this outsourcing may even shift the incentives for climate science away from the public interest and towards profiteering (Keele, 2019).

[1] Cross-national examples include Louisville, Pasadena and Stockholm (Rincon, 2013; Trinity and Louisville, 2008), Durban, South Africa (Constable and Cartwright, 2009; Roberts and O'Donoghue, 2013), several Mexican cities (Viscidi, 2017) and Chinese cities (AMECFW, 2006; Romano and Ruggeri, 2015).

Research on the emissions reduction processes facilitated by the government-consultant relationship is more limited, but helpfully points to specific mechanisms. Urban political ecologists discuss the use of energy service companies in the urban climate mitigation context, for instance how London used these companies to reduce building emissions by providing on-site energy generation for new building development projects (Bulkeley et al., 2013). This refers to a particularly prominent mechanism through which consultancies provide climate mitigation-related service to local government clients, the "energy performance contract." This type of contract involves local government contracting to an energy service company, or a company involved in developing, installing and financing facility-level energy efficiency improvements (Vine, 2005), which include energy utility companies, engineering firms and environmental consultancies that offer energy performance contracting as one of their services (Ürge-Vorsatz et al., 2007).

The contracted company upgrades existing building systems, including installation of emissions-reducing retrofits, to reduce energy costs as well as arranges for financing to pay for it (Vitiello, 2015). The energy performance contract model is unique in that payment is directly linked to the amount of energy saved (Ürge-Vorsatz et al., 2007), such that the client does not pay upfront, but pays in accordance with the demonstrated energy savings achieved over time (APEC, 2017). This enables governments to achieve emissions reductions without making large budgetary investments (Vitiello, 2015), and in this way the energy performance contract is designed to overcome financial obstacles (Capelo, 2011).

This appeals directly to the cost-minimizing governance assumptions of urban political ecology (Keil, 2018) and identifies a distinct mechanism through which environmental consultancy contracting facilitates urban emissions reduction. To the latter, it is argued that climate policy is more likely to succeed in reducing emissions when it involves such economic co-benefits as cost-savings or the generation of new revenue (Heinrichs et al., 2013; Nakhooda et al., 2014; Swyngedouw, 2018). Energy performance contracting would appear to offer the co-benefit of cost savings, and may thus be expected to result in greater emissions reductions when used. This represents a departure from and a critique of the developmentalist imperative, as it posits that positive rather than negative environmental outcomes can follow from economic development and growth processes.

An additional political-economic element of city government contracting to environmental consultancies for climate mitigation expertise is local procurement. The process of consultancy expertise transmission to local governments is often localized, in that a strong tendency exists for city governments to contract specifically to local environmental services consultancies. When city governments make purchases, they are often incentivized to procure from local rather than non-local private entities, as local procurement allows for a contribution to the local tax base from which the government draws revenue as well as an investment in the long-term growth of local industries (Nijaki and Worrel, 2012; Preuss, 2009). This is also true of local government procurement for expertise needed to implement climate mitigation efforts.

For example, the city of Raleigh, North Carolina contracted specifically to the local branch of AECOM Energy & Construction, a $4 billion consultancy, for climate mitigation project implementation assistance, rather than any of the other nationwide branches. AECOM then calculated the greenhouse gas inventory for the city, showed that stationary infrastructure such as large buildings were the largest contributor to local emissions. The consultancy recommended that electrical energy efficiency be increased in municipal government-owned buildings by implementing on-site generation of renewable energy via solar panels, installing

LED lighting and lighting motion sensors and designing city codes regulating these measures (AECOM, 2016).

Stockholm, Sweden similarly contracted to the Stockholm-based office of the consultancy AFRY (ÅF Pöyry), rather than other locations to assist in the implementation of the local climate action plan. AFRY is a mid-size consultancy with annual revenue of $1.5 million. Specifically, Stockholm officials determined oil heating as a major source of emissions and sought to install a district heating system using biofuels to reduce emissions. The city then contracted to AFRY in order to calculate the projected of emissions reductions that could be achieved from the project, the accuracy of which allowed the city to determine both that the project could achieve reductions, and by how much (Lönngren, 2012). In addition to the incentive of contributing to local economic growth, geographic proximity also plays an important role in the tendency to procure services locally, reducing the time and distance associated with service provision. Several other similar examples include Paris, France awarding a major energy performance contract to local consultancy Nov'ecoles Paris (Energy Cities, 2015), Houston, Texas (USA) contracting to CenterPoint Energy and Schneider Electric/T.A.C. (City of Houston, 2008), and Cape Town, South Africa contracting to Mthenthe Research Consultants (City of Cape Town, 2015).

Environmental management consultancies are also frequently hired by participants in the carbon market, both in the EU emissions trading system and the Clean Development Mechanism.[2] The city government tendency to select locally-based consultancies occurs in

[2] Hiring environmental management consultancies for project implementation is a common transaction cost for companies participating in the EU emissions trading system (Braun, 2009; Engels, 2009; Jaraite et al., 2010). Such consultations are expected, as noted in the EU Emissions Trading Directive section on "The role of consultancies and environmental NGOs in the European policy network on emissions trading" (Krause, 2014; Scheuer, 2005). Similarly, Clean Development Mechanism projects require auditing by external agencies known as Designated Operation Entities (DOEs) that include but are not limited to environmental consultancies (Broderick, 2011; Schneider and Mohr, 2010; Michaelowa et al., 2003).

different scenarios as part of the early stages of urban climate governance. To procure desired services, cities will often release a request for proposals for environmental services, to which consultancies both local and non-local respond, and among which the city tends to choose the locally-based consultancy. Such was the case for Knoxville, Tennessee (USA) in 2007 when it awarded a contract to the local firm AMERESCO rather than other non-local firms (City of Knoxville, 2007).

This tendency is also seen in municipal procurement in more international settings with candidate pools including large multinational professional services corporations, which have branch offices located in major cities globally. Melbourne, Australia sought to procure energy performance contract services via an international pool of consultancies made available via the C40-Clinton Climate Initiative partnership with several multinational energy service companies. In ultimately awarding the contract to the large multinational firm Honeywell, Melbourne specifically awarded the contract to and worked with the local Melbourne branch of Honeywell to provide services (HBS, 2017).

Hence, when cities initiate climate action plans but lack the necessary in-house expertise to carry out all technical components, they are likely to procure requisite knowledge and services locally from environmental management consultancies, supposing there exists a local presence of such firms. This often takes place alongside additional collaborative knowledge sourcing from local environmental nonprofits, universities and other entities housing viable climate mitigation expertise.

The tendency for local procurement articulates the urban political ecology assumption that urban climate mitigation policy action, from initial emissions tracking to retrofitting, "is always already part of the processes driving and sustaining capitalist urbanization" (Rice, 2014:

390). The incentive to procure locally may be stronger in cities with a relatively larger environmental services industry, as the procurement process normally involves a city-issued request for proposals for required services, to which interested companies respond by submitting competitive bids. It is further plausible that cities housing more environmental consultancies may see more competitive bids in the form of companies offering more expertise and services for a lower proposed bid. The above political-economic mechanisms are increasingly salient as agents for environmental change, as calls for post-COVID-19-pandemic green recovery extoll the cost-saving, job-creating and emissions reducing utility of energy performance contracting for buildings and local procurement practices of the same sort as noted here (Bozuwa et al., 2020; Lenka, 2020). While these political-economic forces are understood to be associated with emissions reduction processes, they also bring the long-term risk of stymied climate mitigation potential, which is address in greater detail in the pages below.

Beyond political-economic forces, the normative flow of globally-legitimated urban climate governance models further explains the process by which expertise provided by environmental management consultancies facilitates emissions reduction. Urban political ecologists point out that among other normative flows, scientific expertise meaningfully influences policy formation, as climate change governance often involves a stakeholder-based process where government actors work together with experts (Swyngedouw, 2010; Zimmer et al., 2020). I argue further that environmental management consultancies act as a key delivery mechanism of urban climate mitigation expertise, in which the process of transmission is constitutive of a world society process of norm diffusion, but that structurally occurs via a decentralized, global-scale polycentric system of environmental services companies.

While world society theorists normally consider public and civic sector entities to be norm diffusing institutions (Hironaka, 2014; Longhofer and Schofer, 2010), this does not necessarily exclude private sector entities. Consultancies offer as a paid service access to technical knowledge of an internationally-recognized and competitively high standard (Biagini and Miller, 2013; Feser and Runst, 2016; Keele, 2017), in effect, diffusing globally-legitimated normative governance models, or in this case, specialized urban climate mitigation expertise.

The global diffusion of energy service performance contracting as a normative model follows much the same pattern that world society theorists argue is the case for other environmental policy norms, that is, from the developed world in North America and Europe and out to less developed countries (Hironaka, 2014; Shorette, 2012). The energy performance contract as a means for national and local government to achieve energy efficiency goals appeared first in the early twentieth century in Europe, in the United States in the 1970s, and began diffusing to many of the less developed countries in the 1990s (Bertoldi, et al 2006; Ürge-Vorsatz et al., 2007). As a result, energy performance contracting was popularized and successfully used in the Americas (Westling, 2003), Europe (Nolden et al., 2016; Polzin et al., 2016) and Asia (Rashid et al., 2011). Hence, energy performance contracting may be understood as a globally-legitimated normative governance model.

The structural forms through which this transmission occurs, however, is not restricted to the national-to-subnational government flow normally posited by world society theorists, but also through the horizontal plane of a polycentric system. That is, the global landscape of environmental management consultancies constitutes a decentralized system of competing firms. In sum, city governments may achieve emissions reductions via expertise accessed from a large local environmental services industry, with the additional incentive of supporting local economic growth. The greater the number of consultancies physically located within a city, be it a single-location, branch or headquarters office, the higher the probability that a contract of the above sort will result from city governments initiating climate mitigation policymaking.

The emissions reductions theoretically achievable through the above consultancy-related processes are assumed to be a net reduction to the carbon footprint, such that reductions are isolated within the urban boundary and do not externalize emissions increases. Reductions attributable to consultancies are not assumed to represent all observable emissions reductions in the city, but rather co-exist among other reductions attributable to other forces, including but not limited to externalized emissions. A caveat is that while these firms provide contracts that facilitate emissions-reducing processes, this is separate from the business calculus of the firms themselves, which are purely transactional. Further, though the contracts and associated services may facilitate emissions reductions in the short-run, there are a number of long-term risks including shifting climate policy incentives toward profiteering in a way that may ultimately stifle rather than improve climate mitigation efforts (Keele, 2019). These caveats notwithstanding, a greater local presence of environmental consultancies should, by way of the above processes, allow for non-trivial urban emissions reducing potential. Accordingly, I hypothesize:

The local presence of environmental management consultancies will be associated with urban emissions reduction (H1)

Environmental Transnational Municipal Networks

The other prominent polycentric system of interest that provides city governments access to climate mitigation expertise is the transnational municipal network, or membership-based organizations of city governments providing access to policy knowledge and related resources to help cities reduce greenhouse gas emissions (Abbott, 2019; Betsill and Bulkeley 2004; Schroder and Janda, 2009). These environmental transnational municipal networks were created by subnational authorities as a response to the failure of traditional institutions, including nations, to provide sufficient access to policy best practices, and the resultant need for new policy knowledge diffusion mechanisms (Tosun, 2019).

They provide a milieu where city officials can access a knowledge pool of successful urban management practices (Mejía-Dugand et al., 2016), thus facilitating the adoption of new best practices, reducing information asymmetries among local governments globally (Coe and Bunnell, 2003). While networks vary in specialization, from the climate resilience focus of 100 Resilient Cities to the megacities focus of C40 Cities Climate Leadership Group (C40), they all provide policy knowledge comprising the core components of climate change governance (Bellinson and Chu, 2018; Heikkinen et al., 2018; Wolfram et al., 2019). For instance, urban political ecology literature highlights C40 providing member cities expert assistance in building efficiency and renewable energy production (Hodson and Marvin, 2009), and ICLEI – Local Governments for Sustainability (ICLEI) providing assistance in climate action plan design and emissions accounting (Rice, 2014).

As with environmental consultancies, the process by which expertise transmission via environmental network membership may facilitate urban emissions reduction involves both political-economic and normative forces. Urban political ecologists argue that climate policy components such as stated emissions reduction targets often reflect not just the ambition of the climate action itself, but serve as a means to competitively attract investment into new low-carbon economic activities and more broadly promote the city to global markets (Jonas et al., 2011). Environmental network membership exhibits the same dynamic, whereby city governments often join not only for the sake of more ambitious climate action, but also to leverage reputations as policy leaders to attract investment and pursue broader place-branding goals (Lee, 2015).

As matters of cost are concerned, annual dues for city government membership in the world's largest environmental network, ICLEI, ranges from $600 to $8,000 depending upon member city population size (ICLEI, 2020), which is fairly representative of other environmental network membership fees. This differs from environmental management consultancies whose services are markedly more expensive than environmental network membership. For example, the City of San Diego's contract with the private environmental consultancy AECOM for climate mitigation services was $85,000 (City of San Diego, 2010). The greater price of consultancy services is due to the larger range of services as well as the more direct, one-on-one service provision by consultants in the urban climate action planning process. Environmental networks are not a perfect substitute for consultancies, though they offer many of the same services.

Environmental networks provide climate action planning models, software for emissions tracking and guidance on obtaining financial and other material resources for carrying out climate mitigation efforts. However, networks normally do not directly provide more advanced services such as energy performance contracting, direct sourcing and implementation of low-carbon technologies or calculating various projections of potential climate policies. To a limited extent, then, joining environmental networks may be thought of as a lower-cost alternative to contracting to a consultancy. The political-economic forces implicated by environmental network-provided expertise and urban climate mitigation is clearly more limited than that of environmental consultancies.

Environmental networks also differ from consultancies in two other important ways. First, while environmental networks provide service to individual member governments much as consultancies do for client governments via contract, environmental networks facilitate cooperation and open knowledge sharing among member cities whereas consultancies do not do the same among client governments. This second difference distinguishes environmental networks as more orthodox polycentric systems of climate change governance (Ostrom, 2010), as they operate in a more cohesive system of governance that is less siloed by competition. Second, contracting to environmental consultancies is more immediately attached to the local tax base of business profits from which city government draws, which as discussed in the previous section, provides an additional local economic growth opportunity.

To the extent that emissions reductions are more likely to occur from climate policy allowing cost savings or new revenue generation (Heinrichs et al., 2013; Nakhooda et al., 2014; Swyngedouw, 2018), it may be expected that local consultancy presence may have a stronger relationship to urban emissions reduction than does city memberships in environmental networks. Perhaps motivated in part by the deeper service provision of consultancies, an increasing trend among environmental networks is to establish partnerships with environmental consultancies to strengthen service provision to member city governments. For instance, C40 has partnered with the environmental consultancies AECOM and ARUP, as well as the Carbon Disclosure Project, to produce various public reports on best practices in urban climate change mitigation among C40 member cities (C40, 2017; CDP, 2014; Davidson and Gleeson, 2016). While publicly accessible and a useful starting point for city officials to learn about the state of practice in urban climate mitigation, these reports do not provide the equivalent level of detail and customized support that environmental network and environmental consultancies provide to member and client governments.

Environmental networks are also partnering in particular with energy service companies and environmental consultancies that are able to carry out energy performance contracts. C40, together with the Clinton Climate Initiative, established partnerships with the four largest energy services companies in the world, Honeywell, Johnson Controls Inc., Siemens and Trane in order to launch a Building Retrofit Program. The aim is to provide both the expertise—via energy service companies—and the finance implement energy efficiency upgrades in commercial and government-owned buildings in cities globally (Bulkeley and Schroeder, 2008). Like most large multinational corporations, branch office locations tend to be found in most major world cities, often allowing for allowing for local service provision, as was the case for Melbourne and Honeywell.

These network-consultancy partnerships demonstrate the expansion of neoliberal logic in the conduct of urban environmental governance, where governance processes increasingly incorporate private sector actors (Hodson and Marvin, 2017; Keene, 2017; Whitehead, 2013). This also shows intentional interaction between two polycentric systems of climate change governance to diffuse new normative climate governance expertise directly to cities, in this case, the energy performance contracting model offered by consultancies being made available to the member cities of environmental networks.

The normative flow of globally-legitimated urban climate governance models further explains the process by which expertise provided by transnational municipal networks facilitates emissions reduction. As with environmental consultancies, the expertise transmission from environmental networks to member city governments fits the urban political ecology purview of scientific expertise influencing climate policy formation via a stakeholder-based process (Swyngedouw, 2010; Zimmer et al., 2020).

Also like environmental consultancies, the same more-to-less developed nation pattern of environmental policy norm diffusion among nations argued by world society theorists is seen with environmental networks. Membership in environmental networks began first in developed countries, particularly those in the EU and North America, and spread to less developed countries thereafter (Bouteligier, 2013), allowing new models of uniquely urban-adapted climate policy frameworks to spread on a global-scale among cities and become adopted (Tosun, 2019).

Further, world society theorists tend to highlight as norm-diffusing actors civic and public sector entities such the Red Cross, the UN and its national government members and universities (Hironaka, 2014; Longhofer and Schofer, 2010). As nongovernmental organizations comprised of government actors, environmental transnational municipal networks better fit the orthodox type of norm-diffusing actor recognized by world society theory than do consultancies. However, like environmental consultancies, the structural form of expertise transmission in environmental transnational municipal networks is horizontal, traveling from the network secretariats directly to member cities as well as among member cities. That is, contra the national-to-subnational government flow of normative governance models assumed by world society theorists (Henderson, 2019; Schofer and Hironaka, 2005), environmental networks are organized as polycentric systems that bypass national governments in allowing member city governments direct access to climate governance expertise (Hsu et al., 2017; Pichler et al., 2017).

While existing literature refers to these organizations as environmental “networks,” a world society interpretation would correctly recognize them as intergovernmental organizations in their institutional form, albeit on the city-level. Several examples illustrate the normative expertise diffusion facilitated by environmental networks to city governments. For instance, ICLEI actively diffuses greenhouse gas inventorying methods to member cities worldwide. This includes the International Local Government Greenhouse Gas Emissions Analysis Protocol, which was developed by ICLEI in 1993 (ICLEI, 2009). This also includes a later iteration, the 2014 Global Protocol for Community-Scale GHG Inventories via collaboration between ICLEI, C40 and World Resources Institute (Fong et al., 2014). A further example of a normative climate governance model generated and diffused directly by ICLEI to member cities is that of its Cities for Climate Protection program. From 1991-93, ICLEI launched the Urban CO_2 Reduction Project involving 14 pilot cities, and used these experiences to develop a five-milestone urban climate governance model and emissions calculation software.

In 1993, ICLEI launched the Cities for Climate Protection Program to diffuse these resources to cities globally (Betsill and Bulkeley, 2004; Lindseth, 2004). Specifically, this five-milestone process involved local governments establishing a greenhouse gas emissions reduction target, developing a climate action plan, implementing said plan and monitoring progress over time (Connelly, 2014; Yienger et al., 2002; Zimmerman, 2012). For these reasons, cities initiating climate governance that have also joined the membership of environmental networks such as ICLEI are shown to be more likely to adopt a full climate action plan (Brandtner, 2019). As with contracting to consultancies, the theoretical process of interest takes place after city leadership has already committed to some form of climate action, be it the adoption of a climate action plan or otherwise, where city leaders draw upon the expertise and resources of environmental network membership to achieve these emissions reduction goals.

Also like consultancies, the expertise transmitted by environmental networks to member cities are shown to facilitate urban emissions reduction. For example, Milan, Italy used memberships in both ICLEI and the Covenant of Mayors to acquire the equipment and expertise needed to substitute the district heating system's original oil heating systems with low-carbon alternatives, specifically waste-to-energy plants and groundwater heat pumps (ICLEI, 2010a). Belo Horizonte, Brazil's Municipal Committee on Climate Change used the city's membership in ICLEI to draft legislation mandating solar water heating systems on the city's private and public buildings, which led to emissions reductions (ICLEI, 2010b). Curitiba, Brazil used membership in C40 Cities Climate Leadership Group (C40) to find funding necessary to implement solar units on the rooftops of municipal government-owned buildings and bus terminals (C40, 2018a). C40 also provided assistance for conducting the technical feasibility studies that Quezon, Philippines needed to install solar rooftops on 50 public schools (C40, 2018b) and for Mexico City to develop a new fleet of electric buses and an accompanying bus corridor (C40, 2019).

The same caveats with consultancies apply with network memberships. It is assumed that emissions reductions attributable to the above network membership-related processes constitute net reductions to the total carbon footprint, or non-externalized reductions isolated within the urban boundary. These reductions are further assumed to represent a non-trivial yet not total share of observable emissions reductions within a city, for which the remaining share may be attributable to other forces, including externalized emissions. These caveats considered, cities are able to and often do maintain several concurrent memberships in environmental networks, and the above examples illustrate that a single membership can allow access to expertise which urban authorities may use to facilitate emissions reduction. It may follow that more simultaneous memberships may provide access to more diverse expertise access and, by way of the processes discussed above, allow for non-trivial urban emissions reduction potential. Accordingly, I hypothesize that:

City memberships in environmental transnational municipal networks will be associated with urban emissions reduction (H2)

Financialization & urban climate change governance

Financial markets represent a sphere of activity influencing urban climate change mitigation that is unique from the factors discussed in the previous section. This sphere of activity refers specifically to financialization, or the global expansion of financial markets into the daily operation of governments, businesses and households (Davis and Kim, 2015; Dymsky, 2018; Lai, 2018). Following a profit-maximizing logic, financialization involves the creation of financial products, such as loans with attached interest or tradeable securities, that when used by a consumer generate profit for the producer (Layfield, 2013). The economic character of financialization, then, is defined by the generation of profit primarily through financial channels rather than through the trade of physical commodities or services (Krippner, 2005).

Beginning during the post-1970s spatial shifts of manufacturing capital to less developed countries, and accelerating after 2001 the "dot com" crash and 2008 financial crisis, the spread of financialization dynamics saw debt-finance become synonymous with development at multiple levels of government (Mayer, 2018). Financialization dynamics occurring at the city-level involve local government policymaking becoming more reliant on capital markets and the decisions that determine access to them (Hackworth, 2003). This shifts the locus of power away from local officials and local business leaders, and toward more distant finance-market interests, including bond market networks (Mayer, 2018; Peck and Whiteside, 2016). Urban political ecologists explain these dynamics as “mechanisms of the most ravenous forms” in which “financialized capitalism draws every aspect of production and reproduction into its vortex” (Kiel, 2018: 1598).

As with other areas of governance, financialization extends into climate change governance. While facilitating revenue-generating and cost-saving opportunities, financialized climate policy is distinct from the political-economic factors discussed in the previous section. That is, financialized climate policy de-politicizes and de-democratizes climate governance (Swyngedouw, 2018), where the governance of environmental outcomes hinges almost entirely on market forces rather than efforts by public authorities.

I define and test the urban emissions reduction effects of two such mechanisms, the “carbon market” and city government creditworthiness, the latter a proxy for access to climate mitigation loan finance. Both function by directing financial flows to emitting actors while generating revenue (carbon market) or reducing immediate costs (creditworthiness/loans) of climate mitigation, theoretically increasing emission reduction capacity without sacrificing productivity (Sapinski, 2016).

