

University of Louisville

ThinkIR: The University of Louisville's Institutional Repository

Electronic Theses and Dissertations

5-2017

Governing the urban water commons : essays on collaborative policy networks in a polycentric ecology of urban water policy games.

Emmanuel Frimpong Boamah
University of Louisville

Follow this and additional works at: <https://ir.library.louisville.edu/etd>



Part of the [Behavioral Economics Commons](#), [Environmental Policy Commons](#), [Environmental Studies Commons](#), [Models and Methods Commons](#), [Nature and Society Relations Commons](#), [Place and Environment Commons](#), [Political Economy Commons](#), [Public Administration Commons](#), [Public Policy Commons](#), and the [Urban Studies and Planning Commons](#)

Recommended Citation

Frimpong Boamah, Emmanuel, "Governing the urban water commons : essays on collaborative policy networks in a polycentric ecology of urban water policy games." (2017). *Electronic Theses and Dissertations*. Paper 2737.
<https://doi.org/10.18297/etd/2737>

This Doctoral Dissertation is brought to you for free and open access by ThinkIR: The University of Louisville's Institutional Repository. It has been accepted for inclusion in Electronic Theses and Dissertations by an authorized administrator of ThinkIR: The University of Louisville's Institutional Repository. This title appears here courtesy of the author, who has retained all other copyrights. For more information, please contact thinkir@louisville.edu.

GOVERNING THE URBAN WATER COMMONS:
ESSAYS ON COLLABORATIVE POLICY NETWORKS IN A POLYCENTRIC
ECOLOGY OF URBAN WATER POLICY GAMES

By

Emmanuel Frimpong Boamah

BSc. (Hons), Kwame Nkrumah University of Science and Technology, 2010

M.A., Minnesota State University, 2013

A Dissertation

Submitted to the Faculty of the

College of Arts and Sciences of the University of Louisville

in Partial Fulfillment of the Requirements

for the Degree of

Doctor of Philosophy

In Urban and Public Affairs

Department of Urban and Public Affairs

University of Louisville

Louisville, Kentucky

May 2017

Copyright 2017 by Emmanuel Frimpong Boamah

All rights reserved

GOVERNING THE URBAN WATER COMMONS:
ESSAYS ON COLLABORATIVE POLICY NETWORKS IN A POLYCENTRIC
ECOLOGY OF URBAN WATER POLICY GAMES

By

Emmanuel Frimpong Boamah
BSc. (Hons), Kwame Nkrumah University of Science and Technology, Ghana, 2010
M.A., Minnesota State University, U.S.A., 2013

A Dissertation Approved on

December 7, 2016

by the following Dissertation Committee:

Dr. Janet Kelly (Dissertation Director)

Dr. Sumei Zhang (Dissertation Co-Director)

Dr. David L. Imbroscio

Dr. Daniel DeCaro

Dr. Melissa Merry (External Examiner)

DEDICATION

All I am and would ever hope to be is because of my wonderful parents, siblings and loved ones. I dedicate this piece to all these special people in my life and to everyone who has kept me in thoughts and prayers.

ACKNOWLEDGMENTS

I would like to thank Dr. Janet M. Kelly and Dr. Sumei Zhang for their insights, guidance and mentorship. I felt privileged over many of my colleagues for having worked with two scholars with such complementary skills. Dr. Kelly is well-read in the theoretical section of the literature, so she spent some time checking the details, structure, logic, consistency and coherence of my arguments. As a methodologist, Dr. Zhang also spent a lot of time with me checking and cross-checking my data, methods and results. I always felt challenged, inspired and encouraged after every meeting I had with Dr. Kelly and Dr. Zhang. You both mentored me as a young scholar rather than as a doctoral student and I am very grateful.

I am also grateful to my committee members, Dr. David Imbroscio, Dr. Daniel DeCaro and Dr. Melissa Merry, as well as my other faculty mentors, Dr. Tony (Craig) Arnold, Dr. Margath Walker and Dr. Aaron Rollins. I became interested in polycentric governance, generally, and Vincent and Elinor Ostrom's work, specifically, when Dr. Imbroscio encouraged me to explore how the Bloomington School differed from Gar Alperovitz's "Pluralist Commonwealth." Dr. Daniel DeCaro and Dr. Tony (Craig) Arnold, both external faculty affiliates of the Ostrom Workshop, also became great guides and mentors as I journeyed through the literature on environmental governance. I am also grateful to Dr. DeCaro and Dr. Arnold for making it possible for me to participate in the Adaptive Water Governance Project and the University Council on Water Resources respectively. I would

also like to express my appreciation to Dr. Melissa Merry for her careful and meticulous comments and suggestions. Dr. Margath Walker and Dr. Aaron Rollins were very influential in my training as a researcher (in critical theory) and teacher respectively.