Carbon market

The first financial market mechanism of interest is the so-called “carbon market,” which is a system under the Kyoto Protocol in which non-monetary credits are earned via demonstrated emissions reductions, then sold for real money (Parr, 2013; Perrow and Pulver, 2015; Peterson, 2017). The carbon market financializes climate governance such that it commodifies CO_2 emissions to create a financial product (Lohmann, 2010).

Two of the largest components of the carbon market are the European Union emissions trading system and the Clean Development Mechanism, for which participants hail from more developed and less developed nations, respectively. The EU emissions trading system involves an annual cap or maximum amount of greenhouse gas emissions that participating firms are permitted to emit without sanction. Voluntarily participating firms are allocated an amount of non-monetary "carbon credits" by their respective national registry, each credit representing one ton of CO_2 equivalent emissions, and the amount given being equivalent to the annual emissions cap. Firms then surrender to their registries however many of the credits are needed to cover the amount the firm emitted during that year. If the firm emits below the cap, then the firm will have spare credits after the surrender, which they can then sell to other participating firms for real money. Firms that emit over the cap surrender all credits and, in order to avoid sanction, must purchase a sufficient amount of carbon credits to cover the additional amount of CO_2 that the firm emitted beyond the cap.

Firms that must purchase additional credits may do so from two sources: From other participating firms that have spare credits, or by investing in "carbon offset projects." The latter refers to the Clean Development Mechanism, or the Kyoto Protocol's carbon offsetting initiative, in which several pre-designated emissions reduction projects are set up in less developed countries, and the aforementioned firms can invest in said projects in exchange for more carbon credits (Parr, 2013). Clean Development Mechanism carbon offset projects must demonstrate to their respective national registries the emissions reductions achieved in order to sell carbon credits, and projects may take one of twenty-seven different project types. These include biomass offset projects generating power from organic material to substitute higher-emitting energy production; coal mine methane projects capturing methane emissions from mines prior to entering the atmosphere; gas and heat projects generating electricity from waste gas or other waste energy from production processes, and many others (Perrow and Pulver, 2015; Peterson, 2017).[3] In sum, both the EU emissions trading system and the Clean Development Mechanism involve private sector actors incentivized with a marginal profit opportunity to achieve emissions reductions.

By design, the carbon market seeks to avoid the economic drawbacks of such traditional governance mechanisms as pollution taxes (Layfield, 2013), and instead relies on incentives for private sector actors, attempting to use profitability as a pathway to emissions reduction. It assumes that in this way the market will promote emissions reductions in an economically efficient and low-cost manner (Hermanns, 2015). Urban political ecology emphasizes the ways in which networked systems provide the material basis for the capitalization of urban resource flows, and as such, characterizes the carbon market as new networked, multi-scalar systems formed to capitalize on climate change governance (Silver, 2017). As with other financial processes, carbon market activity concentrates most in urban areas, where it expands processes of capital accumulation (Layfield, 2013). Taking carbon market participation as a meaningful factor assumes that the profits achieved by participating firms will be sufficient to reduce firm-level emissions, and given the urban clustering of firms, that these reductions may be visible collectively at the city-level.

Testing the emissions reduction efficacy of carbon market participation directly tests the assumption that market incentives can allow for the achievement of emissions reductions

[3] Energy distribution projects involve reducing the carbon intensity of energy sources such as power grids; fossil fuel switch projects involve replacing fossil fuel-based energy facilities with less emissions-intensive sources; landfill gas capture projects involve capturing methane from landfills prior to entering the atmosphere; methane avoidance projects involve reducing methane production from anaerobic wastewater treatment, manure management or similar systems; and hydro, wind and solar power projects replace existing power sources with less carbon-intensive hydroelectric dam, wind turbine, and photovoltaic solar panel energy production alternatives.

(Hermanns, 2015; Ninan, 2011; Skovgaard, 2017; Von Malmborg and Strachan, 2005). While some existing research offers support for the emissions reduction efficacy of carbon market activity,[4] the majority of research renders a clear judgement that the carbon market is ineffective. This research emphasizes how distant the firm-level carbon market activities are from the physical environmental impacts they are designed to incur. Others maintain that the carbon market considers only economic exchange value in its design while ignoring other facets of governance crucial for effective service provision, including how factors of time, space and social norms may impact decision making (Knox-Hayes, 2015). It is further argued that the carbon market transforms the physical process of emissions reduction into a financial transaction, functionally disconnecting one from the other (Ellerman et al., 2003; Knox-Hayes, 2013; Lohmann, 2005, 2009a).

In this vein, Layfield (2013) explains that "the dangers of such a complex web of financial flows concern abstraction, that is, the distance between traders and the 'real' environmental problem they are supposed to be solving" (908). This disconnection is a structural symptom of financialization more broadly, where an increasingly autonomous realm of global finance is altering the underlying logics of democratic society (Van der Zwan, 2014). In light of these and other problems,[5] one of the most common criticisms of the carbon market is that it does not allow accountability, and as such is no substitute for traditional regulation (Layfield, 2013). Accordingly, I hypothesize that:

Carbon market activity will not be associated with urban emissions reduction (H3)

[4] This includes a positive relationship shown between profitability in emissions trading and environmental improvements (Delarue et al., 2008; Martin et al., 2016; Segura et al., 2018); German firms participating in the EU emissions trading system reducing emissions more than non-participating firms via reduced oil and natural gas use and more efficient use of process heat (Martin et al., 2016; Petrick et al., 2011; Petrick and Wagner, 2014); and similar processes in Spain (Segura et al., 2018).

[5] This includes such corruption problems as outright fabrication of reporting on emissions reduction progress in order to obtain carbon credits (Lohmann, 2009b; Mate and Ghosh, 2009; Petersen and Bollerup, 2012).

Creditworthiness

The second city-level financial market factor is city government creditworthiness. Over the past several decades, debt-based or loan financing became increasingly available for individuals and organizations for a range of purposes. In these conditions, access to financing developed into a key asset for governments and firms to achieve basic operational goals and economic goals (Davis and Kim, 2015; Dymsky, 2018; Lai, 2018). For instance, to facilitate its increasing use of bonds to finance infrastructure projects, the City of Chicago has put in place programming to streamline private investment in into public infrastructure and attract investments from global infrastructure funds (Farmer and Poulous, 2019).

Global demand by high-emitting and environmentally-interested actors for pay-offs to fund emissions reduction efforts has driven a wide range of banks, governments and international institutions to offer various lines of finance specifically labeled or earmarked for use in climate mitigation, adaptation or resilience activities (Buchner et al., 2017). Many such lines of finance are loans, which are ultimately financial products on which profit can be made, as interest on the principal amount borrowed grows and is paid by the borrower to the lender (Layfield, 2013). High-income countries tend to have a more mature financial sector, allowing greater access to and options for lending, bonds and other forms of climate finance (Kennedy and Corfee-Morlot, 2012). This dynamic also penetrates to the city-level, particularly as it concerns reaching local government policy goals (Hackworth, 2003; Mayer, 2018).

Urban political ecology literature argues that local governments use loan instruments for decarbonization goals in various ways, for instance providing residents a loan for solar energy installations that would be paid off via property tax (Hadfield and Cook, 2019). However, larger-scale projects require larger loans, which local governments often obtain from large banks within a regional, national or international scale. For instance, in 2014 the City of Johannesburg (South Africa) issued a $145 million municipal green bond for solar water heaters and conversion of buses from diesel to biogas (Rocca and Fernandez, 2017). A growing practice is city governments directly borrowing loans, and from a variety of sources. Globally-reaching sources include urban lending via multilateral development banks such as the European Investment Bank and development finance institutions such as the World Bank (Buchner et al., 2017). For instance, in 2011, Bucharest (Romania) borrowed 125 million Euros (USD $141 million) from the European Investment Bank to build energy efficient family housing (European Commission, 2011). Other examples include international funds such as the Green Climate Fund, focused on funding climate mitigation projects in less developed countries; national climate funds such as the Indonesia Climate Change Trust Fund that lend only domestically given their national purview; and subnational entities such as the Connecticut Green Bank that lend only to state-level entities.

Climate mitigation loans are loans used specifically to help organizations such as governments and firms to fund emissions reduction projects or related efforts to decarbonize their operations. This includes but is not limited to the purchase of equipment and technology used for retrofitting stationary or transport exhaust systems, costs for installing solar or other renewable energy sources, and contracting to consultants or other experts to assist in any or all of these processes.

Most climate mitigation loans are concessional loans, such that they are offered with interest rates far lower than the market rate. Lowering the cost of debt for climate mitigation efforts in this way allows for low-carbon technologies to compete with traditional, fossil fuel-based alternatives (Buchner et al., 2012; Kennedy and Corfee-Morlot, 2012). A green bond is a loan financed by an investor in which all proceeds are exclusively applied to finance projects that provide clear environmental benefits, including pollution prevention and mitigation (ICMA, 2014). Unlike climate mitigation loans, green bonds can be publicly traded among borrowers, and in both cases, higher credit ratings can allow city governments to obtain these finance tools at lower interest rates. These debt instruments offer immediate financing for climate mitigation projects that otherwise may not be available to city governments, and in this way act as the mechanism by which city governments achieve emissions reduction.

This process has taken place in various cases. For instance, green bond financing was instrumental in achieving 108 million tons of greenhouse gas emission reductions globally by financing increased renewable energy capacity (Trolliver et al., 2019), and the stationary infrastructure emissions reductions achieved by various cities have been attributed to climate mitigation loans financing retrofits of building energy systems (Nocera et al., 2017).

At present there exists a dearth of data on city-level climate mitigation debt finance allocations. However, the city government credit rating may be taken as a proxy for ability to access these resources, and in so doing, as a proxy for the emissions reduction potential associated with access. Creditworthiness tends to directly delimit local government ability to borrow debt financing for climate change mitigation activities, notably climate mitigation loans and green bonds (Rashidi et al., 2019) and climate mitigation loans (Lynn, 2013; March and Saurí, 2013). A higher credit rating denotes a low risk of default on debt obligation, allowing city government borrowers better access to these financial resources (Rashidi et al., 2019), including lower interest rates, which are then used to fund emissions reduction efforts (C40, 2016; Fankhauser et al., 2016). Recognizing that creditworthiness delimits access to climate mitigation loan finance, and that said finance is understood to help reduce emissions (Nocera et al., 2017;

Trolliver et al., 2019), I thus take higher local government credit rating as a proxy for greater emissions reductions capacity. Accordingly, I hypothesize that:

Credit rating will be associated with urban emissions reductions (H4)

In the next chapter, I describe the data and methods necessary to test the above hypotheses, perform a statistical analysis, report results and discuss how the findings contribute to both the previously discussed social science frameworks and offer progress toward achieving a systemic understanding of global-scale, city-level environmental change.

CHAPTER 3 Statistical analysis of global urban climate mitigation

A perennial problem for research on global cities is the relative dearth of detailed city-level data on a global scale (Smith and Timberlake, 1995a; Smith and Timberlake, 2002), including data germane to urban environmental governance. However, a substantial amount of this kind of data is now increasingly available as cities around the world submit greenhouse gas emissions inventory data to global repositories such as the carbon*n* Climate Registry (Bertoldi et al., 2018; Johnson, 2018). As emissions *reduction* is the phenomenon of interest, this requires that cities with repeat emissions inventories be identified. While the number of cities globally that have conducted only their first inventory far exceeds those that have reported a second or third, the latter comprises a sufficiently large sampling of cities to perform a global-scale analysis of urban emissions change. It is further possible to wrangle data on city-level attributes of expertise, climate finance flows and other theoretically meaningful factors on a global-scale using relatively new statistical and accounting databases.

Accordingly, I draw upon a range of such data resources to test the stated hypotheses: That the local presence of environmental management consultancies will be associated with urban emissions reduction (H1); that city memberships in environmental transnational municipal networks will be associated with urban emissions reduction (H2); that carbon market activity will not be associated with urban emissions reduction (H3); and that credit rating will be associated with urban emissions reduction (H4).

Data & Methods

Dependent variable

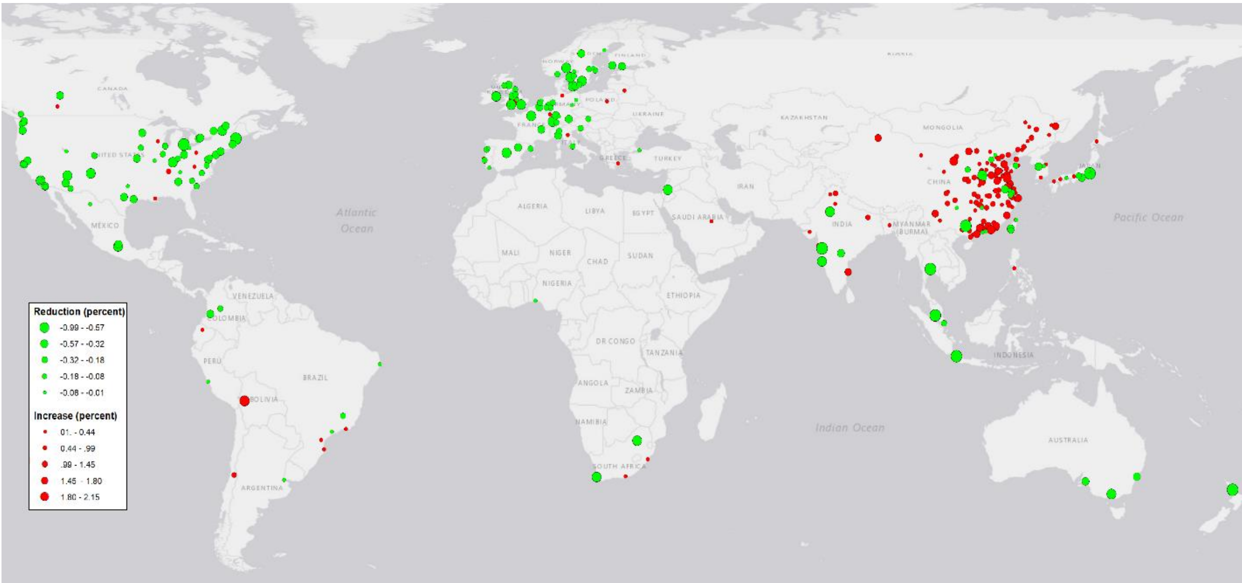
The dependent variable expresses percent change in per capita greenhouse gas emissions at the city-level for across two groupings of cities, including a cross-national sample of cities representing several countries and a sample of cities in mainland China. Each grouping was derived ultimately based on availability of comparable, repeat urban emissions metrics for the same or similar years. The first grouping consists of 204 cities from 47 countries representing emissions change at 2013 from a base year of 2005, sourced from greenhouse gas emissions inventory reports covering 2005-2013 from the Carbon Disclosure Project (CDP), carbon Climate Registry, the C40 Cities Climate Leadership Group's (C40) Greenhouse Gas for Cities Dashboard, and individual city government websites. All data represent greenhouse gas inventories carried out and reported by the government officials of each respective city.

The other grouping of cities represents the emissions change at 2012 from a base year of 2005 for 127 Chinese cities, sourced from Shan et al. (2017, 2018a, 2018b, 2019), which use bottom-up calculations of urban emissions factors understood to be highly accurate. The full sample collectively represents 331 cities from 48 countries, spanning more developed and less developed countries. The inclusion of Chinese city-observations allows for roughly half of the city-observations (52%) in the full sample to represent less developed countries, providing for more equal representation of across levels of national economic development.[6] An additional benefit is that Chinese cities housed a disproportionate share of Clean Development Mechanism projects, discussed in the sections below. Figure 1 visualizes the sample of cities, displaying

[6] Per Jorgenson and Clark (2012), countries occupying the upper quartile of the World Bank's income classification of nations are designated as more developed while those below the upper quartile are designated as less developed.

emissions reducing cities as green nodes and emissions increasing cities as red nodes, with node size displayed proportional to percentage change.

Figure 1. Urban emissions change across 330 cities, 2005-2013



All urban emissions data represent Scope 1 and Scope 2 emissions, or direct emissions discharged within the city by owned or controlled sources, and emissions from the generation of purchased energy, respectively. Since Scope 3 emissions are not included in the dependent variable, the externalization of emissions change within cities cannot be directly controlled for, and the full carbon footprint of observed cities is thus not accounted for. Scopes 1 and 2 nevertheless provide a substantial accounting of direct and indirect urban emissions and allow for empirically meaningful analysis.

The varying or non-uniform emissions accounting methods used in the greenhouse gas emissions inventories across cities makes direct comparison between cities difficult (Kennedy et al., 2010). The tonnage of greenhouse gas emissions thus cannot be directly compared across cities, as different accounting methods may capture different total emissions levels in a given city-year. Variation in the definition of political or administrative boundaries between world cities can further problematize direct comparison of emissions levels (Moran et al., 2018).

I manage these concerns to create a relatively comparable measure of emissions change across cities as follows. Repeat city emissions inventories for an individual city tend as a matter of necessity to accurately reflect change from the base year, using the same methodologies and boundaries and thus allowing officials to observe change at year *t+1* from the base year or earlier year of *t*. This comparability across years within an individual city is necessary for the leadership of a particular city to monitor progress toward emissions reduction goals.

I express emissions change as percentage change, which standardizes the quantity of emissions change across cities, preserving the relative positive or negative trend of change observed per city while obscuring the non-comparable metrics of total emissions tonnage across city observations. This produces a metric of emissions change across cities that overcomes the non-uniformity of accounting methods in ways that other metrics of change do not. For instance, calculating the difference in total (or per capita) emissions levels between 2012/3 and 2005 would still reflect non-comparable emissions levels across cities, whereas percent change standardizes change between these values. Percentage change (Δ) is calculated as given in model 1 below, expressing change at year 2013 in per capita emissions (μ) from the base year of 2005.

$$\Delta_i = \left(\frac{\mu_{i,2013} - \mu_{i,2005}}{\mu_{i,2005}}\right) x\ 100 \qquad (1)$$

Emissions reduction, or negative change in the dependent variable, is the phenomenon of interest which independent variables are operationalized to detect association with. OLS linear regression modeling is performed treating urban emissions change as the dependent variable and all others, described in the next section, as independent. A negative and significant beta coefficient will denote that a given independent variable is associated with emissions reduction, while a positive and significant coefficient will denote an association to emissions increases. To reduce skewness in the distribution of the dependent variable the cube root is taken, as log transformation is not possible with variables containing zero and negative values. Model 2 below expresses the regression, where Δ_i represents the emission change for observed city i and x_{ij} are the covariate values for city i.

$$\sqrt[3]{\Delta_i} = \beta_0 + \sum_{j=1}^{p} \beta_j x_{ij} \qquad (2)$$

Sample cities are comparable in that all have implemented at least minimal climate action efforts. The 204 city observations sourced from repositories and city government websites all represent cities implementing climate action plans or undertaking similar climate mitigation policy efforts. The 127 Chinese cities are also comparable, as by 2012, all Chinese prefectural-level cities had established some form of low carbon or eco-city development strategy (Liu and Wang, 2017).

Sample cities are also distinct in terms of the independent variables. On average, sample cities house more environmental network memberships, environmental management consultancies, high-polluting firms, higher world city hierarchy rankings, and more emissions trading transactions than the larger population of cities covered by these metrics. This is illustrated in the Welch's two-sample t-test in Table A-1 in the Appendix, which shows that these metrics are significantly larger in the observed sample of 331 cities than all other cities represented by these metrics. As explained in greater detail below, data gathering for these metrics involved a comprehensive accounting for the world cities housing observations, thus allowing the comparison shown in Table A-1.

H1, H2 and H4 test the full global sample (N=331), while H3 tests two separate sub-samples of the dependent variable given the geographic divisions of the carbon market. First, those cities in the developed world eligible for participation in the EU emissions trading system (N = 164) and second, those eligible for the Clean Development Mechanism (N=167). A strength of the sample is that it represents measurement of emissions change for the largest currently available sample of cities across the same years. A weakness of the sample is that completeness of inference on global urban emissions change requires a universal accounting for cities worldwide.

The following two sections describe independent variables for hypothesis testing and empirically important control variables that together explain variation in the dependent variable. The following caveats are critical for inference and context. Significant associations found between the dependent and independent variables are assumed to be explanatory of part but not all observed emissions change for two reasons. First, the independent and control variables used are delimited by availability of comparable data for all sample cities and are therefore non-comprehensive in nature. That is, other factors unaccounted for may also explain a portion of observed emissions reductions. Second, beyond-boundary emissions resulting from city activities (Scope 3) are not included in the dependent variable, meaning that some observed reductions may be attributable to externalized emissions, and/or that beyond-boundary emissions may have increased regardless of change in within-boundary emissions.

Independent variables of interest

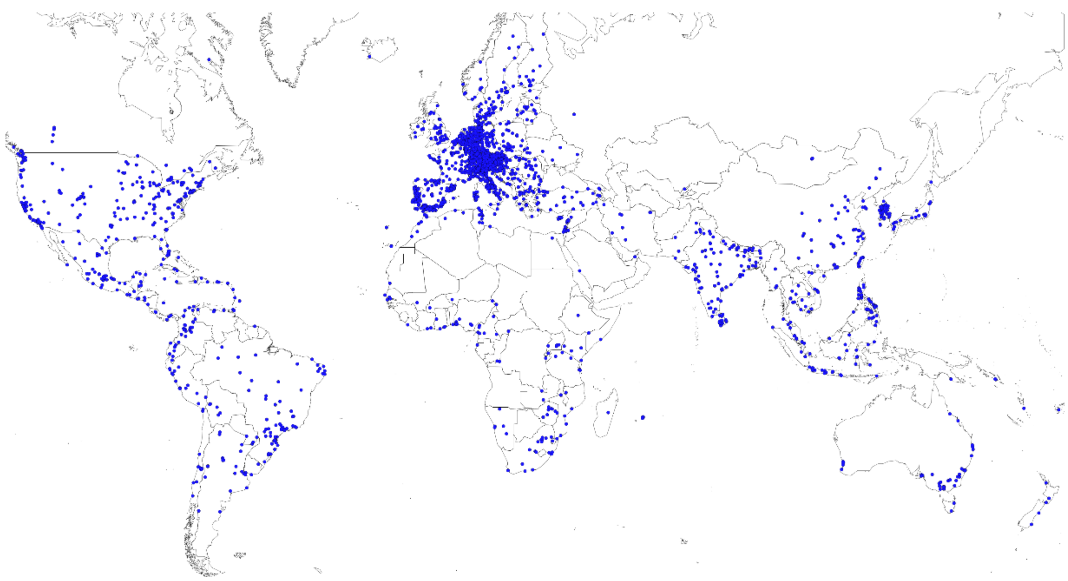
To test H1, I operationalize a measure expressing as count data the number of environmental management consultancies present in each city. These data are collected via a search of global enterprises via the Mergent Intellect (Dun & Bradstreet), Standard & Poor's Capital IQ and Uniworld databases, which together provide the widest possible search results identifying firms at the city-level by specific industry. Industrial classification codes associated with environmental management consultancies are used to identify and extract the appropriate firm data. Specifically used was the North American Industry Classification System code for "Environmental Consulting Services" and Standard Industrial Classification codes including for "Energy Conservation Consultancies" and "Pollution Control Engineering," among others.[7] The resultant sample represents the city-level presence of individual environmental consultancies as of the year 2018.

Environmental management consultancy presence represents both access to expertise and the opportunity to generate new tax revenue from environmental efforts. While a more ideal way to represent the role of revenue would be to show the environmental services industry's relative share of the overall economy in each city, data availability problems preclude this approach. The count variable used to represent the presence of environmental management consultancies within each sample city is comprehensive in coverage. While sales data is available for some firms, it is not comprehensive, as the majority of firms accounted for chose not to report sales data due to the proprietary nature of annual revenue, hence the count of firms is the most appropriate metric.

[7] Standard Industrial Classification codes for "Energy conservation consultant", "Environmental research", "Pollution control equipment installation", "Air pollution control equipment and supplies", "Pollution control equipment, air/environmental"; and "Air pollution measuring services". All firms included offer air pollution reduction-related services, including those pertinent to climate change mitigation.

To test H2, I operationalize a measure expressing as count data the number of city government memberships in environmental transnational municipal networks per city. These data are sourced from a database project of the Connected Cities Lab at the University of Melbourne, led by Michele Acuto, that myself and a team of international scholars compiled (Acuto et al., 2020). This dataset represents the membership of 10,536 city governments across 202 transnational municipal networks for the year 2016, as gathered both via direct reporting from network secretariats and from online records. Among these, 24 transnational municipal networks include environmental governance foci, including climate change mitigation, energy management and general sustainability. Within my sample of 331 cities, 195 cities have 535 memberships in environmental networks. The full listing of these networks are shown in Table A-2 in the Appendix. Figure 2 below visualizes world cities with at least one membership in environmental networks as blue nodes.

Figure 2. City membership in environmental transnational municipal networks



The cross-database search of environmental management consultancy presence by city does not offer comprehensive data on the year of founding for individual firms, particularly if they are branch operations. Similarly, the Acuto et al. (2020) database on city membership in transnational municipal networks does not distinguish the year each city joined each network of interest. The result is that my data reflects consultancy presence for 2018 and city network membership for 2016. Significant associations found between emissions reduction and both environmental consultancy presence (H1) and environmental network memberships (H2) are inferred as net reductions to the carbon footprint achieved by the processes in H1 and H2, where reductions are non-externalized and are isolated within the urban boundary. It is further assumed that reductions attributable to these processes are partial in that they most likely do not account for all observed reductions. This means that an association with emissions reduction denotes both the presence of the hypothesized processes and co-location with other urban emissions reductions.

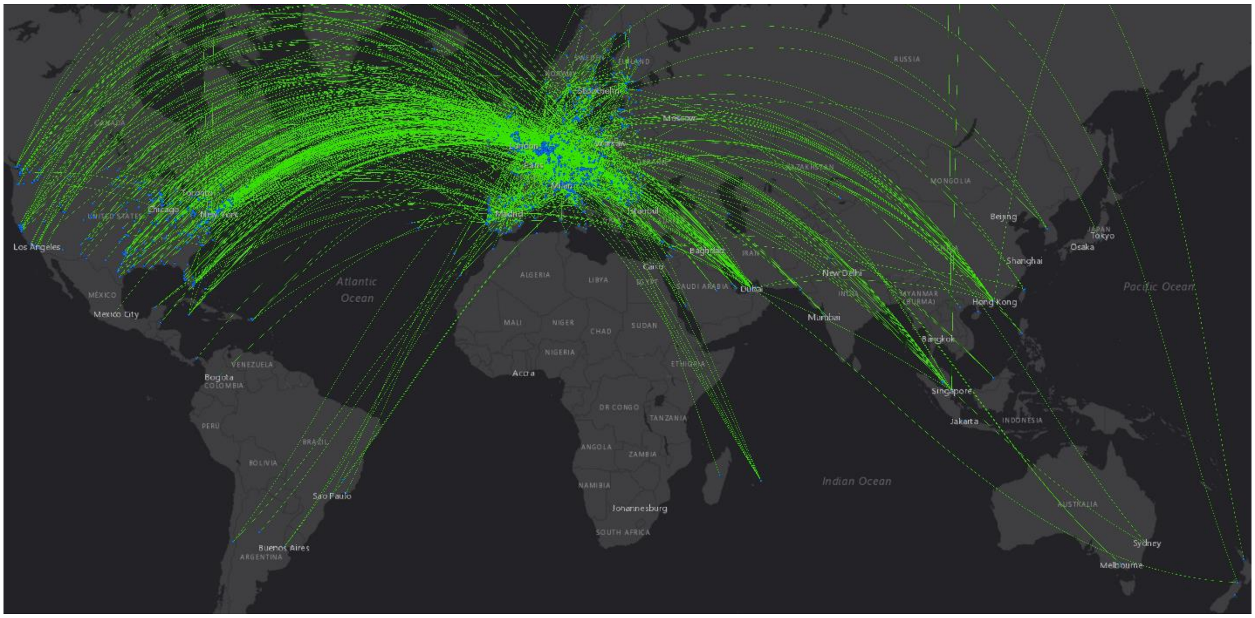
After linear modeling results reveal which city-level variables if any most strongly account for variation in emissions change, an additional test is performed to determine if and to what extent the observed relationship varies significantly by country, if at all. This is done by running linear models interacting the variable of interest and country and observing if any significant interactions with any country is present. A non-significant interaction denotes that there is no cross-national variation of the relationship of interest, while a significant interaction denotes significant differences by country. In the latter case, the beta coefficients per country are used to infer which country and/or groupings of countries the stronger effect is taking place in.

Testing H3 involves detecting whether marginal profits earned by carbon market-participating actors at the firm/project-level is associated with collective urban-level emissions reductions, where the carbon market is divided into two separate components: The EU emissions trading system and the Clean Development Mechanism, which are geographically restricted to the more developed and less developed countries, respectively. Participating actors in both carbon markets—firms in the EU emissions trading system, projects in the Clean Development Mechanism—are incentivized to achieve and demonstrate emissions reduction to their respective national registry, as doing so allows for a marginal profit opportunity.

To test the EU emissions trading system component of H3, I identify the specific conditions in which participation yields the marginal profit that incentivizes emissions reduction. Emissions trading-participating firms can sell surplus credits and thus generate profit only by consistently emitting below the annual cap (Parr, 2013; Peterson, 2017). Given that the cap decreases annually, it would be expected that a given EU emissions trading-participating firm that sells more carbon credits than it buys during a given time period should, *ceteris paribus*, yield firm-level emissions reductions during said time period.

To create an appropriate measure for this phenomenon, I access the European Commission Emissions Trading System Registry and extract data on the full universe of emissions trading transactions during 2005-2013. Each observed transaction represents an individual instance of a firm-level purchase or sale of carbon credits, accounting for the amount of credits traded, the identity and the location of the buying and selling firm. This collectively comprises 549,164 emissions trading transactions among 12,358 firms across 4,008 cities. Every emissions trading transaction is attributed to a specific firm with a specific address, allowing for reliable identification of the city location. Every transaction attributable to a given facility is directly tied to the physical emissions of that facility, meaning the transaction data and the emissions activity associated with it to represent the same location. The inter-city transactions by way of participating firms within observed cities is visualized in Figure 3 below, where cities are represented as blue nodes and transactions are represented as green lines.

Figure 3. EU emissions trading transactions



I account for the amount of carbon credits traded per city as give in model 3 below, where θ_i accounts for the sum of firm-level observations of carbon credits traded (z) for a given firm (k) in a given city (i), denoted as z_{ki}, where the amount of credits traded can vary by city, denoted by K_i.

$$\theta_i = \sum_{k=1}^{K_i} z_{ki} \tag{3}$$

I then calculate the difference between carbon credits sold and carbon credits bought by each firm during the observed time period, producing a continuous measure where a positive value reflects a firm that has sold more carbon credits than it bought and the size of the value reflects the extent. Firms with a negative value reflect the converse. I then aggregate these values to the collective city-level in each of the sample cities represented in the dependent variable, expressing the extent to which, in each sample city, more emissions credits were sold than bought or vice-versa during the observed time period.

To test the Clean Development Mechanism component of the H3, I similarly identify the specific conditions in which participation yields the marginal profit that incentivizes emissions reduction. A given Clean Development Mechanism project earns carbon credits which it may sell for real money only by demonstrating to designated authorities that the project can achieve emissions reductions that would be unique or additional, or reductions that in the absence of said project, would not occur (UNFCCC, 2011). An approved project is then able to earn carbon credits commensurate with the emissions reductions demonstrated and sell them for real money, meaning that the conditions in the Clean Development Mechanism where marginal profit incentivizes emissions reduction is represented by any approved carbon offset project.

Accordingly, I operationalize as count data the number of carbon offset projects that took place in each city during the observed time period. The variable is created by identifying the city location of every project[8] listed in the CDM Pipeline (Fenhann, 2019) via their individual Project Description Documents, available via the UNFCCC website. There are twenty-seven types of carbon offset projects, and the sample cities include projects covering nine of these types: Biomass energy, coal methane capture, energy efficient (gas and heat) generation, fossil fuel switch, landfill gas capture, methane avoidance, and hydro, solar and wind power. Total counts of each project type per city are modeled for association to the dependent variable, and separately modeled are total counts of offset projects across all project types per city. Given the

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[8] Out of the total of over 8,000 offset projects that took place during the observed time period, a total of 5,345 projects were identified at the city-level for cities in my dependent variable dataset.

respective geographic restrictions of EU emissions trading system-eligible (more developed) and Clean Development Mechanism-eligible (less developed) cities, H3 separately tests both groupings of cities, reflected in the descriptive statistics in Table 2.

Regarding the operationalization of carbon market data: Existing research treats EU emissions trading system emissions trading transactions as comparable across different participating firms (Ellerman et al., 2003; Czerny and Letmathe, 2017), as well as for Clean Development Mechanism projects across different sites (Murphy et al., 2015; Schneider, 2007). My metrics for carbon market activity, then, are suitable for inclusion in a regression, granted that EU emissions trading system transactions are observed separately from the Clean Development Mechanism. In function, emissions trading-participating firms and Clean Development Mechanism projects both translate their own emissions reduction into carbon credits which can then be sold (Kirkman et al., 2013). They differ in form, however, as emissions trading involves existing firms while Clean Development Mechanism projects are normally stationary sites such as wind farms created specifically for Clean Development Mechanism participation. Clean Development Mechanism projects also often involve more government oversight than emissions trading, though principally maintained by private sector actors.

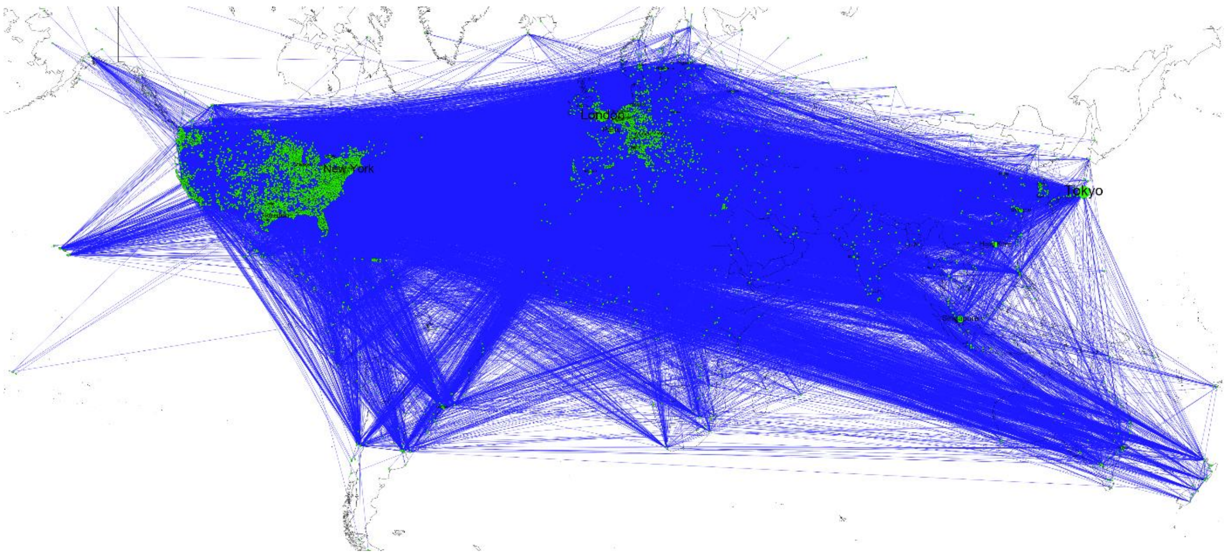
This general comparability aside, it is possible that one EU emissions trading system transaction or one Clean Development Mechanism project may be more effective on-the-ground at achieving reductions than another, and in modeling terms, my carbon market variables assume that one EU emissions trading system transaction or one Clean Development Mechanism project is equal to another. But what matters is the increasing local scale of these activities—that is, the more transactions and projects as measured here that occur within a given city, the more emissions reductions should occur and thus contribute to a visible reduction of collective city-level emissions if indeed the carbon market system "works."

To test H4, I operationalize a measure of city government creditworthiness, expressing as count data city government credit ratings sourced from Moody's Analytics. There are 22 ratings, for which I coded the lowest (D) as 1 and the highest (Aaa) as 22, and calculated the average 2005-2013 rating per city, during which time there was little to no variation in the rating of most cities. City government credit rating is tested in the same models as carbon market variables (H3) to be consistent with the theoretical purview of financialization. However, given credit rating is not a geographically-restricted phenomenon, like different segments of the carbon market, the credit rating variables is also tested against the full global sample of urban emissions change.

Control variables

A series of control variables are operationalized both for their expected empirical significance and for their theoretical values. Variables for the world city hierarchy and manufacturing presence are operationalized as conceptual translations at the city-level of structurally advantaged and disadvantaged positions, respectively, in the world economy as understood by ecologically unequal exchange literature. To create the world city hierarchy variable, I use the *Directory of Corporate Affiliation* data from LexisNexis, which covers all multinational headquarter and branch locations for corporations earning over $10 million in annual revenue for the year 2016. I follow the approach used by Alderson and Beckfield (2004), calculating world city hierarchy as a degree centrality metric derived from inter-city ties defined by corporate headquarter-branch office locations. I account for the headquarter-to-branch office relationships of 30,405 companies across 22,312 cities, creating an inter-city social network, visualized in Figure 4 below, with cities displayed as green nodes and ties displayed as blue lines.

Figure 4. World city hierarchy



Degree centrality C_D' is a social network metric calculated as given in model 4 below (Wasserman and Faust, 1997: 179), representing the proportion of nodes with ties to the observed node n_i within group g, for which the maximum group size is g – 1. The world city hierarchy network treats a given city as the node (n_i), where a single inter-city headquarter-branch tie (d) constitutes a single relation between a pair of cities. The sum of these ties per city constitutes the degree centrality, taken to represent ranking of a given city's connectivity within the world city hierarchy.

$$C_D'(n_i) = \frac{d(n_i)}{g-1} \qquad (4)$$

To create the manufacturing variable, I express as count data the total number of all city-level high-polluting manufacturing firms in each sample city as of 2016. This variable is generated via two steps. First, 100 companies are responsible for over 70% of global greenhouse gas emissions in a recent Carbon Disclosure Project report (Griffin, 2017), and I identify the Standard Industrial Classification codes for every individual company. Table A-3 in the Appendix shows all industrial classification codes and associated labels, which may be used for replication purposes. Second, I perform a global search of all firms belonging to those codes using the Mergent Intellect, Standard and Poor's Capital IQ and Uniworld databases, I remove duplicate listings, note the city-location of all firms and code the resultant value for each sample city. To determine if urban emissions change varies significantly city-level structurally advantaged (world city hierarchy) and disadvantaged (manufacturing), both the world city hierarchy and manufacturing variables are modeled separately from other independent variables economy of urban emissions change. Both controls are also included in fully-loaded models in order to test the uniqueness of effect of local environmental industry on urban emissions change.

Affluence or income levels are a standard measurement cross-national analysis of environmental change, such as the Stochastic environmental Impacts equal to the multiplicative product of Population, Affluence and Technology (STIRPAT) model (York and Rosa, 2003). However, a number of issues prevent the inclusion of an income variable for use in the analysis. It was not possible to obtain reliable city-level income data for all 331 cities, however a partial accounting of income in 96 of these cities showed high collinearity (p>.69) with world city hierarchy. Given the corporate power-related nature of the world city hierarchy metric, it is likely that accounting for income in the full 331 cities would show the same correlation, and in any case suggests that world city hierarchy is highly representative of urban income level. The same may be said for urban GDP per capita. A full accounting of national-level per capita income was obtained and an average value for the observed years of 2005 to 2013 was produced.

However, this national income metric was highly collinear with both national climate policy ($p>.75$) and treaty ratification ($p>.74$), preventing inclusion in the same model. I choose to include the more empirically and theoretically important variables of national climate policy and treaty ratification in the main analysis and omit the national income variable. However, for reference I show the results of separate modeling including national income in Table A-4 in the Appendix for reference. This shows that national per capita income is significantly associated with urban emissions reduction.

Given the perennial importance of national government climate change mitigation policy for urban emissions change (Kern and Bulkeley, 2009; Peterson, 2017), I operationalize a measure of national government climate change policy frameworks. This variable expresses as continuous data the average value over 2010-2013 of the “national climate policy” component of the Climate Change Performance Index that covers 58 countries (Burck et al., 2011, 2012, 2013, 2014), all of which overlap with the 48 observed in this dissertation. This measures on an ordinal scale of 1 to 5 the presence and stringency of national policies aimed at greenhouse gas emissions reduction across the energy, manufacturing, construction, transport and residential sectors, based on direct input from climate change experts within each country scored (Burck et al., 2013). Measures for years prior to 2010 were unavailable. The average national climate policy values for the observed countries can be viewed in Table A-5 in the Appendix.

Given the importance of treaty ratification for cross-national environmental outcomes, particularly as shown in world society literature (Henderson, 2019; Shorette, 2012), I operationalize a measure for national-level ratification of international environmental treaties.

This expresses as count data all international environmental treaties signed by all observed countries as of 2014. This metric was originally coded by Andonova et al. (2017), which they sourced from the International Environmental Agreements Database (Mitchell, 2002-2014).

While tests of H1 and H2 operationalize the independent variables for environmental management consultancies and environmental network memberships as variables of interest, H3 operationalizes them as controls given their presence in both carbon market regions and to offer a more robust test of the financial market variables of interest. To reduce skewness in variables containing zero and negative values, including credit rating, environmental consultancy presence and percent change variables measurements, the cube root was taken. Variables with only positive values but with a skewed distribution, were log transformed. The resulting final models contained both cube-rooted and log transformed independent variables. The values for variables shown in the below table express the full original values to clearly represent their distribution.

The summarized values for the dependent variable indicate the observed urban per capita greenhouse gas emissions change range from a reduction of -99% and to an increase of 215% in 2013 from a base year of 2005, on average more reductions took place in more developed than less developed countries. While the range and mean of environmental network memberships is relatively lower than environmental consultancies, there is adequate variability for statistical inference. The median value of 1 illustrates that most cities with any membership in an environmental network tend to have only one, suggesting that the difference between a zero versus a non-zero value for memberships, particularly a single membership, is a highly important distinction in the distribution. This is as opposed to environmental consultancy presence, with a median value of 6 and generally higher values per city.

Table 2. Variable descriptive statistics & source, H1-2 test sample

Variable Names	Mean	Range	Data source
Dependent Variable			
GHG % change	.10	-.99 – 2.15	Carbonn Climate Registry, C40, Carbon Disclosure Project, individual city government websites; Shan et al. (2017, 2018a, 2018b, 2019)
Independent Variables			
Credit rating	7	0 – 22	Moody's Analytics
Env. consultancies	3.9	0 – 76	Mergent Intellect
Environmental network memberships	1.6	0 – 12	Acuto et al. (2019)
Controls			
National climate policy	3	2 – 4.7	Germanwatch
Treaty ratifications	74.4	2 – 144	Mitchell (2002-2014); Andonova et al. (2017)
Manufacturing count	18.2	0 – 459	Mergent Intelligence
World city hierarchy	8.5	0 – 214	Lexis Nexis
Observations	331		

Table 3. Variable descriptive statistics & source, H3-4 test samples

	EU emissions trading system-eligible cities		Clean Development Mechanism-eligible cities		
Variable Names	Mean	Range	Mean	Range	Data source
Dependent Variable					
GHG % change	-.34	-.99 – 1.89	.51	-.96 – 2.15	Carbonn Climate Registry, C40, Carbon Disclosure Project, individual city government websites; Shan et al. (2017, 2018a, 2018b, 2019)
Independent Variables					
Credit rating	11.7	0 – 22	.84	0 – 13	Moody's Analytics
Env. consultancies	5.74	0 – 76	1.29	0 – 62	Mergent Intellect
Environmental network memberships	.2	0 – 12	.9	0 – 9	Acuto et al. (2019)
EU emissions trading system transactions		-590K – 2.2M			European Commission ETS Registry
Clean Development Mechanism projects	-	-	5.7	0 – 69	UNFCCC CDM Pipeline
Project counts & credits					
Biomass energy	-		.3	0 – 4	
Coalbed/mine methane	-		.14	0 – 5	
Energy efficiency	-		.62	0 – 10	
Fossil fuel switch	-		.12	0 – 2	
Hydro power	-		1.14	0 – 30	
Landfill gas	-		2.11	0 – 64	
Methane avoidance	-		.25	0 – 7	
Solar power	-		.16	0 – 6	
Wind power	-		2.08	0 – 65	
Controls					
National climate policy	3.38	2.2 – 4.7	2.5	2 – 3.9	Germanwatch
Manufacturing count	10.8	0 – 222	33.2	0 – 459	Mergent Intellect
World city hierarchy	11.3	0 – 214	4.1	0 – 88	Lexis Nexis
Observations		164		167	

Values denoted "K" and "M" represent thousands and millions, respectively. Values displayed for *Project counts & credits* in the Clean Development Mechanism sample show project count values

The geographic distribution of key city-level variables reflects global political-economic divides understood to be meaningful for national-level environmental change. Following Jorgenson and Clark (2012), I designate nations occupying the upper quartile of the World Bank's income classification of nations as developed, and nations falling below the upper quartile as less developed. The Welch's two-sample t-test in Table 4 shows that per city, both the number of environmental consultancies and environmental network memberships are on average significantly higher in more developed countries, while the number of high-polluting manufacturing firms is significantly higher in less developed countries. This suggests that the more/less developed nation divide, shown in ecologically unequal exchange literature to be consequential for national emissions change (Jorgenson, 2016), is also meaningful for mechanisms affecting urban emissions change.

Table 4. Welch's two-sample t-test for geography of consultancies and manufacturers

	Variable mean	*t*	*df*
Env. consultancies		-4.98***	276.7
More Developed	60.5		
Less Developed	16.1		
Env. network memberships		-5.53***	305.4
More Developed	2.24		
Less Developed	1.05		
Manufacturers		-3.95***	227.8
More Developed	872.7		
Less Developed	2,322		

Levels of significance are denoted as follows: **p<.05, ** p<.01, ***p<.001*

The correlation matrix of independent variables represented in Table 5 shows no significant correlations, alleviating concern for potential multicollinearity issues.