Last but not the least, I am grateful to my parents, siblings and friends for creating the conditions that made this dissertation possible. I am especially very thankful to Wes Grooms for taking some to read through, comment, and edit some of the initial drafts of this dissertation.

ABSTRACT

GOVERNING THE URBAN WATER COMMONS: ESSAYS ON COLLABORATIVE POLICY NETWORKS IN A POLYCENTRIC ECOLOGY OF URBAN WATER POLICY GAMES

Emmanuel Frimpong Boamah

December 7, 2016

Governing social-ecological systems, such as the urban water commons, is a multi-scale and multi-sector (polycentric) human-environment process. This dissertation interrogates this process by situating itself within the Ecology of Games Framework by Norton Long (and updated by Mark Lubell) and the literature on polycentric governance by the Bloomington School of Political Economy. The dissertation's three essays 1) offer both theoretical and methodological means to enact polycentric public economies within the ecology of games framework, and 2) explicate the conditions under which interorganizational collaboration is fostered within a polycentric ecology of policy games in governing the Middle Rio Grande urban watershed. First, it deploys a synthesized theoretical construct which puts into conversation three theoretical paradigms to excavate the conceptual pillars to study the polycentricity of urban water governance in the United States. A novel conceptual tool is hereby constructed to help engage the thoughts that polycentricity is not the antithesis of monocentricity but the co-constitution of actors at multiple governing scales and within multiple sectors. Second, the conceptual pillars are

reworked into theoretical and methodological models to study the polycentricity of governing the Middle Rio Grande (MRG) urban watershed in New Mexico, USA. Four indices are developed to measure the level of political, market, nonprofit, and overall polycentricity in governing this urban water commons. Employing multiple methods like the social network analysis, social-ecological network analysis (SENA), and regression analysis, the dissertation's findings suggest that polycentric water governance could primarily be about the politics of power and resource distribution, the reconfigurations of actors' positionalities as they align themselves and their interests strategically. This, among other findings in the dissertation, points to the need to centralize the politics of power and resource distribution in the study of polycentricity in social-ecological governance. Third and finally, the overall polycentric index is used to model the role of polycentricity in interorganizational collaboration within the Middle Rio Grande (MRG) urban water commons. The exponential random graph models (ERGMs) is used in this analysis. Among other findings, the results show that polycentric governance increases the probability of interorganizational collaboration within the MRG. The implications of the dissertation's three cohesive essays to theory, methods and policy are discussed in the conclusion chapter of the dissertation. In all, this dissertation concludes that there is still no panacea in governing the (urban water) commons.

TABLE OF CONTENTS

ACKNOWLEDGMENTS	IV
ABSTRACT.....	VI
LIST OF FIGURES	XI
LIST OF TABLES.....	XII
CHAPTER I: INTRODUCTION.....	1
1.1 BACKGROUND: COLLABORATIVE POLICY NETWORKS IN GOVERNING SOCIAL- ECOLOGICAL SYSTEMS	1
1.2 STUDY OVERVIEW: POLYCENTRIC ECOLOGY OF URBAN WATER POLICY GAMES.....	3
1.2.1 Setting: The Urban Water Commons/Watershed.....	3
1.2.2 Governing the Urban Water Commons as a Polycentric Ecology of Water Policy Games.....	5
1.3 SIGNIFICANCE OF RESEARCH	8
1.4 OUTLINE OF CHAPTERS	10
CHAPTER II: (RE) MAPPING POLYCENTRICITY: THE POLITICAL ECONOMY, SPATIALITY, AND NETWORK OF POLYCENTRIC WATER GOVERNANCE	13
2.1 INTRODUCTION.....	13
2.2 GOVERNING THE URBAN WATER COMMONS IN THE UNITED STATES.....	15
2.3 THE POLITICAL ECONOMY OF POLYCENTRIC GOVERNANCE: A BRIEF HISTORICAL- THEORETICAL CONTEXT	19
2.4 CONCEPTUALIZING THE POLITICAL ECONOMY OF POLYCENTRIC GOVERNANCE.....	23
2.5 THE CONCEPTUAL PILLARS OF POLYCENTRIC WATER GOVERNANCE	26
2.5.1 The Political Economy and Spatiality of Polycentrism: European Spatial Planning School Meets Bloomington School	26
2.5.2 The Network of Polycentrism: SENA Meets European Spatial Planning School and Bloomington School.....	30
2.6 MAPPING THE MULTIDIMENSIONALITY OF POLYCENTRIC WATER GOVERNANCE	36
2.7 CONCLUSION	38