Table 5. Correlation matrix of independent variables

	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
Credit rating	1								
Environmental network memberships	.29	1							
Environmental consultancies	.39	.41	1						
EU emissions trading system	.17	.03	-.01	1					
Clean Development Mechanism	-.13	-.12	.06	.01	1				
Manufacturing presence	-.01	.06	.23	.12	.17	1			
World city hierarchy	.35	.42	.43	.15	-.01	.23	1		
National climate policy	.4	.45	.44	-.07	-.32	-.22	.47	1	
Environmental treaty ratifications	.35	.36	.24	-.01	-.20	-.31	.31	.44	1

Results

The results are divided into three sections, the first reporting results for H1, H2 and H4 across the full, global sample of cities, and the second and third reporting results for tests of H3 separately across EU emissions trading system-eligible cities and Clean Development Mechanism-eligible cities. Percent change of urban per capita greenhouse gas emissions in 2013 from a base year of 2005 is treated as the dependent variable, meaning that for all results shown, a negative and significant coefficient denotes an association with reduced emissions.

Polycentric systems and global effects

Table 6 shows the results for H1, H2 and H4, or the tests of association with urban emissions reduction of environmental consultancy presence, environmental network memberships and city government creditworthiness. Inference on hypothesis testing rests with Model 6, which displays the fully-fitted model, while Models 1-5 fit individual and combinations of variables to better show the relative explanatory value each adds. Model 1 shows only the results for world city hierarchy and manufacturing presence. These represent the city-level conceptual translation of ecologically unequal exchange, where a structurally advantaged position (world city hierarchy) versus a disadvantaged position (manufacturing) in the world economy is expected to be associated with emissions reductions and increases, respectively. The results in Model 1 show that, absent other covariates, a higher rank in the world city hierarchy is associated with emissions reduction while a greater number of high-polluting manufacturing firms is associated with emissions increases.

Models 2-4 introduce environmental consultancy presence, environmental network membership and city government credit rating, which shows a negative and significant bivariate relationship to emissions change, absent other covariates. These three independent variables of interest are combined in Model 5, along with two of four controls, world city hierarchy and manufacturing. Environmental consultancies and environmental network memberships show a robust and significant relationship to emissions reduction, the effect of credit rating attenuates and the effect of world city hierarchy and manufacturing remain highly significant. The fully-fitted model (Model 6) shows that environmental consultancies and network memberships remain significantly associated with emissions reduction, and the effect of city credit rating attenuates to non-significance. This lends support for H1 and H2, and no support for H4.

National climate policy also is significantly associated with urban emissions reduction, evincing the ongoing importance of sovereign government climate policy intervention and illustrating multi-level governance dynamics at play. The significant association shown by both environmental consultancy presence and network memberships with urban emissions reduction are inferred as net reductions to the carbon footprint, or non-externalized reductions that are isolated within the urban boundary. These particular reductions are assumed to comprise part of but not the full negative percentage change in per capita emissions in the observed cities, with the remaining reductions attributable to national climate policy and other factors not controlled for in modeling.

Other factors may well include other components of climate policy or to the externalization of emissions increases beyond the urban boundary, the latter quite possible given that Scope 3 emissions are not included in the dependent variable. Nevertheless, the direct, within-boundary emissions (Scope 1) and indirect emissions from the purchase of energy (Scope

2) included in the dependent variable comprise a significant portion of the total carbon footprint, for which the above factors are shown to be associated with urban reductions.

In Model 6, the effect of world city hierarchy attenuates to non-significance while manufacturing slightly attenuates, national climate policy maintains a strong association overall to urban emissions reduction and environmental treaty ratification is weakly associated with emissions reduction. The fully-fitted model illustrates multi-level forces associated with emissions reduction as well as increases. City-level presence of environmental consultancies and environmental network memberships, as well as national-level stringency of climate policy, are strongly associated with urban emissions reduction, while the presence of high-polluting manufacturing firms is strongly associated with urban emissions increases.

That the city-level factors associated with emissions reduction versus increases are respectively more present in more versus less developed nations reflects the differential outcomes expected by ecologically unequal exchange (Jorgenson, 2016), suggesting urban environmental outcomes are affected by structurally advantaged versus disadvantaged national-level position in world trade. More broadly, these results suggest both city-level factors and national factors are meaningful for explaining variation in urban emissions change. Beyond the top-down regulatory forces imposed by sovereign national governments, urban emissions reductions are meaningfully associated with the local availability of professional climate mitigation expertise offered by environmental services consultancies and environmental network memberships.

Consultancies in particular afford city governments access to cost-minimizing climate governance models such as energy performance contracts as well as the opportunity to procure these resources locally, thus financially contributing back into to the same local tax base from which the local government draws revenue and investing in the long-term growth of local industries. City-level factors are similarly meaningful in explaining urban emissions increases, as cities housing relatively more firms that belong to the highest-polluting industries globally are more likely to increase emissions. Population change shows no significant effect on the results. While the range of population change spans from -81% (decline) to 72% (growth), the average is 10% with a median of 4%, suggesting a modest population change across the sample.

To determine if the observed relationship with urban emissions reduction shown by both environmental consultancies and network memberships varies significantly by country, I interacted both associations with country location. In both cases, no significant associations were found, suggesting that the relationship between urban emissions reduction and both consultancy presence and network membership is not relegated to one specific country. The same is true for the relationship between high-polluting manufacturing firms and urban emissions increases. This means that the association between these city-level factors and emissions reduction remain constant across regardless of what nation they are located in. While a limited sample of 331 cities across 48 countries, this exhibits a geography of emissions change that is defined both by city-level and national-level factors.

Table 6. Effects of polycentric systems on global urban emissions change

	1	2	3	4	5	6
City-level variables of interest						
Environmental consultancies		-.34 (.03)***			-.17 (.04)***	-.18 (.03)***
Environmental networks			-.46 (.05)***		-.18 (.05)***	-.16 (.05)**
Credit rating				-.23 (.03)***	-.08 (.03)**	.01 (.03)
Controls						
Population change					-.08 (.06)	-.07 (.05)
World city hierarchy	-.08 (.01)***				-.02 (.01)***	.02 (.01)
Manufacturing	.11 (.02)***				.10 (.01)***	.03 (.01)**
National climate policy						-.39 (.06)***
Treaty ratifications						-.01 (.01)**
Constant	.19 (.05)	.42 (.05)	.47 (.05)	.29 (.04)	.30 (.07)	1.78 (.19)
R^2	.25	.18	.20	.15	.38	.47
obs.	331	331	331	331	331	331

Numbers in parentheses are standard errors. Levels of significance are denoted as follows: **p<.05, ** p<.01, ***p<.001*

Visualized in the scatterplots in Figures 5-6 are the relationships between urban emissions change and both environmental management consultancies and environmental network memberships. Figure 5 shows that environmental consultancies are more present in emissions-reducing than increasing cities, the greater the number of environmental consultancies, the lower the emissions increases. The same pattern shows in Figure 6 with urban emissions change and environmental network memberships. The effect of environmental network memberships on urban emissions change can be partially but not completely isolated from that of environmental consultancies.

First, these effects may be isolated to the extent that the geography of cities with environmental network memberships does not overlap completely with cities housing environmental consultancies. There are 48 cities in the sample with zero environmental network memberships and with one or more environmental consultancies, and there are 32 cities with zero environmental consultancies and one or more environmental network membership. The rest of the sample, comprising the majority, overlaps, but imperfectly. Among cities with at least one of each, the number of consultancies per city does not significantly increase, as a correlation test in Table 5 in the Data & Methods section shows a correlation of .41 between the two variables.

Second, the effects of environmental networks on urban emissions reduction may interact at least partially with that of environmental consultancies. That is, to the extent that several environmental networks are partnering with environmental consultancies to provide member cities access to the resources offered by the latter, including energy performance contracts. While this trend of partnerships does not reach across all environmental networks, there are sample cities such as Houston (USA) and Melbourne (Australia) that are members of environmental networks with such partnerships that are shown to have obtained energy performance contracts via these partnerships. In the next chapter, qualitative inquiry narrates instances of environmental networks and environmental consultancies facilitating emissions reduction both independently of one another and by way of interaction.

Figure 5. Environmental management consultancy presence and urban emissions change

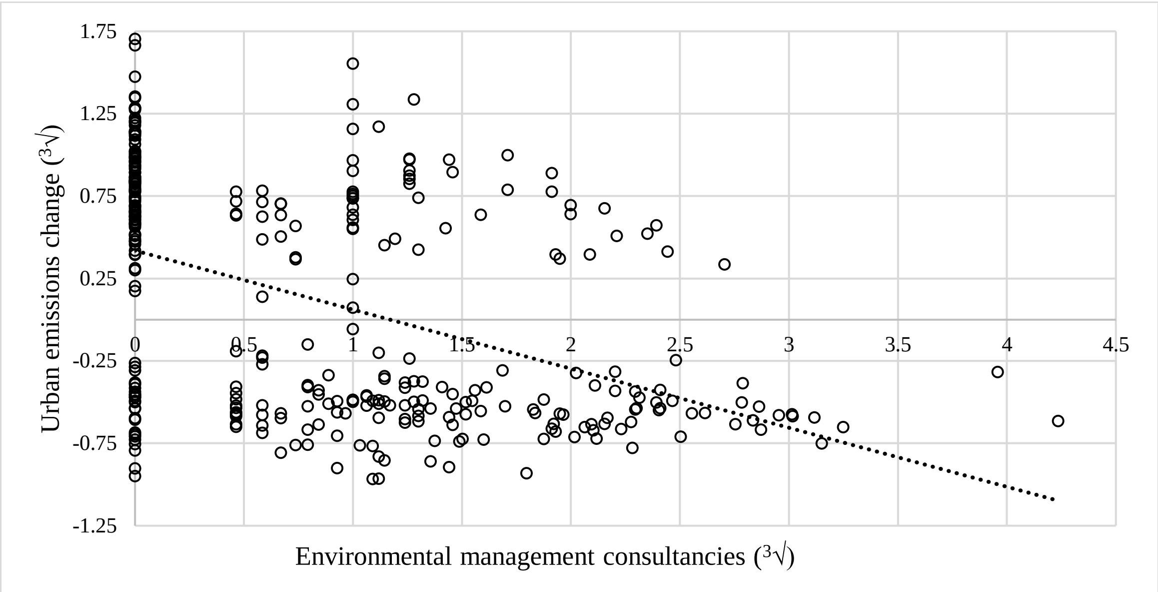
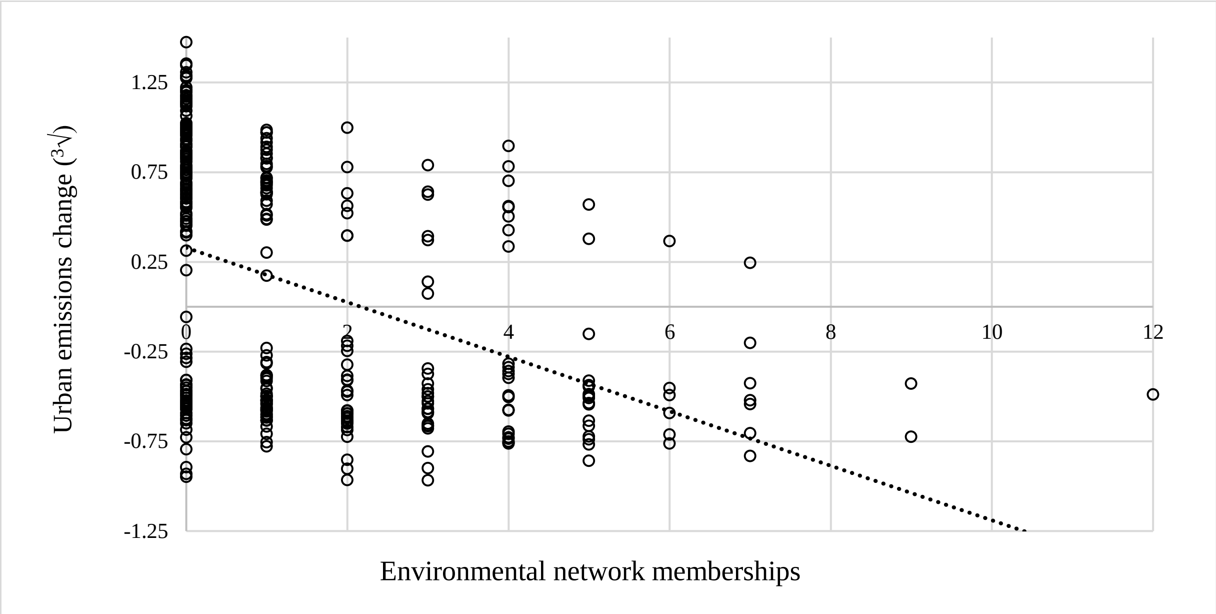


Figure 6. Environmental network memberships and urban emissions change



Carbon market effects on urban emissions change

The tests for H3 involve testing for association between city-level carbon market activity and urban emissions change, observing specifically the carbon markets of the EU emissions trading system and the Clean Development Mechanism. Table 7 shows the results for both components of the carbon market. Model 1 shows the results for the sample of cities (N=155) in EU emissions trading-eligible countries, which includes those in the EU and with recorded transactions in the US, Canada and other developed countries. No discernible relationship is found between participation in the EU emissions trading system and urban emissions change. This finding holds both for the sample of 155 cities and for a separate model of only those 64 cities specifically within EU, where the majority of emissions trading transactions occurred. Participation in the system is specifically measured by the extent to which firms sold more carbon credits than they bought at the collective city-level, which directly represents the conditions one would expect emissions trading activity to yield emissions reductions.

This finding suggests that the urban spatial concentration of emissions trading activity does not lead to collective urban-level emissions reductions. More specifically, this means that to whatever extent emissions trading-participating firms increased or reduced facility-level emissions, this change is not visible at the collective city-level. It further suggests that while the carbon market designates carbon credits as representative of physical greenhouse gas emissions, the two are in fact decoupled. It is possible, though unknowable from this analysis, that an emissions trading transaction attributed to one city location may be attributable to physical emissions reduction in a separate facility located elsewhere.

Modeling also includes covariates of interest and controls, which show that only environmental consultancies show a significant association to urban emissions reduction, though little overall explanatory value is offered in Model 1, denoted by the relatively low R^2. In any case, the relationship shown with environmental consultancies is likely explicable by the relatively greater presence of consultancies in more developed countries, which largely overlap with countries housing firms (and cities) participating in the EU emissions trading system. World city hierarchy is omitted from the Model 1 given high ($p>.5$) collinearity with environmental consultancy presence, which attenuates all covariates to non-significance.

The less developed nation-portion of the carbon market use the sample of Clean Development Mechanism-participating cities (N=167), with results reported in Models 2-3 in Table 7. Model 2 includes the aggregate count of Clean Development Mechanism projects, Model 2 includes the counts of specific Clean Development Mechanism project types, and both models include other covariates of interest as controls. The variable for Clean Development Mechanism projects in aggregate shows no association to urban emissions change, and only the fossil fuel switch and wind power variables show a weak association with urban emissions reduction and increases, respectively. Many carbon offset project types are found in initial modeling to be non-significant, and are omitted from the final models to offer more parsimonious results. For reference, the fully-loaded model results can be seen in Table A-6 in the Appendix.

Among Clean Development Mechanism types, only the fossil fuel switch projects variable shows as significantly associated with emissions reduction. However, this result is based on the presence of such projects in only 16 cities, and thus does not reflect a meaningful pattern.

In sum, no support is found for H3, as no carbon market-related variables are associated with urban emissions reductions.

Most associated with urban emissions reductions is the variable for city memberships in environmental transnational municipal networks. That environmental network memberships and environmental consultancy presence is most associated with urban emissions reduction in the sample of Clean Development Mechanism- and EU emissions trading system-participating cities, respectively points attention to the global north/south divide. Participation in the Clean Development Mechanism and EU emissions trading system principally occur in less developed and more developed nations, respectively. As shown in Table 6, while there are on average significantly more environmental network memberships in more developed than less developed nations, the average environmental network memberships in more (less) developed nations of 2.24 (1.05) is a markedly smaller gap than the average environmental consultancies in more (less) developed nations of 60.5 (16.1).

That is, relatively more environmental network memberships exist in cities of less developed nations than do environmental consultancies, the greater reach of the former into the less developed nations potentially explaining why Clean Development Mechanism-participating cities show an association between urban emissions reduction and environmental network memberships. Last, city government credit rating is included in modeling for both components of the carbon market, and as with the results in the full sample of cities, no association with urban emissions change is detected.

Table 7. Urban emissions change and carbon market participation

	EU emissions trading system	*Clean Development Mechanism*	
	1	*2*	*3*
Financialization			
Credit rating	.01 (.01)	.01 (.08)	.01 (.08)
Emissions trading	.01 (.01)	-	-
Clean Development Mechanism	-	.05 (.06)	-
CDM projects			
Fossil fuel switch	-	-	-.33 (.14)*
Wind power	-	-	.10 (.05)*
Controls			
Env. Consultancies	-.13 (.50)***	.09 (.09)	.15 (.09)
Env. networks	-.01 (.01)	-.41 (.09)***	-.39 (.08)***
Manufacturing	.01 (.01)	.03 (.04)	.03 (.04)
National policy	-.16	-.73 (.79)	-.91 (.74)
World city hierarchy	-	-.04 (.02)*	-.04 (.01)*
Constant	.53 (.38)	1.74 (.10)	1.78 (.11)
R^2	.14	.32	.36
obs.	155	167	167

Numbers in parentheses are standard errors. Levels of significance are denoted as follows: **p<.05, ** p<.01, ***p<.001*

Discussion

The findings evince that patterns of greenhouse gas emissions reduction in cities worldwide are explicable in part by both city-level factors and national-level climate mitigation policy, which involve both political-economic and normative forces operating at the local- and macro-scales. Local-scale political-economic forces of cost-minimization and capital accumulation, and normative forces of scientific expertise on climate policy, interact to influence urban environmental outcomes. These processes are contextualized by urban political ecology.

Explaining the macro-scale forces involves both drawing upon and filling gaps in existing macrosociological theory on global environmental change. The structurally advantaged position in the world economy argued by ecologically unequal exchange to affect national emissions change also provides geographic context for the mechanisms associated with urban emissions change. The process of global norm diffusion argued by world society theory explains the global spread and adoption process of climate governance models that, through polycentric organizational structures, influence urban environmental outcomes. Urban political ecology literature similarly helps link these macrosociological processes to the city-level. The below sections describe in detail the theoretical and empirical advances afforded by the findings. In addition to these contributions, the findings also offer applied, policy-relevant insights for implementing urban climate mitigation in the context of post-pandemic green recovery efforts.

Local-scale forces

The results illustrate both local-scale political-economic and normative forces associated with urban emissions reduction via the mechanisms of environmental management consultancy presence and environmental network memberships. Local-scale effects of a strictly political-economic nature are also seen in the associations as national climate policy and high-polluting manufacturer presence.

The governance of urban climate change mitigation begins with municipal authorities seeking out the requisite technical expertise for policy design and implementation (Jones, 2018; Rice, 2014; Tzaninis et al., 2020). When said expertise is obtained from environmental management consultancies via contract and from environmental networks via membership, this involves the local-scale normative process of city governments interfacing with professional experts (Swyngedouw, 2010; Zimmer et al., 2020).

Environmental consultancies as a source of expertise is more embedded in local-scale political-economic forces than environmental networks. City governments tend to procure services locally when contracting to environmental management consultancies, acting as an investment in local industrial growth that city governments draw tax revenue (Nijaki and Worrel, 2012; Preuss, 2009). This may be interpreted as the tendency for urban climate change governance to support capitalist urbanization (Keil, 2018), specifically where entrepreneurship becomes integrated into urban environmental governance (Hodson and Marvin, 2017; While et al., 2004).

Further, among the sample cities contracting to environmental services companies, the use of energy performance contracts was very common. Emissions reductions tend to be more achievable when climate policy measures offer such economic co-benefits as cost-savings

(Heinrichs et al., 2013; Nakhooda et al., 2014; Swyngedouw, 2018). Energy performance contracts articulate this dynamic, such that client governments do not pay for the energy efficiency upgrades installed in full at the time of service, but rather only pay for demonstrated energy savings achieved over time (APEC, 2017; Ürge-Vorsatz et al., 2007; Vine, 2005). This contract model is designed to overcome financial obstacles by minimizing the costs of infrastructure upgrades necessary to achieve emissions reductions (Capelo, 2011; Vitiello, 2015), hence its high popularity.

These local-scale political-economic factors are likely why environmental management consultancies show a stronger association to emissions reductions than do environmental network memberships. This includes not only the cost-minimizing and growth-enabling quality of energy performance contracts, but also the on-site one-on-one services provided by consultancies: Direct assistance in the emissions reduction project design, the relevant sourcing of materials, equipment and personnel, and the direct implementation of said projects (Biagini and Miller, 2013; Feser and Runst, 2016). While environmental networks provide member city governments access to a range of climate planning models, emissions tracking software and assistance in obtaining climate mitigation-related financial resources and equipment (C40, 2018a; ICLEI, 2010b), these services tend to be more remote in nature and relatively less rigorous than that of consultancies. The ostensibly greater emissions reduction efficacy offered by the wider range of services offered by consultancies is likely why environmental networks are partnering with environmental consultancies.

The networks-consultancies dynamic further explains why urban emissions reduction is more associated with consultancies than environmental network memberships. For instance, three of the sample cities tested are known to have entered into energy performance contracts with environmental services firms via their membership in C40. Specifically, it was through C40's partnership with the Clinton Climate Initiative and several energy services companies, or the Building Retrofit Program, that Houston, Texas (USA) contracted to Siemens (C40, 2008) and both Melbourne and London contracted to Honeywell to carry out building energy retrofits (Bulkeley and Schroeder, 2008; HBS, 2009). All cases also likely involved local branches of those consultancies implementing the energy performance contracts. Together, the findings lend support to calls for post-pandemic "green recovery" and "green stimulus" that argue for energy performance contracting and local procurement as a cost-effective, emissions-reducing means for local authorities to transition to a low-carbon economic growth model (Bozuwa et al., 2020; Lenka, 2020).

The network-consultancy partnership dynamic is also visible on a larger scale when closely examining the transnational municipal network data in the Acuto et al. (2020) data used in this analysis, which includes not only networks and member cities, but also the partnerships between networks and individual businesses. This shows that as of 2016, six environmental networks had established partnerships with Siemens, including C40, City Protocol, Cities for Mobility, ICLEI and Sharing Cities—making Siemens the business with the most simultaneous partnerships with environmental networks. The data also show that several environmental networks have partnered with such environmental consultancies as ARCADIS, Amec Foster Wheeler, ENGIE (formerly GDF Suez), JT Environmental Consulting, TCO Development and Veolia.

Inherent in the establishment of these partnerships is the expansion of services provided. City governments obtain greater value from their environmental network memberships via new access to professional consultancy services, providing marginal benefit to environmental networks matched by the expanded clientele base for environmental services consultancies. These developments articulate the expansion of neoliberal logic in urban environmental governance, as governance processes become increasingly intertwined with entrepreneurial goals and commodification (Hodson and Marvin, 2017; Whitehead, 2013). The new interactions that emerge from this, between city authorities and experts in consultancies and networks can also be understood in future research as local-scale normative forces of technical expertise transmission influencing climate policy (Swyngedouw, 2010; Zimmer et al., 2020).

The strong association between national climate policy and urban emissions reduction demonstrates the ongoing crucial importance of sovereign government policy intervention and affirms the multi-level context of modern climate change governance (Kern and Bulkeley, 2009; Peterson, 2017). The association between high-polluting manufacturer presence and emissions increases illustrates the local-scale political-economic forces of growth-oriented capitalist urbanization (Keil, 2018) and the resultant increased urban environmental degradation (Bridges, 2016). Local government dependence on local business profits for tax revenue paired with pro-growth planning ambitions can translate to the stifling of environmental policy in favor of the interests of high-grossing polluting industries (Bargaoui and Nouri, 2017; Gould et al., 2016).

The political-economic forces and associated environmental outcomes shown in the results contribute greater nuance to the relationship between economic development and environmental protection. First, the findings specify developmental forces associated with emissions reductions, or the cost-minimizing and growth-generating forces involved with expertise and service provision by environmental consultancies and networks. This offers a critique of the developmentalist imperative argument that economic growth interests lead to negative environmental outcomes, but within limits defined by the short- versus long-term.

In the short term (i.e., 2005-2013), the assumptions of the developmentalist imperative would appear more applicable to the relationship between high-polluting firm presence and emissions increases, which itself is more prominent in less developed countries, and less applicable to the relationship between emissions reduction and environmental consultancies/networks, which is more prominent in more developed countries. While this offers nuance to the assumptions of the developmentalist imperative, the long-term brings a number of risks that may stymy climate mitigation efforts. Expanded government outsourcing to private sector-based expert climate governance knowledge may deepen stratification among cities to access to these resources (Barnett, 2020; Keele, 2017), and potentially shift incentives for climate science away from the public interest and towards profiteering (Keele, 2019). These hazards ultimately stem from the commodification of resources needed for urban environmental governance, and may stymy rather than improve environmental governance, per the contradictions of neoliberal logic (Hodson and Marvin, 2017; Keil, 2018). The relationships discussed here are subject not only to *local*-scale political-economic and normative forces as discussed above, but also *macro*-scale forces, the focus of the next section.

Macro-scale forces

The macro-scale political-economic forces shown to be acting on urban emissions change shed light on the linkages between city-level environmental outcomes and the larger global economic system of which they are part. The relationship between urban emissions reduction and both consultancy presence and environmental network membership shows no significant cross-national variation, and the same is the case for the relationship between for the association between high-polluting manufacturing firms and urban emissions increases. However, significant differences do appear at when considering location within the broad groupings of more developed versus less developed nations, situating urban emissions change within a larger geographic context.

More developed countries tend to occupy the structurally advantaged position in international trade flows that ecologically unequal exchange theorists show is associated with national-level emissions reduction, while less developed or global south countries occupy the disadvantaged position associated with emissions increases (Ciccantell, 2019; Givens et al., 2019; Jorgenson, 2016). At the city-level, I find that there are significantly more environmental consultancies and environmental network memberships in the cities of developed nations, and more high-polluting manufacturing firms in the cities of less developed nations. This suggests that the global north versus south divisions that are consequential for national emissions change are also consequential for urban emissions change. This further provides an initial pathway for linking ecologically unequal exchange processes, or those global political-economic forces affecting national environmental change, to urban environmental change.

Further nuance is revealed in the results for the different segments of the carbon market, which show that environmental consultancy presence is most associated with urban emissions reduction among EU emissions trading system-participating cities (more developed nations) and environmental network memberships are most associated with urban emissions reduction among Clean Development Mechanism-participating cities (less developed nations). This is likely due to environmental network memberships being comparatively more common among world cities in less developed nations than environmental services firms. It is further plausible that cities lacking access to professional consultancies will by default seek and obtain environmental governance expertise via environmental networks.

The phenomenon of achieving within-boundary emissions reductions by externalizing emissions increases, via offshoring high-polluting industries or otherwise, occurs at the urban-level much as it occurs at the collective national-level (Thombs, 2018; Tzaninis et al., 2020; Wilson and Jonas, 2018). As such, some portion of the observable urban emissions reductions analyzed here may be attributable to this phenomenon given that Scope 3 emissions are not included in the dependent variable and not directly controlled for. While I therefore assume that some of the observed emissions reductions in my sample cities may be attributable to externalized emissions increases, I argue that the reductions attributable to environmental consultancy- and network-related processes are isolated to within the urban boundary. That is, urban climate mitigation projects facilitated by environmental consultancy- and environmental network-provided services often involve permanent infrastructure upgrades or replacements (C40, 2019; ICLEI, 2010a; Keele, 2017). This allows facility-level emissions reductions to be achieved without relocating any existing operations and externalizing emissions, contributing a net reduction to the total carbon footprint.

An important caveat is that, notwithstanding this short-term process of emissions reduction, increased outsourcing to consultancies brings the long-term risk of shifting incentives for climate science away from the public interest and towards profiteering (Barnett, 2020; Keele, 2019). The ultimate result of this neoliberal encroachment on urban environmental outcomes is stymied rather than improved climate mitigation. The next chapter details several individual cases illustrating contract-related emissions reduction processes and also discusses at greater length the long-term risks that may threaten progress in effective climate mitigation.

The findings provide a macro-scale, structural context for normative processes affecting urban environmental change. Informing urban climate policy is principally not locally-generated knowledge, but rather normative policy models, techniques and practices that are spread globally, accessed by local authorities and then adapted for local use. This broader schema of global knowledge flows and local implementation is understood as a world society process (Schofer et al., 2016; Shorette et al., 2017). In this case, urban access, adaptation and implementation of this non-local knowledge in policy form results in urban environmental change. The structural form through which this process occurs, however, is not the traditional national-to-subnational schema assumed by world society theorists (Frank et al., 2000a, 2000b; Schofer and Hironaka, 2005; Shorette et al., 2017). Rather, the environmental consultancies and environmental networks facilitating the norm diffusion process are polycentric systems, or decentralized networks of sub- and non-state actors operating in a horizontal rather than hierarchical organization (Carlisle and Gruby, 2017; Ostrom, 2010; Van der Heijden, 2019).

These two polycentric systems are key entities in the organizational rescaling of global climate change governance to the city-level, offering direct access to climate policy technical expertise independently of national governments. Further, the dynamic of environmental networks partnering with environmental consultancies discussed in the previous section articulates a global-scale structural evolution among polycentric systems. By enabling environmental network member cities more immediate access to consultancy-based services, this structural evolution may allow for increased collective urban capacity to achieve emissions reduction. However, it may also deepen the risks mentioned in the previous section, namely the commodification of climate knowledge and services, shifting incentives toward profit and away more effective climate action and ultimately leading to more environmental degradation than improvements.

The results also show that environmental consultancy presence and environmental network memberships are disproportionately located in cities of more developed countries, which provides further nuance on the global structure of normative processes. The global spread and use of both consultancy-facilitated energy performance contracts and city memberships in environmental networks have followed a pattern beginning with developed countries, particularly those in the EU and North America, and thereafter outward to less developed countries (Bouteligier, 2013; Nolden et al., 2016; Polzin et al., 2016). This mirrors the more developed-to-less developed country diffusion pattern that world society theorists argue has taken place for environmental policy norms adopted by national governments (Hironaka, 2014; Shorette, 2012). These observations allow for an initial linkage between the traditionally national-focused tradition of world society theory and the horizontal diffusion carried out by polycentric systems directly to cities globally.

Last, given that data used in testing represents consultancy presence for 2018 and city network memberships for 2016, it is also plausible that many of the observed cities first reduced emissions and then both joined environmental transnational municipal networks and experienced a budding environmental services industry. That is, reverse causation cannot be ruled out. However, individual case studies, including those in the next chapter, illustrate a chronology in which environmental consultancy contracting and environmental network membership preceded urban emissions reduction, casting doubt on the possibility of reverse causation. In any case, an intentional goal or unintentional byproduct of urban climate policy can be the attraction of environmental services firms over time, which may be an important phenomenon for future researchers to explore.

Forces of financialization

The intersection between purely financial market forces and urban climate mitigation is observed through carbon market participation by city-level actors and city government creditworthiness as a means of accessing climate mitigation loan finance. The results show that both have no discernible relationship to urban emissions change, yielding a number of important insights. Urban political ecologists recognize the carbon market as one of many networked systems by which urban resource flows are capitalized (Silver, 2017). Unlike the polycentric systems of governance discussed in the previous section, there appears no detectable relationship between resource capitalization and environmental outcomes, as the urban spatial concentration of both emissions trading activity and clean development mechanism projects are unassociated with collective urban-level emissions reductions.

While climate policy offering the economic co-benefit of revenue generation is more likely to successfully achieve emissions reduction (Heinrichs et al., 2013; Nakhooda et al., 2014; Swyngedouw, 2018), these findings indicate that this principle does not extend into carbon market participation. As a market-oriented climate change governance mechanism, the carbon market functions by directing financial flows toward and creating new revenue generating activity for emitting actors. The design carries the assumption that profit incentives and earnings allow for an economically efficient and low-cost means of achieving emissions reduction (Hermanns, 2015; Skovgaard, 2017) because it is further assumed that revenue earned will be used to reduce emissions (Pellizzoni, 2011; Sapinski, 2016). As it concerns collective urban environmental change, my findings cast doubt on these assumptions.

To whatever extent emissions trading-participating firms increased or reduced facility-level emissions, this change is not visible at the collective city-level, suggesting that that while the carbon market designates carbon credits as representative of physical greenhouse gas emissions, the two are in fact decoupled. This finding lends support to existing research arguing that by relying only on economic exchange value in its design, the carbon market transforms the physical process of emissions reduction into a financial transaction, functionally disconnecting one from the other (Ellerman et al., 2003; Knox-Hayes, 2013, 2015; Lohmann, 2005, 2009a).

This disconnection is evocative of a financialization process shifting power away from local authorities and toward distant finance-market interests (Mayer, 2018; Peck and Whiteside, 2016). In the specific context of urban climate governance, this takes the form of the carbon market creating distance between carbon market participants and physical environmental improvements that their actions are designed to achieve (Layfield, 2013). In sum, when revenue generation is sufficiently distant from the physical environmental improvements that the climate policy is designed to incur, significant emissions reductions are unlikely to occur. As the carbon market appears to reproduce these conditions, carbon market participation is thus not a sufficient substitute for traditional urban regulation of climate change.

While city government credit rating delimits access to debt financing (Lynn, 2013; Rashidi et al., 2019) that funds emissions reduction projects (Nocera et al., 2017; Trolliver et al., 2019), city government credit rating is shown to be unassociated with urban emissions change. This suggests that city government credit rating does not meaningfully impact access to climate mitigation loans and green bonds that theoretically may be determinant in enabling successful emissions reduction.

This chapter shows global patterns of association between urban emissions reduction and both environmental management consultancy presence and membership in environmental networks. The next chapter examines individual cases in order to illustrate the on-the-ground processes represented by these quantitative associations, revealing a range of detailed policy interventions over time that demonstrate the theorized political-economic and normative forces at play.

Chapter 4 Qualitative analysis of global urban climate mitigation processes

The quantitative analysis in the previous chapter evinces a strong association between urban emissions reduction to the presence of local environmental services industries and with city government memberships in environmentally-focused transnational municipal networks. By way of selected case studies, this chapter discusses the specific processes by which these relationships occur, adding explanatory nuance not necessarily visible in the statistical analysis. Financialization-related factors are not investigated both because of the null findings and because little qualitative information is available. For instance, city governments during the observed time period of 2005-2013 do not provide detailed reporting on local carbon market activity and its linkage or contributions to local climate action planning efforts. While some documentation reports the use of climate mitigation loan financing, no mention is found of the role of city government credit rating in accessing that financing. Case studies thus focus on individual sample cities to trace the on-the-ground processes linking environmental consultancy contracting and environmental network memberships to urban emissions reduction.

The cases show the polycentric systems of environmental networks and environmental consultancies directly delivering globally-legitimated climate mitigation expertise, models and resources to cities independently of national governments. Environmental network memberships provide cities emissions inventorying and technical climate mitigation policy models, and environmental consultancies and services companies provide cities energy performance contracts and perform energy efficiency upgrades, which allow for emissions reductions. Cases show a commitment *a priori* to economic growth in urban climate planning that precludes economic sacrifice as an acceptable condition for climate change mitigation measures. As such, economic co-benefits of cost-minimization and job growth in local environmental industries are built into urban climate policy. This includes energy performance contracts that yield short-term cost savings via deferment of upfront costs, energy efficiency upgrades yielding cost-savings that over time pay off initial installation costs, and local procurement measures that institutionalize job growth in local environmentally-related industries. These dynamics also carry the distinct risk of profit-driven climate policy that may ultimately stymy rather than improve urban climate governance outcomes over time.

The cases also illustrate a structural hybrid of polycentric systems in the form of partnerships between environmental networks and consultancies, which mutually expand member/client city service provision opportunities and leverage pooled municipal procurement power to lower costs of environmental services and technologies. These developments represent an expansion of neoliberal logics that bear a range of certain risks, which are discussed. The specification and demonstration of these processes advances knowledge of the political-economic and normative forces influencing urban environmental change, and illustrate a more complex global structure of normative expertise diffusion than is traditionally assumed by world society theory. Last, the cases provide immediate pathways for city-level "green recovery" efforts that could recoup mass economic losses from the novel coronavirus (COVID-19) pandemic in a manner that supports sustainable, low-carbon long-term economic growth.

While these case studies isolate and highlight the role of consultancies and networks in urban climate mitigation, this study acknowledges that a broad diversity of actors are often involved. For instance, the climate mitigation efforts of Portland, Oregon (USA) involved establishing a public-private partnership called Clean Energy Works Portland, which included the municipal government and a diverse range of actors beyond contractors and environmental networks: The nonprofit community bank Shorebank Enterprise Cascadia, the national environmental nonprofit Green for All, Energy Trust of Oregon, Pacific Power, local labor unions and community groups (City of Portland, 2015).

Literature on comparative urban case studies for climate mitigation follow a range of selection criteria, for which the common thread is isolating a sample of city cases where the phenomenon of interest is most likely or most prominently taking place. For instance, Aylett (2013) sought to study urban climate change response in conditions of crisis, and hence chose as case studies the cities of Durban (South Africa), and Portland, Oregon (USA) on the basis of their mutual stringency of climate action efforts and shared experience of implementing these efforts during drought and energy crises. Research on the income inequality impacts on climate planning selected cases in Boston, Massachusetts (USA), Jakarta (Indonesia) where wealthy residents determine adaptation planning and benefit from resultant protective infrastructure, but relocate poor residents to areas more vulnerable to heat and other climate hazards (Anguelovski et al., 2016; Wachsmuth et al., 2016).

Other studies focusing on the demographic, consumption and industry-related effects on climate planning selected city cases by population density (Ewing and Cervero, 2010), population size (Kennedy et al., 2009), energy use (Creutzig et al., 2015) and industrial composition (Shan et al., 2018a). Studies focusing on particular regional climate regulatory regimes chose cases on the basis of shared location within the same state, such as California (Boswell and Mason, 2017) or within the same country (Dhakal, 2009; Minx et al., 2013).

Comparative urban studies on climate action are beset by various data limitations. For instance, Jones' (2018) comparison of the municipal climate action of C40 member cities was limited to Copenhagen (Denmark), Stockholm (Sweden) and Tokyo (Japan) on the basis that these were the only cities with officials willing to discuss policy matters in sufficient detail to build comparative case studies. Another common limitation is the dearth of cities with repeat emissions inventories and related statistics, making difficult the selection of comparable urban case studies experiencing similar changes in emissions over time (Croci et al., 2010; Kennedy et al., 2012). My study takes advantage of the considerable expansion of repeat emissions inventories by cities and the availability of climate action planning documents and updates with detailed information documenting events during the past several years. This allows for a comparable, valid selection of potential cases in which the theorized phenomenon of interest is occurring.

Case studies are selected based upon having relatively high values for both emissions reduction and the independent variables of interest, for instance, cases with cities with minimum thirty local environmental management consultancies and/or with memberships in a minimum of three environmental networks. This helps ensure that the hypothesized environmental consultancy and environmental network-related processes are observable in the cases, making visible the mechanisms connecting these processes to urban emissions reduction. Candidate cases were also filtered based on the availability of detailed information on city government climate action and geographic diversity. To provide reference to the relative emissions intensity in each case, I note the base year (2005) level of per capita greenhouse gas emissions for each case city, represented by ranking in four quartiles of base year emissions across the full sample of cities.[9]

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[9] "Detailed information" includes documents reporting details of urban climate change mitigation, including climate action plans and environmental progress reports detailing stakeholders involved, target actions, policy actions taken and progress made over time. Geographic diversity of selected cases span Asia (Singapore), Europe (Barcelona), North America (Knoxville) and Oceania (Melbourne). The base year emissions values for the fourth (upper), third,

This chapter is organized as follows: The first two sections, *Environmental management consultancies & emissions reduction* and *Environmental transnational municipal networks & emissions reduction*, detail cases explaining the processes by which environmental consultancy contracting and environmental network memberships, respectively, facilitated urban emissions reduction. The third and fourth sections, *Economic growth and polycentric systems* and *Evolving norm diffusion in polycentric systems*, discuss the political-economic forces and the normative forces, respectively, observed in the cases and their theoretical implications. The final section, *Conclusion* synthesizes and summarizes findings, suggests pathways forward for future researchers, discusses potential risks from observed trends and offers policy recommendations based on the findings.

Environmental management consultancies & emissions reduction

I would like to argue that environmental management consultancies directly diffuse governance models to city government clients via contract, allowing for emissions reductions to be achieved (Baker et al., 2012; Keele, 2019; Vine, 2005). The statistical association found in the previous chapter between urban emissions reduction and environmental management consultancy presence articulates this pattern globally. Selected case studies trace the ground-level processes lead to this broader pattern, taking specifically the form of environmental management consultancies contracted for general climate mitigation policy design and implementation of such services as energy performance contracts.

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second and first (lower) quartiles represent the ranges of 11-156 tons, 6-11 tons, 3-6 tons and .05-3 tons of greenhouse gas emissions per capita, respectively.

The first case study observes Singapore, a city-state, which represents the third quartile of base year emissions levels in the sample, houses 37 environmental management consultancies and is a member of 2 environmental networks. Singapore covers 721 square kilometers, with a population that grew from 4.2 to 5.2 million between 2005 and 2013. The second case study observes Knoxville, Tennessee (USA), which a represents the third quartile of base year emissions levels, houses 107 environmental consultancies and is a member of 1 environmental network (ICLEI). Knoxville covers 270 square kilometers, with a population that grew from approximately 174,000 in 2005 to 182,000 in 2013.

The emissions reductions that occurred in Singapore between 2005 and 2014 are attributed to the switch in fuel mix for industrial and household energy from oil to less carbon-intensive natural gas, and to the various energy efficiency promotion schemes launched by the government. The latter include the Green Mark Scheme, the Energy Smart Office Label Scheme and the Grant for Energy Efficient Technologies (NEA, 2014). These do not represent an exhaustive review of all climate mitigation efforts of the Singaporean government, but they are highly consequential for emissions reduction and illustrate the theoretical processes of interest. Responding to both environmental protection needs and low productivity in the local construction industry, in 2005 the Singaporean government launched the Green Mark Scheme, a system of energy efficiency performance labeling to promote sustainable building design, expand the green building industry and reduce emissions embodied in stationary infrastructure (Low, 2011).

The Green Mark Scheme requires building owners and developers to engage professional environmental services firms to tabulate an energy efficiency performance score that would be submitted to local government for approval to ensure compliance (Low, 2011). Energy efficiency is the most important criteria on which building environmental performance is evaluated, alongside water efficiency and indoor environmental quality. A point-based score is tabulated by consultants which determines whether and which Green Mark rating is awarded (Li et al., 2011). Green Mark plaques bearing tiered award level names such as Platinum and Gold Plus are affixed to exemplary buildings, whose status is regularly reported in newspapers (Deng et al., 2012; Hwang et al., 2017). It tends not to cost much more to construct a Green Mark-compliant building than a non-compliant building because energy cost savings gained from the energy efficient retrofit normally offsets the cost of the retrofits in 5 to 7 years (NCCS,2012).

In 2008, Singapore introduced building control regulations requiring new and existing buildings with over 2,000 square meters of floor space to achieve a 28% energy efficiency improvement from 2005, retrofitted to meet Green Mark Scheme certification standards (Hwang et al., 2017; NCCS, 2012). One of the certification mechanisms for the Green Mark Scheme was the “Energy Smart Building Labelling Scheme,” which required building owners to apply to Singapore’s Building and Construction Authority to be assigned a Green Mark Assessor (BCA, 2016; NEA, 2010). An Assessor must be an “appropriate practitioner,” which includes individual engineers, representatives of engineering or similar firms and/or Building and Construction Authority officials (BCA, 2008; Liu et al., 2017; Low, 2011). These include environmental management consultancies, engineering firms or energy service companies that provide energy efficiency technology and services including financing, design, implementation and management of projects (EES, 2019).

Another Green Mark Scheme certification mechanism is the Energy Smart Office Labelling Scheme, developed by the Energy Sustainability Unit of the National University of Singapore and implemented jointly with the National Environmental Agency. The Energy Smart

Office Label Scheme involves building owners being able to attain the label if their building was shown to rank among the city-state's top 25% performers in energy efficiency. The scheme required participating building owners to enter into energy performance contracts with local (Singaporean) energy service companies to both assist in installing energy efficiency improvements and to audit the improvements gained (Lee and Rajagopalan, 2008). Consultancies are technically designated an "energy service company" when energy performance contracting is a primary service offered, but is conceptually the same as other environmental management consultancies that provide the same and/or other climate mitigation-related services.

Building owners view the Energy Sustainability Unit website listing of accredited energy services companies and reach out to them for services, which involves evaluating and certifying that the building adheres to the required standards (BCA, 2014; ESU, 2005). Specifically, an energy performance contract normally first involves the contracting firm conduct a preliminary analysis of the energy consumption patterns in order to evaluate the savings potential of a target building. After upgrades are installed, the contracting firm monitors the installation and the new energy consumption patterns of the building, making all necessary adjustments to achieve the agreed to efficiency increases in energy consumption (Bobbino et al., 2014).

Eligible buildings include those for which electricity is the main source of energy and for which central air conditioning is used for over 1,000 square meters of gross floor area. Lighting, air conditioning, ventilation and air supply components of the buildings are often targeted for upgrades to achieve energy reductions. For example, energy services companies often replaced the controllers in building chiller plants—or air conditioning units—and used controller data optimize the operation of the chiller plant equipment, reducing facility energy consumption and reducing emissions (APEC, 2017).

One of two broad models of energy performance contracting are normally used. The first is the guaranteed savings model, in which the energy services company guarantees a specific amount of energy cost savings to be achieved from a given energy efficiency project. The client does not pay up front, but only for the energy savings actually gained over time, and if energy cost savings fall below the guaranteed amount, the energy service company will finance the difference. The second model is the shared savings model, in which the energy service company fully finances the energy efficiency project implementation and then receives payment in the form of a fixed proportion of the money saved by the client company on energy bills over a specified time period (NCCS, 2012).

The Singaporean government also helped building owners finance the contracts by launching the Energy Efficiency Improvement Assistance Scheme, which co-funded the contract costs (NCCS, 2012; NEA, 2014). This is similar to the Grant for Energy Efficient Technologies, which funds up to 50% of the costs for industrial facility owners in Singapore to invest in energy efficient equipment or technologies (Green Future, 2009).

It is understood that the earlier a consultant is involved in the design and construction stages of a given building project, the more likely that a Green Mark certification will be achieved (Li et al., 2011). Hence**,** the Singaporean government emphasizes that the earlier and deeper the engagement with consultants, the higher the likely outcomes in building energy performance. To that end, the Building and Construction Authority introduced a $5 million (Singapore dollars) Green Mark Incentive Scheme to provide building owners funding to engage environmental consultants “to conduct collaborative design workshops and assist in early simulation studies” (NCCS, 2012: 56).

By March 2012, there were over 1,000 green building projects collectively covering 30 million square meters in Singapore, or 14% of the total gross floor area in local buildings (NCCS, 2012). By 2015, over 2,300 green building projects were completed, accounting for approximately 27% of Singapore’s total gross floor area (Hwang et al., 2017).

The following describe specific examples of individual green building projects. In 2008, The Regent Singapore Hotel used the environmental consultant SuperSolutions Pte Ltd to replace its diesel boiler with a heat recovery system and replace lighting systems with LED displays, achieving an estimated annual energy savings of 300,000 kilowatt-hours (BCA, 2008). The Building and Construction Authority publicizes details of annual Green Mark Award winners. In 2009, the Bosch South East Asia Regional Headquarters received a Green Mark Platinum rating for achieving an estimated annual energy savings of 1.7 million kilowatt-hours using an energy efficient chiller plant system, with G-Energy Global Pte Ltd as the consultant (BCA, 2009). The Galen building, which houses chemical, life science and information technology companies, was a Green Mark Platinum rating recipient in 2010, for which an estimated annual energy savings of 5.5 million kilowatt-hours was achieved through an energy efficient air conditioning plant system, implemented by the energy service company Trane Singapore (BCA, 2010). Building energy was part of the broader energy sector, the largest sectoral contributor to total emissions (46%), as opposed to manufacturing (38%) and transportation (15%). The above building retrofits and energy reduction measures contributed over 150,000 tons of emissions reductions, which played a significant role in Singapore achieving a 37% reduction by 2014 from 2000 levels (NEA, 2014).

Climate governance efforts in Singapore are also tied to a number of global-scale initiatives. The Singapore-Tianjin Eco-city project, launched in 2008, involved Singapore sharing master planning expertise to build a renewable energy-based city in Tianjin (China) with a range of low-carbon features, including green buildings of the sort achieved in Singapore (Miao and Lang 2015; Zhan and De Jong 2017). The goal of the endeavor is to develop a model that is replicable, practical and scalable for other Chinese cities and rapidly developing cities globally (NCCS, 2012). For instance, the Singaporean consultancy Building System & Diagnostics Pte Ltd worked with Tianjin-based construction companies to retrofit the Shimao Eco-Exhibition Centre, attainting an annual energy savings of 294,000 kilowatt-hours (BCA, 2011).

The second case study covers the City of Knoxville, roughly a third of the size of Singapore. In 2007, Madeline Rogero was hired as the Director of Community Development and launched several initiatives to spur climate action and broader green development in Knoxville. The City joined the ICLEI network in July 2007 to access to case studies, software and methodologies for improving local sustainability. In August 2007, Knoxville Mayor Bill Haslam convened the first meeting of the Energy & Sustainability Task Force, which would develop recommendations for reductions in the cost and consumption of energy, in greenhouse gas emissions, and increase the overall sustainability of Knoxville (City of Knoxville, 2012).

Between 2007 and 2014, the City of Knoxville used ICLEI's *Clean Air and Climate Protection Software* to inventory emissions with a 2005 baseline, showing that buildings, street and traffic lights comprise the largest sources of urban emissions. From a 2005 baseline, the City set a target of reducing emissions 12% by 2012, 15% by 2015 and 20% by 2020. Energy cost savings were cited as a key motivation for urban climate mitigation, with projected rising energy costs coupled with energy expenditures already comprising 4.3% of the annual municipal budget. The City opted for an energy services performance contract approach, which offered a budget-neutral approach for achieving long-term energy cost savings.

In 2007, the City released a request for proposals to which environmental firms across the country responded, including AMERESCO, Constellation Energy, Energy Systems Group, Honeywell, Johnson Controls, Siemens, Tetra Tech and Trane (City of Knoxville, 2007), for which AMERESCO was ultimately selected. Likely playing in favor of AMERESCO's selection was its downtown Knoxville office location, contra the more peripheral office locations of Johnson Controls, Tetra Tech and Trane, and the remaining responding firms having no Knoxville locations. The consultancies responding to the request for proposals reflects the diversity of firms from which local governments obtain environmental services. AMERESCO is a relatively smaller consultancy focusing principally on environmental services with $8 million in revenue, while Johnson Controls is a multinational energy services company energy performance contracting, environmental services and other services such as security systems with $31 billion in revenue.

AMERESCO carried out an energy performance contract that involved auditing the energy and water consumption of and implementing renewable energy upgrades on all city-owned facilities, including LED light retrofits across the city, in garages and on streets (Burns et al., 2005; Gill and Tisinger, 2014). The contract provided for a $19 million guaranteed return on investment for retrofits performed on 99 city-owned facilities, attainable by the end of 13-15 years (City of Knoxville, 2012). This target was ultimately met during that period, with the full scope of the contract expanding to perform retrofits on 130 city-owned facilities (Lamphere and Shefner, 2017).

Audits were performed on all meters contributing to city utility bills. Ballasts and bulbs were replaced with LED and fluorescent lighting in facilities ranging from gymnasiums to schools to commercial buildings. These included light sensors that automatically shut off when no movement is detected in ten-minute intervals. Boilers, pumps, windows and doors were replaced or retrofitted with more energy efficient alternatives. As of 2011, the contract with AMERESCO resulted in energy cost savings of 15% compared to prior years for facilities managed by the Parks and Recreation Department alone, which includes aquatic facilities, recreation centers and parks (Brown, 2011). AMERESCO also replaced the heating, ventilation and air conditioning systems in 11 fire stations alongside numerous other facilities, collectively yielding $1.1 million in annual energy cost savings (City of Knoxville, 2012).

Separate from the energy performance contract, in 2008 Knoxville was one of 12 cities designated by the U.S. Department of Energy as Solar America City, providing grant funding which was then used by the city to fund two photovoltaic installations, one in the Knoxville Station Transit Center and the other on the Knox Heritage House (City of Knoxville, 2012). By 2011, the Knoxville Solar Cities increased the city's installed solar capacity by 400% (DOE, 2011). Madeline Rogero, the Director of Community Development who launched many of the city's sustainability initiatives in 2007, became the mayor of Knoxville in 2011 and carried on emissions reduction activities, consistently matching or exceeding the climate mitigation targets set by the State of Tennessee. In part due to the above efforts, by 2014, the Knoxville had reduced emissions by 7.75% from 2005 levels (Gill and Tisinger, 2014).

Environmental transnational municipal networks & emissions reduction

This section discusses two cases of environmental network memberships providing climate mitigation expertise influencing emissions reduction outcomes. The first is Barcelona (Spain), which represents a case of network memberships directly influencing urban climate governance. The second is Melbourne (Australia), which represents a case of environmental network partnership with environmental consultancies providing the city access to consultancy resources.

The case of Barcelona represents the first quartile of base year emissions levels in the sample, is a member of twelve environmental transnational municipal networks, the most simultaneous network memberships of any city in the sample, and houses 14 environmental consultancies. Barcelona covers 101 square kilometers, with a population that grew from 5.1 to 5.4 million between 2005 and 2013. The case of Melbourne represents the third quartile of base year emissions levels in the sample, is a member of 5 environmental networks and houses 33 environmental consultancies. Melbourne covers 2,453 square kilometers, with a population that grew from 3.5 to 4.3 million between 2005 and 2013.

By the end of the 20th century, Barcelona had been serviced by non-renewable energy inputs, yet was spearheading the deindustrialization of the Catalan economy with a rapidly expanding high technology sector among other service sectors (BEA, 2011). In 1993, the city joined ICLEI's Cities for Climate Protection program, providing the city the tools to inventory emissions, identify and target high-emitting sectors with mitigation measures and set emissions reduction targets. In 1995, a Green Party victory in Barcelona's municipal elections resulted in the appointment of a Sustainable City Councilor and a commitment to achieving greater renewable energy use in buildings.

The Sustainable City Councilor was aware that officials in Berlin, Germany had in 1996 attempt to develop a city-wide application of solar thermal technology to reduce building emissions (Puig, 2008). Given the opportunity inherent in harnessing the 28,000 hours of annual sunshine in Barcelona (C40, 2011), the city underwent an extensive consultation process with engineers, architects, building administrators, renewable energy sector representatives and government officials responsible for energy (ESTIF, 2007). The product was the development and passage of the Solar Thermal Ordinance in 1999, which mandated all buildings, including commercial buildings and residential buildings with over 16 apartments, use solar thermal water systems to supply 60% of hot water (ICLEI, 2014; Puig, 2008).

The following decade saw a number of climate mitigation measures implemented, including the replacement of public lighting with low-carbon lighting, allowing for an annual reduction of 380 tons of CO_2 emissions, and solar thermal installations in schools and sports facilities, transportation infrastructure upgrades and rooftop solar energy installations for non-water-related energy needs. While a range of policies were implemented, I focus here on the Solar Thermal Ordinance given its robust role in local emissions reduction. Solar thermal energy rapidly replaced non-renewable building energy generation in schools, sports facilities and residences city-wide, which by 2008 was sufficient to reduce an annual average of 8,836 tons of greenhouse gas emissions (Ajuntament de Barcelona, 2009).

In 2002, the city created the Barcelona Energy Agency, a public consortium of local government officials and universities, to manage the implementation of the Solar Thermal Ordinance and other components of urban climate mitigation (Camano-Martin, 2009). That same year, the city implemented the Barcelona Energy Improvement Plan, in which the city created an action plan with 55 measures for emissions reduction and a monitoring and assessment mechanism for the Solar Thermal Ordinance implementation (ICLEI, 2014). To enforce the ordinance, the city required that proposed new buildings have compliant building design, otherwise no construction permit was granted. This further involved building inspectors checking whether construction met the criteria and applied fines when in violation.

The city monitored progress and ultimately the ordinance led to 1.7 million tons of greenhouse gas emissions reduction between 1999 and 2008. Between 2002 and 2010, solar thermal energy production reached 70,121 megawatt-hours per year with solar thermal panels covering 87,600 square meters of building space in the city, allowing for the annual reduction of 12,329 tons of CO_2 emissions (BEA, 2011).

Barcelona also became a member of ICLEI's Procura+ Network the year it launched in 2004, which helps ICLEI member cities purchase a range of goods and services in the conduct of sustainable governance, from renewable electricity to consulting. The Barcelona City Council required that all procured cleaning services use only non-toxic products that meet Procura+ criteria on sustainable procurement (Hidson and Clement, 2008). In 2006, the Barcelona Solar Thermal Ordinance led to the development and adoption of national legislation that required that new building and renovation projects use a minimum level of solar-heated water, the minimum depending on consumption and other factors per building (CCAP, 2012).

In 2008, Barcelona became a signatory to the EU Convenant of Mayors, which calls for a 20% reduction in greenhouse gas emissions by 2020. The 2011 update to the Barcelona Energy Improvement Plan set a target of 20% local emissions reduction by 2020, which the city cited as pursuant to fulfilling Covenant goals. Beyond building upon and expanding the strengths of the previous plan, such as solar thermal installations, the update called for the incorporation of Procura+ criteria in the procurement of renewable electricity, and for the use of energy performance contracts to both improve industrial energy efficiency and stimulate a new market associated with it (BEA, 2011). To the latter, energy performance contracts were a viable means of implementing solar thermal installations pursuant to the Solar Thermal Ordinance, however, as of 2014 the contracting model had not been widely applied in the city.

For instance, Barcelona officials entered into an energy performance contract with a local environmental services firm, Sol Solar, to install solar thermal systems in an apartment building, whereby the firm would pay 100% of the installation costs and receive a 15% reimbursement from the City Council. However, the municipal climate mitigation legislation, including the Solar Thermal Ordinance and Energy Improvement Plan, did not stipulate a means of city payment of the partial reimbursement to the firm, ultimately leaving the homeowners association to pay the city's share of the 15% reimbursement of installation costs (Bobbino et al., 2014). Hence, the viability of energy performance contracting can hinge on whether urban climate mitigation legislation contains provisions for public-private financing mechanisms.

In sum, Barcelona's memberships in environmental networks provided initial policy tools as well as meaningfully shaped the ambition of its climate mitigation policies. Barcelona also joined the Global Cities Covenant on Climate (Mexico City Pact) in 2010, and similarly has been an active member in 100 Resilient Cities, Cities for Mobility, City Protocol, C40, the Global Compact Cities Program, the Global Parliament of Mayors, Mediterranean Cities Network, Polis and the World Mayors Council on Climate Change (ICLEI, 2014). Due in large part to the above efforts, by 2014 Barcelona had reduced emissions by 31% from 1999 levels (Ajuntament de Barcelona, 2018; BEA, 2014).

Environmental network memberships, particularly Barcelona's early membership in ICLEI, provided foundational expertise for urban climate mitigation to follow. This would serve as one of many building blocks of climate policy that would yield emissions reduction over time. The different components of Barcelona's climate mitigation, such as the Solar Thermal Ordinance, were separate from the city's environmental network memberships, as these networks provide a finite selection of services. However, environmental networks are partnering in with environmental consultancies in ways that meaningfully expand service provision to member cities, an empirically and theoretically important development for studying these polycentric systems.

To illustrate this process, the second case study covers Melbourne, Australia. Several cities in my sample, including Houston, Texas (USA), London (UK) and Melbourne, entered into energy performance contracts with energy service companies through the C40-Clinton Climate Initiative partnership with multiple energy service companies, or the Energy Efficiency Building Retrofit Program. I focus here on Melbourne, which drew on environmental network membership expertise to design climate mitigation policy but also contracted to Honeywell for an energy performance contract via the above environmental network-consultancy partnership (HBS, 2009). As an energy services company, energy performance contracting is one of the primary services offered by Honeywell, but again given its size also offers a range of other services. This is no different from larger environmental management consultancies without the "energy services company" designation like AECOM or ARUP that, given their size, offer a range of services beyond strictly environmental, including engineering and architecture services. Further, energy services should be understood as distinct from the business conducted by such firms as Exxon or Shell, which are in the energy industry insofar as they source fossil fuel used by the energy sector, but are not distinct sources of firm-based expertise of the sort observed in this study.

In 1997, Melbourne and other cities in the Australian State of Victoria responded to the threat posed by unmitigated climate change to their economies and way of life by joining the ICLEI Cities for Climate Protection Program, establishing emissions inventories and reduction targets. This led in 2002 to the creation of the Victorian Greenhouse Strategy to encourage further local climate action, and the formation of the Northern Alliance for Greenhouse Action among regional cities to coordinate joint climate action (Bulkeley and Schroeder, 2009). In 2003, Melbourne adopted the *Zero Net Emissions* strategy as its climate action roadmap, committing to a target of 100% emissions reductions, or net zero emissions, by 2020, a goal attributed as a natural extension of the city's work in the ICLEI Cities for Climate Protection program.

The design of strategy was framed as replicable for other Asia-Pacific Economic Cooperation cities, which Melbourne would share with other cities both through local networks such as the Northern Alliance for Greenhouse Action and through transnational networks such as C40, ICLEI and 100 Resilient Cities Network (City of Melbourne, 2003, 2008, 2014). The strategy was also framed explicitly as a triple bottom line business equation for economic, environmental and social benefit by which Melbourne would position itself as a center for green productivity. This was defined as "the enhanced economic efficiency achieved through investment in knowledge-based industries and technologies that respond to consumer, shareholder and worker demand for improved environmental performance and social responsibility" (City of Melbourne, 2003: 5). With a focus on green buildings, this strategy involved re-directing investment from across sectors into energy efficiency, thereby reducing operating costs and enhancing the city's competitiveness in emerging green markets. The city achieved these goals via a number of efforts, which includes but is not limited to the following.

In December 2005, the city made mandatory energy audits on buildings greater than 5,000 square meters to achieve greater energy efficiency, thus reducing energy costs, and in the following year joined C40. Melbourne financed a $51 million new administrative building using a low carbon design, which earned the highest rating from the Green Building Council of Australia and was opened and showcased in August 2006. Last, the city sought to pool its purchasing or procurement power with that of other like-minded cities in order to bulk buy low-carbon technologies, services and renewable energy for lower costs (Bulkeley and Schroeder, 2009; City of Melbourne, 2008). As of 2007, C40 and the Clinton Climate Initiative had begun collaborating on green building-focused cooperative procurement, providing an avenue for Melbourne to achieve its green productivity goals of both low-cost green procurement and energy efficient buildings.

Earlier work by the Clinton Foundation on HIV/AIDS prevention found that the diffusion of relevant technology could be achieved through global procurement efforts. The Clinton Climate Initiative, subsidiary to the Foundation, later translated this concept into global procurement of environmental services in the form of the Energy Efficiency Building Retrofit Program, launched in 2007 at the second C40 summit. This program, administered jointly by the Clinton Climate Initiative and C40, sought to enable C40 member cities to conduct large-scale building retrofit projects for lower costs via pooled purchasing power and creative financing models, thereby expanding the global market for building retrofits. This was accomplished by partnering with the world's largest energy service companies, Honeywell, Johnson Controls Inc., Siemens and Trane. The Clinton Climate Initiative then leveraged the pooled purchasing power of C40 members cities to negotiate substantially lower-cost energy performance contracts and related technologies from the aforementioned companies, an arrangement through which multiple C40 cities procured services for large-scale building retrofit projects (Revkin and Healy, 2007; Román, 2010).

Melbourne's green building goals included retrofitting existing buildings, the up-front capital costs of which presented a major financial obstacle, but for which the energy performance contract model provided a solution. Hence in 2008, Melbourne used its membership in C40 to access the Energy Efficient Building Retrofit Program, entering into an energy performance contract with Honeywell, which was implemented in the form of Melbourne's 1200 Buildings Program. This contract, which began in 2008 and was completed in 2012, involved retrofitting 13 City Council buildings, Campbell Arcade and Kensington Community Center with highly efficient heating, ventilation, air conditioning, plant, lighting, water and building management systems.

The project was performed by the Melbourne branch of Honeywell at a cost of $2.6 million, and with a 15-year payback period from annual energy cost savings of $190,000 (HBS, 2017). Due in large part to the above efforts, by 2013 Melbourne had reduced per capita emissions by 22% from 2008 from levels (City of Melbourne, 2014). While the City of Melbourne has made significant progress, it did not reach its target of zero net emissions by 2020. Rather city officials are considering a 2040 target, but Lord Mayor Sally Capp argues that this is not achievable without greater state and federal support, and is calling on the federal government to identify ways in which different levels of government can work together and facilitate such support (LGC, 2020; Topsfield, 2020).

Economic growth and polycentric systems

Political-economic forces figure prominently in the processes by which the polycentric systems of environmental consultancies and environmental networks facilitate urban emissions reduction. The cases illustrate a commitment to economic growth made *a priori* by city governments that precludes economic sacrifice as an acceptable condition of climate mitigation policy. Rather, the observed economic benefits provided by energy cost reductions as well as new job creation through the climate mitigation efforts allowed for economic growth to be achieved simultaneously as emissions reduction. In these conditions, achievable environmental improvement is delimited by the extent to which local growth may be held constant or accelerated. This reflects urban political ecology assumption that due to the ubiquity of cost- and growth conscious interests in urban environmental governance (Keil, 2018), urban climate mitigation measures are from their inception involved in the processes driving capitalist urbanization (Rice, 2014). While emissions reductions are observed, these conditions bring to bear risks of commodifying urban climate mitigation that can lead to stymied rather than improved environmental governance over the long term.

The cases also illustrate urban growth machine dynamics, where public-private collaboration leads to economic growth becoming a primary goal of urban governance (Adua and Lobao, 2019; Logan and Molotch, 2007), leading to government deference to business interests in environmental governance decision making (Bargaoui and Nouri, 2017; Gould et al., 2016). While the developmentalist imperative assumes that these conditions will lead to increased urban environmental degradation (Bridges, 2016), these cases show environmental improvements instead occurring due to cost saving dynamics allowing for economic benefits to co-occur with environmental benefits. It is generally expected that in conditions where pollution abatement is relatively more costly, emitting actors will avoid abatement in favor of cost savings, thus resulting in emissions increases (York and Rosa, 2003). It follows, then, that emissions reductions tend to be more achievable when climate policy measures offer such economic co-benefits as cost-savings and revenue generation (Heinrichs et al., 2013; Nakhooda et al., 2014; Swyngedouw, 2018). Satisfying these conditions are the observed cases, which exhibit city-led energy efficiency upgrades achieving permanently reduced energy costs, and thus likely reversing the cost-benefit calculus for polluters that otherwise would lead to emissions increases.

This offers a critique of the developmentalist imperative by specifying processes whereby economic development conditions lead not to environmental degradation but to improvements, here in the form of urban greenhouse gas emissions reductions. However, this critique is limited by the extent to which these same neoliberal forces may ultimately stymy climate mitigation efficacy, as discussed in greater detail below.

The selected cases are in more developed countries, a geographic context which, as shown in the previous chapter, house a greater presence of the environmental consultancies and networks associated with urban emissions reductions. The processes shown here and the critique of the developmentalist imperative they offer may most closely be applicable to more developed countries, however this does not negate the potential replicability of these processes in less developed nations. Revenue generating co-benefits are also observed through job creation and the expansion of targeted industries via climate action.

These dynamics are observable in the prioritization of economic growth, job creation efforts, local procurement and cost-minimizing preferences throughout the cases, discussed in detail below. Energy performance contracts articulate this dynamic, such that client governments do not pay for the energy efficiency upgrades installed in full at the time of service, but rather only pay for demonstrated energy savings achieved over time (APEC, 2017; Ürge-Vorsatz et al., 2007; Vine, 2005). This contract model is designed to overcome financial obstacles by minimizing the costs of infrastructure upgrades necessary to achieve emissions reductions (Capelo, 2011; Vitiello, 2015), hence its high popularity. Such was the case for the Singaporean government, which chose energy performance contracting in large part because it allowed for deferring immediate, upfront costs (NEA, 2014).

Further, energy cost savings gained from the energy efficient retrofit normally offsets the cost of the retrofits in 5 to 7 years, meaning it did not cost much more to construct a Green Mark-compliant building than a non-compliant one building (NCCS, 2012). This was also the case for Barcelona, as the energy cost savings from solar thermal heating pays off the initial installation costs (CCAP, 2012). The City of Knoxville's choice to engage in urban climate mitigation was itself motivated by saving on rising energy costs, which paired with city concerns over up-front retrofit costs guided the choice of an energy services performance contract approach (City of Knoxville, 2007; Hibbard, 2009). The same cost-minimizing logic informed Melbourne's choice of energy performance contract (Bulkeley and Schroeder, 2009; City of Melbourne, 2008).

These observations lend support to urban political ecology assumptions of the ubiquity of cost- and growth conscious interests in urban governance (Keil, 2018), which become the primary goal of urban environmental governance (Hodson and Marvin, 2017; Whitehead, 2013). This is further evinced by all cases embedding emissions reduction goals in the language of economic growth, particularly via "sustainable development" or some other rhetorical variant, where economic growth goals were achieved via job creation or other means of investing in local industrial growth. The sustainable development strategies undertaken by these cities involved a long-term economic planning move toward increasingly profitable green markets, including green building, renewable energy and environmental services. Increasing profitability and employment in these sectors were of course not the only avenue used by these cities to maintain local economic growth, but they represented strategically important sectors to expand growth in.

Singapore's Green Mark Scheme was designed both to reduce emissions and to counter low productivity in the local construction industry (Low, 2011). The scheme institutionalized local job growth in the environmental services sector by requiring building owners to contract to local, government-accredited consultancies for services required to ensure compliance with building energy efficiency regulations. The economic result was the construction industry becoming the fastest growing sector in the city-state (Hwang et al., 2017). A significant part of Knoxville's sustainable development strategy was "growth in clean and advanced energy markets that offer good jobs for our local workforce" (Gill and Tisinger, 2014: 3). The energy performance contract also stipulated that AMERESCO was to work with local contractors to create jobs in the energy sector wherever possible (City of Knoxville, 2012).

The "green productivity" goals at the center of Melbourne's *Zero Net Emissions* strategy were designed to enhance the city's competitiveness in emerging green markets by supplying consumer and shareholder demand for improved environmental performance (City of Melbourne 2003). The transportation and tourism sectors in Barcelona were both pillar industries and key sources of the city's high emissions levels, hence building retrofits carried out targeted hotels in particular, and mobility-related mitigation measures targeted vehicles used heavily by tourists (BEA, 2011). Economic benefits accruing from Barcelona's Solar Thermal Ordinance included job creation in the environmental services sector, particularly for energy audit and solar companies, as well as reduced energy costs for solar energy users.

Further, branding or re-branding played an important and ongoing role in many of the observed climate mitigation efforts. Singapore sought to earn a reputation as "Asia's greenest city" (NCCS, 2012). Knoxville sought to gain greater recognition for East Tennessee's livability, health and prosperous economy, particularly with regard to sustainable entrepreneurship (Gill and Tisinger, 2014). The existing pillar industry or industries of a given city can, but do not always, have direct bearing on the formulation and direction of climate mitigation policy. Knoxville's shipping, retail trade, healthcare and educational services industries (Burns et al., 2005) were acknowledged in official documents but were more incidental to the climate policymaking process.

Outsourcing is a prominent form of increased private sector involvement in urban environmental governance processes (Barnett, 2020; Keele, 2017), whereby local government purchases, or procures, services from entities external to the government to perform functions that otherwise would be performed by the government itself. When local government uses procurement to outsource services from firms located locally, this acts as an investment in the growth of the same local private sector tax base from which government draws revenue. Hence the tendency is for local government to procure from local firms, as this yields local economic growth benefits that accrue in tax revenue (Nijaki and Worrel, 2012; Preuss, 2009).

The cases exhibit this dynamic, whereby local procurement of environmental services is used as a means of both obtaining climate mitigation expertise and investing in local environmental services sector growth, the latter being an extension of the sustainable development strategies discussed above. Singapore's Green Mark certification mechanisms required building owners to source the necessary energy efficiency auditing and retrofitting services from the local environmental services industry (Bobbino et al., 2014; Lee and

Rajagopalan, 2008; Liu et al., 2017), thus promoting local economic growth. The Singaporean government even encouraged accelerated client-contractor engagement by providing funding for early collaboration between building owners and consultancies, in the form of the Green Mark Incentive Scheme (NCCS, 2012). The City of Knoxville contracted to the locally-based energy service company AMERESCO over other non-local consultancies that responded to the city-issued request for proposals. The City of Melbourne contracted to a local branch of Honeywell for energy performance contracts obtained via C40 membership. In all cases where city governments contract to local consultancies, this provides for local growth via revenue generation and job creation, which is as true for cases involving the local branch of a large firm as it is for smaller single-location local consultancies, as the revenue and jobs exist within the municipal tax base.

A caveat is that while I emphasize the tendency for city governments to contract to local as opposed to non-local environmental management consultancies, the latter circumstance is not unheard of. For instance, the 2007-2012 climate action plan in Bangkok (Thailand) involved environmental consultants that were not local or even domestic, but from the Japan International Cooperation Agency (JICA, 2012; OECD, 2015). Local government procurement constitutes a unique market power, as it positions local government as a wealthy consumer. Mechanisms of market power that are designed to be consequential for climate policy are not made equal. A different mechanism of market power is the carbon market, which represents more autonomous financialized forces involving distant financial markets (Layfield, 2013), while local procurement represents purchasing power controlled by local government actors. While the financial transactions occurring in the carbon market are largely separate from the environmental policy outcomes they are designed to affect (Knox-Hayes, 2015), the use of local government procurement more directly connects financial expenditures to environmental processes.

The organized pooling and leveraging of local government procurement power provides a specific example of how environmental network partnerships with environmental consultancies and related service providers are expanding neoliberal logics in global environmental governance. The C40-Clinton Climate Initiative partnership with energy services companies facilitated energy performance contracts between Houston with Siemens (CCI, 2008; Jones, 2009), and both Melbourne and London with Honeywell (Bulkeley and Schroeder, 2008; HBS, 2009) among others. This constitutes global procurement as a form of governance (Román, 2010), where a public-private hybrid of urban climate change governance pools and leverages metropolitan procurement power to lower prices of low-carbon services and technologies (Acuto, 2013). While prices are lowered for the demand-side, this maximizes profits for the supply-side by sourcing new clientele in the form of city governments procuring from private sector actors.

As Keele (2019) warns, private climate services focus on offering politically-palatable and financially-profitable solutions to clients, a focus that can obscure systemic or politically-charged issues that should be addressed for maximal climate mitigation outcomes. This manages climate mitigation in ways that privilege dominant political and economic interests, hence risking a shift in climate knowledge and the policy formed from it away from science and public interest and toward profit. As explained in greater detail below, to whatever extent environmental benefits result from these contract relationships, the risks may translate to greater losses than gains in urban sustainability over time.

This public-private hybrid in urban climate governance expands outward into other environmental services industries via the ICLEI Procura+ Network, which leverages pooled municipal purchasing power to achieve climate mitigation goals. The ICLEI Procura+ Network is "using public authority market power to bring about major environmental, social and economic benefits locally and globally" (Hidson and Clement, 2008: 571). The EU Commissioner for the Environment, Maritime Affairs and Fisheries, a participant in the Procura+ Network, said of this dynamic: "Across Europe, on average, public authorities spend about 20% of the EU Gross Domestic Product (GDP) purchasing goods, works and services. That represents enormous leverage, and it means that public authorities wield tremendous market power" (ICLEI, 2018: 2).

These dynamics demonstrate how municipal procurement power is one specific mechanism through which polycentric systems of climate change governance are both evolving and expanding neoliberal logics. The network-consultancy partnership model is itself a structural evolution whereby two otherwise separate polycentric systems, environmental services firms and environmental networks, cooperate to improve urban climate mitigation capacity as well as benefit from an economically symbiotic relationship. To the latter, the network-consultancy partnership model allows environmental networks to increase the value of membership via expanded environmental service access, while expanding the local government clientele base of environmental consultancies. The outsourcing involved increases public dependence on private sector actors for public service capacity, deepening the commodification of and expanding neoliberal logics in urban environmental governance (Hodson and Marvin, 2017; Keele, 2017; Rice, 2014; Swyngedouw, 2018). This commodification increases the risk of shifting climate policy incentives in a way that may ultimately stifle rather than improve climate mitigation efforts, which is explained in greater detail in the pages below.

As observed in the previous chapters, the Acuto et al. (2020) data shows that among all environmental network-consultancy partnerships, the energy service company Siemens maintains the most simultaneous such partnerships, with six environmental networks including C40. This is likely explicable, if partially, by the demonstrated cost-minimizing properties of energy performance contracting, which would demonstrate the fiscal behavior assumed by urban political ecologists in environmental governance decision making (Keil, 2018). There are, to be sure, partnerships with non-energy service companies are present, including ICLEI, City Protocol and the Covenant of Mayors partnering with TCO Development, JT Environmental Consulting and LonMark International, respectively. All ostensibly involve the same economic symbiosis of the more detailed partnership examples explored here.

An inherent risk in neoliberal logics expanding into urban environmental governance is that it may stymy rather than improve environmental governance outcomes (Hodson and Marvin, 2017; Keil, 2018). This may occur through increased outsourcing resulting in restricted urban access to climate expertise and may shift incentives for climate science away from the public interest and towards profiteering (Barnett, 2020; Keele, 2019). While the environmental-network partnership model does appear to be both expanding access to private sector climate management services and reducing prices for them, future price increases for such services may restrict access to less wealthy cities.

Further, higher economic stakes from larger profits pose a perennial risk of shifting incentives away from environmental protection. For instance, in Singapore, Green Mark-certified buildings have a substantially higher price premium compared to comparable, non-certified buildings, meaning that in the Singaporean housing market, green mark certifications yield substantial economic returns to building owners (Deng et al., 2012). If premiums are not controlled, then excessive rent costs risk a loss of commercial and residential tenants to green buildings, and thus the demand for and use of them.

The observed cases are cities located in more developed countries. The global political-economic context set forth in previous chapters conceptually translates ecologically unequal exchange to the city-level by taking urban location in a more developed country to represent a structurally advantaged position in the world economy. This further means that the selected cases in this chapter are assumed to have, on average, more environmental management consultancies, more environmental network memberships, less high-polluting manufacturing industries, greater wherewithal to reduce emissions and also greater likelihood of off-shoring or externalizing emissions increases elsewhere. Future research is needed on urban cases in less developing countries to provide a comparative lens on how meaningful political-economic differences across the more/less developed country divide articulate themselves at the city-level.

A crucial political-economic context for climate change governance is the novel coronavirus (COVID-19) pandemic that, over the course of the first six months of 2020, led to economic recession in most nations of the world, leaving tens of millions unemployed. Multiple calls have emerged for “green recovery” as a pathway out of recession, which aims to recover the mass losses in jobs and broader economic growth in a low-carbon manner that allows for strengthened progress in climate mitigation over the long-term.

The strategies, frameworks and recommendations in these green recovery calls both align with and are substantially complemented by the urban-level lessons discussed above. I discuss here these complementarities and how the urban practices highlighted in this study allow an immediate pathway toward post-pandemic green recovery for world cities. The economic vacuum created by the pandemic motivated calls for accelerated pro-environmental reform, with widespread recognition that the economic shutdown effects are a “dress rehearsal” for the more severe effects of unmitigated climate change (Latour, 2020). This interpretation has merit, as unmitigated climate change will induce more mass property and infrastructure damage from stronger tropical storms, food shortages, energy blackouts, unemployment and wildfires (Archila et al., 2020; Williams et al., 2019); as well as greater health risks to outdoor workers such as agricultural and construction workers, children and the elderly (Kunreuther and Slovic, 2020).

Beyond the need to avoid these foreseeable catastrophic economic impacts, calls for green recovery are also motivated by the increased profitability of renewable energy caused by the pandemic. During the first two quarters of 2020, all energy markets including fossil fuels experienced a substantial decrease in demand, except for renewable energy. As oil and coal demand have fallen and are projected to continue to fall, the opposite is the case for renewables (IEA, 2020).

The COVID-19 pandemic has arguably substantially hastened recognition that short- and long-term avoidance of economic harm and achievement of economic growth requires immediate and more stringent climate change mitigation efforts globally. Green recovery frameworks and policy recommendations provide the pathways on which these efforts can be implemented. Kunreuther and Slovic (2020) point out that myopia bias, or the tendency to focus on short- over long-term implications of one’s actions, is a prominent obstacle in achieving green recovery goals. This bias is inherent in the reluctancy by homeowners, building owners and others to adopt low-carbon upgrades due to high up-front costs. However, they argue that this may be overcome via climate policy using low-carbon technology that allows cost savings to exceed upfront implementation costs.

For instance, they point to California's mandatory solar installations on homes, which increases mortgage costs by $40 per month but allows savings of $80 in monthly energy costs, an arrangement possible via incorporating the upfront cost of the solar panels into the mortgage. The open proposal to the U.S. Congress for "Green Stimulus," coauthored among others by urban environmental sociologist Daniel Cohen, calls for green recovery via investment in a range of low-carbon areas to yield job creation and environmental benefits. These include retrofitting commercial buildings and residences and the fulfillment of ongoing green retrofit contracts for public housing, and to reduce prices of relevant materials via bulk procurement (Bozuwa et al., 2020).

In Australia, the recently-released Million Jobs Report sets out a number of measures for green recovery, calling for job creation via shifting investment, both public and private, into renewable energy and technology. For example, it calls for mass residential energy efficiency retrofits to be performed and financed using energy performance contracting, which have been gaining traction for households after being used successfully in commercial buildings for years. The demand for all of the manual labor, materials, technical and professional services[10] are estimated to create 900,000 jobs. Last, the report argues that a "commitment to local procurement can amplify these benefits through increasing demand for Australian made energy efficient equipment and green building materials" (Lenka, 2020: 28).

These examples closely reflect the strategies employed in the climate mitigation efforts of Knoxville, Melbourne and Singapore, which harnessed the simultaneous job creation, cost-minimizing and emissions reduction potential of green building via local procurement, pooled

[10] This includes the replacement and/or installation of such household energy upgrades as clean electric appliances, more energy efficient heating, ventilation and air conditioning, and rooftop solar; the reskilling of construction workers and creation of new construction jobs associated with energy upgrades; and job creation from increased demand for professional environmental services, green building materials and technologies.

procurement and energy performance contracting. These and other insights on urban climate mitigation discussed in this dissertation are thus crucial for green recovery efforts, particularly as subnational governments are recognized as key authorities for carrying out green recovery policy interventions (Bozuwa et al., 2020).

Evolving norm diffusion in polycentric systems

The urban case studies demonstrate normative forces influencing urban environmental outcomes via the local-scale process of external experts directly informing climate policy (Swyngedouw, 2010; Zimmer et al., 2020). Barcelona's early participation in ICLEI's Cities for Climate Protection program provided the city the technical expertise to perform emissions tracking and sector-specific mitigation targeting (Puig, 2008), and set emissions reduction targets in accordance with the EU Convenant of Mayors in (BEA, 2011). Knoxville used ICLEI's *Clean Air and Climate Protection Software* to inventory emissions, allowing for identifying and targeting the highest-emitting sectors and tracking progress over time toward reducing emissions (City of Knoxville, 2012). Melbourne's *Zero Net Emissions* strategy resulted from participation in the ICLEI Cities for Climate Protection Program and was also designed with replication across Asian-Pacific cities in mind, with mutual environmental network memberships acting as the intended diffusion mechanism (Bulkeley and Schroeder, 2009; City of Melbourne, 2003, 2008, 2014).

By these means, the cases show environmental networks diffusing urban climate policy expertise, cultivated over the past three decades, directly to city governments globally (Tzaninis et al., 2020). The same is true for the cases of city contracting to environmental management consultancies and energy service companies discussed in the previous section, which involved the transference of technical climate policy expertise and services (Baker et al., 2012; Keele, 2019; Vine, 2005).

The global structure of this process of normative expertise diffusion is explicable by world society theory, which argues that environmental policy innovations during this time period diffused globally from more developed to less developed countries (Hironaka, 2014; Henderson, 2019; Schofer and Hironaka, 2005). This pattern matches that of both memberships in environmental networks (Bouteligier, 2013; Tosun, 2019) and of energy performance contracting (Nolden et al., 2016; Polzin et al., 2016), allowing the city-level, horizontal diffusion carried out by polycentric systems to be understood within the larger, global purview of world society theory.

The cases show that these polycentric systems bypass national governments by delivering climate mitigation governance information and resources directly to cities (Ostrom, 2010; Van der Heijden, 2019), hence this process is not dependent upon the nation-state-facilitated process traditionally assumed by world society theorists (Frank et al., 2000a, 2000b; Schofer et al., 2012). The partnerships between environmental networks and environmental consultancies discussed in the previous section show intentional interaction between two polycentric systems, diffusing new normative climate governance expertise and models directly to cities. In this case, the energy performance contracting model offered by consultancies being made available to the member cities of environmental networks.

A more complete framework for understanding normative forces affecting subnational environmental outcomes is achieved through the following synthesis of urban political ecology and world society theory. Seen through the multi-scalar lens of urban political ecology (Rice, 2014), a global-scale structure of normative processes is afforded by world society theory, in which efficacious and replicable climate mitigation practices, models and services diffuse globally and are adopted through different scalar channels. In addition to policy implementation from nations, diffusion of these resources also occur horizontally via decentralized polycentric systems, including environmental networks and consultancies. At the local-scale, urban policymakers interface with professional experts (Swyngedouw, 2010; Zimmer et al., 2020) who then prescribe these globally-legitimated climate mitigation practices, models and services to policymakers, from which implementation follows.

The selected cases are all in more developed countries, which previous chapters show are characterized by a higher average of environmental management consultancies and environmental network memberships per city. In a world society framework, this means that the case cities are more embedded in the normative structures of interest and thus more likely to adopt popular policy models (Hironaka, 2014; Shorette et al., 2017). More research is needed on urban cases in developing countries, which may help provide a comparative lens on meaningful normative differences across the more/less developed country divide. For instance, world society theorists argue that institutional capacity barriers tend to stymy diffusion of environmental policy norms into less developed nations (Schofer et al., 2012). Given that these same obstacles are shown to have beset the spread of energy performance contracting to less developed nations (Liu et al., 2017; Painuly et al., 2003), urban cases studies in these regions may elucidate specific constraints and offer insight on how they differ from cities in more developed countries.

Multiple immediate pathways are available for future research in this vein. Further research on the horizontal diffusion of polycentric systems explored here may investigate governance impacts seen from 2013-onward. Beyond horizontal forces, rich potential exists for exploration of bottom-up processes. For instance, that Barcelona's Solar Thermal practices diffused upward to become an adopted national standard in Spain (CCAP, 2012) provides a meaningful counterpoint to the national-to-subnational diffusion purview of world society theory. Important insights may be gained from research on the typologies of other such instances of bottom-up diffusion and their relationship to multi-level governance activities.

Similarly, regional- versus international-scale networks may involve different inter-city knowledge diffusion dynamics, a distinction that would be useful for disentangling varied network influences on city governments party to both network types. For instance, Melbourne is party to both environmental networks and the regional network, Northern Alliance for Greenhouse Action, spanning cities in the Australian State of Victoria (City of Melbourne, 2008). Useful for differentiating effects of membership in networks of these different scales would be establishing typologies of inter-city knowledge transmission, including the speed of diffusion and types of knowledge diffused by regional- versus international-scale networks.

Future researchers may also wish to explore if and to what extend building energy efficiency labeling schemes are explicable by world society theory. For instance, in 1993, the U.S. introduced the ENERGY STAR system in 1993, in which professional engineers are utilized to certify that the energy efficiency of a given building meets a specified benchmark level, and is then designated and publicized as according to its performance. Deng et al. (2012) argues that not long after this model was introduced, analogous certification mechanisms developed in many other countries. These include but are not limited to the Building Research Establishment Environmental Assessment Method rating system in the UK and the Greenstar rating system adopted in Australia. This would roughly match the time frame for which Singapore designed and launched the building energy efficiency schemes discussed above, which are argued to be similar to the ENERGY STAR system given the label eligibility requirements, energy auditing process and incentive of publicity for building owners (Rajagopalan and Leung Tony, 2012). A further possibility is the 14000 family of environmental management standards offered by the International Organization for Standardization, which serves as an important source of firm-level environmental management standards (ISO, 2020).

Conclusion

This chapter discusses the specific mechanisms and processes by which political-economic and normative forces affect urban emissions reduction, contributing a more nuanced urban political ecology framework for understanding urban environmental change in a global, systemic context. Regarding the political-economic forces, climate policy affording the economic co-benefits of cost-minimization and new revenue generation are shown to yield urban emissions reduction. This chapter advances urban political ecology literature on urban climate mitigation by specifying and demonstrating several political-economic mechanisms and processes facilitating emissions reduction outcomes.

These include energy performance contracts and pooled procurement efforts that yield short-term costs savings via deferment of upfront costs and lowered environmental services and technology costs. Long-term dynamics are seen in cost savings from mandated energy efficiency upgrades that eventually exceed the initial installation cost, and where the permanently-lowered energy costs thus provides a long run economic return as well as emissions reduction. Climate policy yielding revenue generation is achieved via procuring environmental services and resources locally, simultaneously sourcing requisite expertise and creating job growth in local environmentally-related industries, turning the gears of supply and demand. This is shown to be particularly successful in green building.

This chapter also advances the understanding of normative influences on environmental outcomes afforded by urban political ecology by specifying and demonstrating normative mechanisms and processes influencing environmental outcomes. Techniques of urban climate change mitigation demonstrated as efficacious become globally-legitimated and diffuse globally in patterns explicable by world society theory. These techniques, such as urban emissions inventorying protocols and energy performance contracts, are then delivered directly to city governments via two polycentric systems: Environmental management consultancies and environmental transnational municipal networks, for which the mechanism of expertise transference is a contract and city government membership, respectively.

Adoption and implementation of these techniques by city governments then lead to the aforementioned political-economic processes by which urban emissions reduction results. While world society theory traditionally assumes a nation-state-centric structure by which subnational environmental change is ultimately affected, polycentric systems are organized horizontally and expose cities to globally-legitimated normative expertise independently of national government. Cases also show bottom-up processes by which nations adopt policy innovations championed first by cities. World society theory must therefore expand its structural purview of normative diffusion processes in order to capture the full complexity of subnational environmental change.

Future researchers also ought to investigate the comparative emissions reduction efficacy of climate policy expertise sources such as local universities and non-profits, including when interacting with the polycentric mechanisms studied here. A critical task for future researchers is to account for Scope 3 emissions, allowing for changes in the full carbon footprint to be accounted for. While the inclusion of Scope 1 and 2 emissions in my analysis provides a large portion of the picture, the full urban environmental impact cannot be accounted for without also including Scope 3 emissions. Future research incorporating all three scopes will enable accounting for the extent to which urban actors off-shore or externalize emissions increases, allowing greater potential for linking urban environmental outcomes to that of macro-scale political economic frameworks such as ecologically unequal exchange.

CHAPTER 5 Conclusions

National-focused research has achieved a global, systemic understanding of national-level environmental change, but lacks a similar global, systemic understanding of forces affecting urban environmental change. My study contributes progress toward achieving such a systemic understanding by demonstrating the political-economic, normative and multi-scalar forces associated with urban climate mitigation outcomes. A common concern in the study of comparative urban climate governance is that the forces driving emissions change across cities are overdetermined, or the result of too many unlike factors to discern meaningful patterns in a large, global-scale sample of urban emissions change. This dissertation shows that these outcomes are not overdetermined, but rather can be uniformly understood, an empirically and theoretically crucial step toward achieving a more systemic understanding of the complex forces associated with urban emissions reduction on a global-scale.

While materialist and idealist explanations for global environmental change have long been positioned against one another, this project argues that a materialist-idealist synthesis provides greater explanatory value, particularly when viewed through a multi-scalar lens. This is done through an urban political ecology framework that explains urban environmental outcomes by way of materialist, political-economic forces and ideational or normative forces acting on the city, and at multiple levels simultaneously (Hodson and Marvin, 2009; Rice, 2014; Swyngedouw, 2018).

In this vein, my project shows that city- and national-level factors are associated with urban greenhouse gas emissions change outcomes on a global-scale. Environmental management consultancies and environmental networks are two among many possible sources of climate mitigation-related expertise and services. Absent an analysis controlling for other sources utilized by sample city governments in climate action planning, I do not argue that consultancies and networks are more impactful than other city-level mechanisms influencing emissions reduction. I do, however, argue that both are empirically consequential mechanisms for urban emissions reduction and that illustrate theoretically important political-economic, normative and multi-scalar processes affecting urban environmental change. I summarize below my findings in terms of the local- and macro-scale political-economic and normative forces affecting urban emissions reduction as explicable by urban political ecology, and the linkages with ecologically unequal exchange and world society theory.

Local-scale political-economic forces observed influencing urban environmental change in this project are climate policy measures offering the economic co-benefits of cost-savings and new revenue generation, which facilitate emissions reduction processes (Heinrichs et al., 2013; Nakhooda et al., 2014; Swyngedouw, 2018). This includes energy performance contracts providing energy efficiency upgrades that allow deferment of up-front costs and leveraging pooled procurement power to lower costs for environmental services and technology, both being facilitated by environmental consultancies and environmental networks. These processes also include the use of local procurement to institutionalize job creation and growth in local environmental services industries.

These findings offer both a critique of the developmentalist imperative for the short-term and a warning of the effects of neoliberal encroachment on governance for the long-term. In the short-term, the growth-oriented political-economic forces observed to facilitate emissions reduction offers a critique of the developmentalist imperative assumption that economic growth processes lead to environmental degradation. This critique is limited to the short-term, however, as increased government dependence on private climate services and knowledge brings the risk of declining rather than improving climate mitigation over the long-term. Consultancies focus only on financially-profitable models of emissions reduction, which obscures larger systemic issues of climate mitigation (Keele, 2019). If urban climate policy becomes increasingly based on models incentivized only by profit in this way, then minimal urban emissions reductions may be expected over the long-term, if not properly managed. The further that private sector interests are intertwined with public administration, the greater that the contradictions of neoliberal logic are likely to appear (Hodson and Marvin, 2017; Keil, 2018). Strict regulatory oversight of urban climate action, then, offers one means of accountability to minimize these harms.

Macro-scale political-economic processes affecting urban emissions change are defined by ecologically unequal exchange theory, in which nations occupying a structurally advantaged versus disadvantaged position in the world economy are expected to experience emissions reductions and increases, respectively (Ciccantell, 2019; Givens et al., 2019; Jorgenson, 2016). I posit an urban articulation of the structurally advantaged position in the form of higher ranking in the world city hierarchy (Alderson and Beckfield, 2004; Sassen, 2006; Smith and Timberlake, 2002), an inter-city corporate office network centrality measure providing a relational measure of urban power in the world economy. Conversely, cities housing more high-polluting firms articulates the disadvantaged position. As with nations occupying a structurally advantaged position in ecologically unequal exchange literature, cities with a higher ranking in the world city hierarchy are found on average to be located in more developed countries and are associated with urban emissions reductions.

As with nations in a structurally disadvantaged position, cities with more high-polluting firms are found on average to be located in less developed countries and are associated with emissions increases. Within this global political-economic structure, cities with more environmental consultancies and environmental network memberships are on average located in more developed countries and similarly have a strong association to urban emissions reduction. This suggests that environmental consultancies and networks are embedded within a structurally advantaged position in the world economy as understood by ecologically unequal exchange. The local-scale political economic forces explained by urban political ecology and the macro-scale forces explained here may interact in more significant ways that should be investigated by future researchers.

Local-scale normative forces affecting urban emissions change involve the process described by urban political ecologists whereby city policy makers interface with professional climate experts (Swyngedouw, 2010; Zimmer et al., 2020). In this case, environmental consultancy contracts and environmental network memberships provide the mechanism through which this expertise and related services are provided, including energy performance contracts, emissions inventorying and reduction targeting models and energy efficient upgrade approaches among many others.

At the macro-scale, these environmental consultancies and networks constitute polycentric systems that provide the structure by which the global diffusion of normative climate expertise occurs. World society theory describes the process by which efficacious and replicable climate mitigation expertise diffuses globally and incurs environmental change via government adoption and implementation. This theoretical traditional assumes a nation-state-centric structure by which subnational environmental change is ultimately affected (Frank et al., 2000a, 2000b; Schofer and Hironaka, 2005; Shorette et al., 2017). However, I show that horizontally-organized polycentric systems directly expose cities to globally-legitimated normative expertise independently of national government (Carlisle and Gruby, 2017; Ostrom, 2010; Van der

Heijden, 2019). My specification of environmental consultancies and environmental networks as polycentric systems adds new explanatory value to the global structure of normative processes understood as affecting urban environmental change.

Beyond these horizontally-organized diffusion processes, this project also highlights bottom-up processes by which nations adopt policy innovations championed first by cities. World society theory must therefore expand its structural purview of normative diffusion processes in order to capture the full complexity of subnational environmental change. Notwithstanding these horizontal and bottom-up forces, my empirical finding that national climate policy also maintains a strong association with urban emissions reduction reinforces the continued importance of nation state-driven processes. This lends further support for the urban political ecology position that multi-scalar governance arrangements, both those of the local, horizontal sort and the national-to-subnational sort, are equally crucial for affecting urban environmental change (Swyngedouw and Kaika, 2014).

The public-private hybrids of environmental networks partnering with environmental consultancies represent a structural evolution the polycentric systems diffusing expertise to cities as well as an expansion of neoliberal logics in global urban climate change governance. The latter involves increased local government dependence on private sector professionals for environmental service provision and the use of coordinated procurement to achieve environmental governance goals. The leveraging of pooled municipal procurement power lowers costs for environmental services and technologies, and could improve urban climate mitigation capacity for yet more cities, but faces the same long-term hazards of neoliberal encroachment on urban governance mentioned above.

For instance, as greater city government use of and dependence on private climate consulting translates to higher demand for these services, costs are sure to rise. In a fashion to be expected of neoliberal market environmentalism, price hikes are likely to be exclusionary and predatory, as profit-maximization is the principal bottom line for service provision by consultancies, particularly the larger multinationals. As Keele (2019) observes, "the business model of consulting is fundamentally transactional, whereby client fees must exceed consulting costs" (19).

In addition to general price hikes for high-demand services, consultancies may impose higher fees on city governments that are first-time clients or based on any other contrived criteria. For those consultancies partnered with environmental networks in pooled procurement partnerships, higher fees may be imposed on cities that are non-members of said environmental networks. Beyond price hikes, consultancies provide climate mitigation solutions to client governments based primarily on profitability, leaving untended various other climate mitigation issues (Keele, 2019), which may result in an overall decline of quality in the climate mitigation carried out by government clients. By these means, incentives may shift away from public interest and science addressing all components of climate mitigation and toward profiteering, for which the ultimate result is stymied rather than improved urban environmental governance outcomes.

In the years after the observed time period of 2005-2013, notably following the 2015 Paris Agreement, the multi-level and polycentric normative processes discussed above continue and grow more complex. As a result of the Australian government ratification of the Paris Agreement and the Victorian State government introduction of the Climate Change Act of 2017, the City of Melbourne sought to align its climate action planning goals with that of the Paris

Agreement. To do this, Melbourne utilized the C40 Cities Climate Action Planning Framework, which provides member cities the guidance to develop climate action plans aligned with the objectives of the Paris Agreement (C40, 2020). The 2017 U.S. government announcement of intent to withdraw from the Paris Agreement drew a sharp bottom-up response, with the formation of domestic coalitions of subnational leaders such as U.S. Climate Alliance and America's Pledge, as well as several international local and state governments becoming signatories of the Under2 Coalition, all pledging to fill the gap left by U.S. leadership (Leffel, 2018).

However, neither this gap nor the larger global emissions gap needed to avert a temperature rise of 2° Celsius above preindustrial levels can be achieved by subnational governments alone, as the regulatory and financial support of national governments is necessary (Kuramochi et al., 2019). This is true in every country, one among many possible examples being the Melbourne mayor's call for greater multi-level governance linkages in Australia, specifically with the national government, as necessary for the City of Melbourne to achieve net zero emissions (LGC, 2020; Topsfield, 2020).

Application

The lessons for urban climate mitigation revealed by this project should be applied immediately to post-COVID-19 pandemic green recovery efforts at the city-level globally and be integrated into coordinated regional and national efforts, which in turn will set standards for long-term climate planning. Job creation capacity sufficient to recover and sustain economic losses from the pandemic that also provide improved long-term emissions reduction capacity can be accomplished by using the techniques investigated here.

Specifically, urban climate mitigation policy can use local procurement to institutionalize job creation in environmental services and related industries by mandating energy efficiency upgrades and retrofits on commercial and residential buildings. The retrofits and upgrades can be performed by (a) requiring local government and/or building and home owners to enter into energy performance contracts with local service providers, which defers upfront costs; (b) mandating energy efficiency upgrades that require the use of local service providers, and whose installation costs are integrated into mortgages, but are paid off over time via energy cost savings incurred; and/or (c) leveraging organized pooling of procurement power among other cities, via environmental network-consultancy partnership programming or otherwise, to secure reduced-cost environmental services and technologies from local industry. A mandated standard would require existing buildings to reduce a target percentage of annual energy use and require new buildings to maintain a standard of energy efficiency that allows for minimized carbon intensity, allowing long-term greenhouse gas emissions reductions.

Urban climate policy would enforce and maintain these conditions over the long run, for which the required local sourcing of services, materials and technology would generate long-term job growth and revenue gains in the local environmental services and renewable energy industry. This would be coupled with the economic returns of permanently-lowered energy costs from the above energy efficiency upgrades, together producing a sustainable model for green recovery. Given the use of private contractors, present will be the risk of climate science and policy incentives shifting away from environmental performance and toward profiteering. To manage these risks, careful regulatory oversight will be required to ensure reasonable limitations on the number of local private contracts made; that knowledge sourcing is diversified beyond corporate entities, where city officials also source climate mitigation expertise from local university and other non-profit entities; and ensuring that corporate actors beyond the consultants themselves do not get a seat at the policymaking table.

Future directions

Every year brings more cities reporting their first repeat (e.g., second) emissions inventory, as well as greater standardization among urban emissions inventories, notably the 2014 Global Protocol for Community-Scale GHG Inventories forged via collaboration between ICLEI, C40 and World Resources Institute (Fong et al., 2014; Moran et al., 2018). Scholars in the immediate future will be able to substantially expand sample sizes and analyze yet more complete and representative samples of global urban emissions change. In much the same way as national-level emissions data before it, efforts will take place to centralize and further standardize urban emissions databases to streamline data availability. Further, the greater common use of more standardized emissions inventorying methods among world cities should make more possible the direct comparison of the exact tonnage of greenhouse gas emissions across cities.

A missing element in the practice of urban climate mitigation is the willingness of subnational authorities to accept economic sacrifice in the course of achieving more ambitious emissions reductions. This beckons future researchers to investigate the conditions in which economic sacrifice, including slowed or reversed economic growth, provides a sustainable climate mitigation approach in cities. Research on successfully implemented de-growth models would in particular be instructive. Future researchers also should investigate the comparative emissions reduction efficacy of climate policy expertise sources such as local universities and non-profits, including when interacting with the polycentric mechanisms studied here.

The emissions reduction commitments made by cities and other sub-state actors can fill the “emissions gap” left by national government commitments in the Paris Agreement (Kuramochi et al., 2019). In order to fulfill these commitments, however, scholars and practitioners in the international community must gain a greater understanding of what factors lead to sub-state emissions reduction. A most important endeavor to this end is accounting for the full carbon footprint of cities. The Scope 1 and 2 emissions included in my analysis do account for a substantial portion of emissions, but the absence of Scope 3 emissions prevents an accounting of emissions that may have been externalized beyond the urban boundary via offshoring or some other means.

While the emissions reductions achieved by environmental consultancy- and environmental network-provided services are argued to be isolated within the urban boundary and thus contributing a net reduction to the full urban carbon footprint, other emissions reductions observed within cities may be attributable to externalizing emissions increases beyond the urban boundary. As more repeat urban emissions inventories that include Scope 3 emissions become available, it is critical for future researchers to incorporate them into analyses of emissions change alongside the other two scopes. This will allow a more comprehensive analysis of change in the full carbon footprint, an improved understanding of patterns of externalization and potentially a means of achieving a more robust urban-level linkage with ecologically unequal exchange theory.

In light of this project's findings on normative forces, world society theory language will have to be adapted in order to include polycentric systems as norm-diffusing mechanisms. Future scholars interpreting environmental consultancies through a world society lens may wish to refer to them "city-level service providers." This term adapts the world society descriptor of "receptor sites," or domestic organizations such as scientific institutes that receive, decode and transmit norms to national government actors (Frank et al., 2000a), to a city-level, service-provision-based mechanism for diffusing globally-legitimated climate expertise. This provides an apt description of the function served by environmental consultancies in a world society context.

Scholars may also wish to refer to environmental networks as "city-level intergovernmental organizations." That is, supranational-level intergovernmental organizations such as the UN are the institutions understood traditionally by world society theorists to diffuse normative governance expertise globally, eventually reaching locales via national governments (Schofer and Hironaka, 2005; Shorette et al., 2017). Since environmental transnational municipal networks diffuse policy expertise among city governments, the terminology of "city-level intergovernmental organizations" would be appropriate language with which to integrate this concept into world society theory.

Carbon market participation is found in this project to be an insufficient substitute for traditional urban regulation of climate change, as it is unassociated with urban emission change. It is plausible, however, that carbon market participation yields emissions reductions at the local facility-level that are simply dwarfed by other urban emissions increases, or that occur in urban or non-urban areas geographically far-removed from the point of the transactions. While this is unknowable from the present study, it may be the subject of future research. Further, while the collective urban sold-more-than-bought metric for emissions trading and the count of Clean

Development Mechanism projects per city represent the most straightforward metrics for testing carbon market effects on urban emissions change, additional modeling approaches are encouraged for future research.

For instance, each carbon credit represents one ton of CO_2 equivalent emissions, for which a collective urban-scale aggregation of credits sold or bought (emissions trading) or earned (carbon offset) would represent the total tonnage of physical emissions each credit is supposed to represent. A one-to-one comparison could then be carried out between the carbon credit-based representation of tonnage versus the actual city-level tonnage of emissions reported by a given city's emissions inventory. This would be contingent upon careful consideration to the comparability of both emissions metrics, including the exact emissions accounting methods used and spatial boundaries they represent. Future research on the carbon market should also target more recently-established regional emissions trading systems including those in Kazakhstan (2013) and China (2017).

City government credit rating was operationalized as a proxy for city access to loan- and bond-based climate finance, and was found to be unassociated with urban emissions reduction. While this rules out credit rating as a determinant of emissions reduction, it does not negate the impact which climate finance may have. This necessitates future research collecting city-level data on loan-based climate finance actually obtained, which will allow for inference on the relationship between credit rating, receipt of climate finance and urban emissions change. At present, there is a major dearth in the availability of data on loan-based climate finance actually obtained at the city-level. However, efforts are presently underway by actors such as the Organization for Economic Co-operation and Development and Climate Policy Initiative to collect urban climate finance allocation data globally and enter these data into a centralized database (UN, 2019).

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Appendix

Table A- 1. Welch's two-sample t-test for independent variable values in sample cities versus full population of cities

	Variable mean	*t*	*df*	*N*
Env. Consultancies		-7.61***	331	10,798
Sample	33.9			
Full population	1.09			
Env. network memberships		-13.5***	331	4,256
Sample	1.62			
Full population	.09			
Manufacturers		-8.57***	331	36,935
Sample	1,756			
Full population	7.48			
World city hierarchy		-6.38***	331	22,312
Sample	598			
Full population	2.19			
Emissions trading		-3.70***	331	4,008
Sample	1,142			
Full population	1.66			

Levels of significance are denoted as follows: **p<.05, ** p<.01, ***p<.001*

Table A- 2. Environmental transnational municipal networks

Environmental Networks	Year of Founding
100 Resilient Cities	2013
C40 Cities Climate Leadership Group	2005
Cities and Climate Change Initiative	2014
Cities for Mobility	2003
City Protocol	2012
CityNet	1987
Climate Alliance	1990
Covenant of Mayors for Climate & Energy	2008
Energy Cities	1990
Global Cities Covenant on Climate	2010
Global Compact Cities Programme	2003
IADB Emerging and Sustainable Cities	2011
ICLEI - Local Governments for Sustainability	1990
International Solar Cities Initiative	2003
Kitakyushu Initiative for a Clean Environment	2000
Local Renewables Initiative	2004
Mediterranean Cities Network	1991
Polis	1989
Sharing Cities	2016
Sustainable Cities International	1993
UNIDO Eco-Cities Network in Southeast Asia	2013
URBACT	2015
World Association of Major Metropolises	1985
World Mayors Council on Climate Change	2005

Table A- 3. High-emitting manufacturing industry codes

Name	Standard Industrial Classification code	North American Industry Classification System code
Cement, hydraulic	3241	
Crude Petroleum and Natural Gas	1311	
Oil and Gas Extraction	1321	
Oil and Gas Geophysical Mapping and Surveying	1382	
Bituminous Coal And Lignite Surface Mining	1221	
Nonmetallic Mineral Mining	1499	
Industrial Organic Chemicals	2869	
Petroleum Refining	2911	
Petroleum and Petroleum Products	2999	
Aluminum Foundries	3365	
Prefabricated Metal Buildings and Components	3448	
Construction Machinery and Equipment	3531	
Gas Utilities	4932	221210
Oil and Gas Refining and Marketing	5172	
Oil and Gas Storage and Transportation	5172	
Gasoline Service Stations	5541	
Chemical Distribution	5169	
Integrated Oil and Gas		211111; 324110; 324199; 424720; 486210
Electric Utilities		211120; 221118
Coal and Consumable Fuels		212111; 213113
Construction Materials		212319; 327310
Precious Metals and Minerals		212399
Oil and Gas Drilling	1381	213111
Oil and Gas Equipment and Services		213112
Commodity Chemicals		325920
Aluminum		331524
Building Products		332311
Construction Machinery and Heavy Trucks		333120
Trading Companies and Distributors	5052	423510; 423520; 424690
Automotive Retail		447190
Other Diversified Financial Services		523130

Table A- 4. Urban emissions change model including national income and population change

	1	2	3	4	5
City-level variables of interest					
Environmental consultancies				-.21 (.01)***	-.21 (.04)***
Environmental networks				-.23 (.04)***	-.20 (.05)**
Credit rating				-.01 (.03)	-.01 (.03)
Controls					
Population change	-.05 (.07)		-.09 (.06)	-.09 (.05)	-.09 (.05)
National income		-.21 (.01)***	-.21 (.01)***	-.16 (.01)***	-.13 (.01)***
World city hierarchy					-.02 (.01)**
Manufacturing					.05 (.01)**
Constant	.11 (.04)	1.15 (.08)	1.17 (.08)	1.20 (.08)	1.07 (.09)
R^2	.01	.37	.38	.44	.47
obs.	331	331	331	331	331

Numbers in parentheses are standard errors. Levels of significance are denoted as follows: **p<.05, ** p<.01, ***p<.001*

Table A-5. National climate policy averages

Country	National climate policy average	Country	National climate policy average
Argentina	7.0	Lithuania	7.0
Australia	5.8	Malaysia	6.5
Austria	7.8	Mexico	5.0
Bangladesh	2.0	Netherlands	7.2
Belgium	6.8	New Zealand	8.2
Brazil	5.8	Nigeria	2.0
Canada	8.6	Norway	4.7
Chile	8.6	Peru	2.0
China	4.8	Philippines	2.0
Colombia	4.8	Poland	7.6
Denmark	5.6	Portugal	5.9
Ecuador	2.0	Saudi Arabia	9.4
Finland	6.9	Singapore	6.7
France	5.9	Slovenia	6.5
Germany	5.2	South Africa	5.4
Greece	7.4	Spain	7.9
Hong Kong	6.2	Sweden	6.3
India	5.3	Switzerland	5.9
Indonesia	6.8	Taiwan	6.2
Ireland	6.7	Thailand	6.4
Italy	8.2	Turkey	8.4
Japan	7.4	UK	5.2
Jordan	7.4	USA	7.7
Korea	4.9		

Table A-6. Urban emissions change among Clean Development Mechanism eligible cities

	1	*2*	*3*	*4*
City-level variables of interest				
Credit	-.02 (.08)	.01 (.01)	-.02 (.08)	-.01 (.08)
Clean Development Mechanism	.01 (.01)		.01 (.01)	
Env. Consultancies	.03 (.09)	.03 (.09)	.03 (.09)	.09 (.09)
Climate/Environmental network	-.23 (.03)**	-.18 (.16)	-.41 (.09)***	-.24 (.10)***
CDM projects				
Biomass energy		.04 (.04)		.03 (.10)
Coalbed/mine methane		-.01 (.13)		.01 (.13)
Energy efficiency (gas & heat)		-.06 (.08)		-.04 (.08)
Energy distribution		-.08 (.20)		-.12 (.20)
Fossil fuel switch		-.39 (.14)**		-.39 (.14)**
Hydro power		-.01 (.06)		-.01 (.01)
Landfill gas		-.01 (.06)		-.01 (.05)
Methane avoidance		.01 (.06)		.01 (.10)
Solar power		.02 (.12)		.03 (.12)
Wind power		.05 (.05)		.06 (.05)
Controls				
Manufacturing	.01 (.04)	.03 (.04)	.03 (.04)	.03 (.04)
National policy	.21 (.88)	.48 (.90)	.36 (.88)	.47 (.89)
World city hierarchy	-.04 (.02)*	-.02 (.02)	-.04 (.02)*	-.02 (.02)
Constant	-.18 (.14)	-.29 (.14)	-.07 (.13)	-.28 (.13)
R^2	.27	.41	.38	.43
obs.	167	167	167	167

Numbers in parentheses are standard errors. Levels of significance are denoted as follows: **p<.05, ** p<.01, ***p<.001*