CHAPTER III: THE POLYCENTRICITY OF URBAN WATERSHED GOVERNANCE: A METHODOLOGICAL APPROACH	40
3.1 INTRODUCTION	40
3.2 MAPPING THE THEORETICAL LANDSCAPE OF POLYCENTRICITY IN URBAN WATER GOVERNANCE	42
3.2.1 Polycentricity as the Multiplicity and Functional Connectivity of Actors	42
3.2.2 Polycentricity as the Mix of Actor Types (Sectors) and Governing Scales	45
3.3 (RE) CASTING THE THEORETICAL PILLARS OF POLYCENTRIC GOVERNANCE WITHIN THE SENA FRAMEWORK: SYNTHESIS AND METHODOLOGICAL APPROACH	49
3.3.1 Synthesizes of the Theoretical Pillars through the SENA Framework	49
3.3.2 Constructing Polycentric Governance Index	54
3.4 CASE STUDY OF THE MIDDLE RIO GRANDE (MRG) URBAN WATERSHED, NEW MEXICO	56
3.5 DATA AND ANALYSIS	59
3.6 RESULTS AND DISCUSSION	63
3.6.1 Determining the Polycentricity of Governing the MRG	66
3.6.2 (Re) interpreting Polycentric Water Governance in Terms of Social Network Analysis	76
3.7 CONCLUSION	79
 CHAPTER IV: GOVERNING THE URBAN WATER COMMONS: INTER- ORGANIZATIONAL COLLABORATIONS IN A POLYCENTRIC ECOLOGY OF URBAN WATER POLICY GAMES	81
4.1 INTRODUCTION	81
4.2 POLYCENTRIC ECOLOGY OF URBAN WATER POLICY GAMES: THEORETICAL CONTEXT	83
4.2.1 Centralization and Closure: Information, Trust, and Risks in Collaborative Policy Networks	85
4.2.2 Actor Activities and Political Homophily	88
4.2.3 Diminishing Marginal Returns in Collaborative Policy Networks	89
4.2.4 Segmentation and Polycentrism in Collaborative Policy Networks	91
4.3 THE EXPONENTIAL RANDOM GRAPH MODELS (ERGMs)	93

4.4 STUDY AREA	96
4.5 DATA PREPARATION.....	98
4.6 DESCRIPTIVE STATISTICS	101
4.7 THE ERGM RESULTS	104
4.8 DISCUSSION AND CONCLUSION	110
4.9 CONCLUSION	113
CHAPTER V CONCLUSION.....	114
5.1 INTRODUCTION.....	114
5.2 THEORETICAL CONTRIBUTIONS	115
5.3 METHDOLOGICAL CONTRIBUTIONS	118
5.4 CONCLUSION: NO PANACEA!	120
REFERENCES	122
APPENDICES	148
CURRICULUM VITA	151

LIST OF FIGURES

Figure 2.1: Urban Watersheds In the United States.....	16
Figure 2.2: Conceptual Framework of Polycentric Governance	24
Figure 2.3: Conceptual Mapping of Functional Polycentric Governance	37
Figure 3.1: Illustrating the Topography and Topology of Polycentrism	44
Figure 3.2: Conceptual Mapping of Polycentric Governance	51
Figure 3.3: The MRG Urban Watershed in Context.....	57
Figure 3.4: Framework for the Archival Snowball Network Sampling Used	60
Figure 3.5: Policy Network in Governing the Middle Rio Grande Urban Watershed	65
Figure 3.6: Density Of SMBEs Based On the Governing Scales Of Actor.....	67
Figure 3.7: Density Of SMBEs Based on the Sectors And Governing Scales Of Actors	70
Figure 3.8: Total SMBEs and Average Polycentric Governance Indices.....	71
Figure 3.9: Actors’ Level of Polycentric Connectedness in the Islands of Polycentric Order	73
Figure 3.10: Bivariate Analysis of the PPI, MI, And NPI Indices.....	74
Figure 3.11: Actors’ Overall Level of Polycentric Connection (FPGI).....	76
Figure 4.1: Ecology of Three Policy Games in Governing Urban Water Resources	84
Figure 4.2: The MRG Urban Watershed.....	97
Figure 4.3: Centralization by Policy Actor Types	102
Figure 4.5: Comparing Degree Distributions for Observed and Randomly Simulated Network.....	102
Figure 4.6: Goodness-Of-Fit Diagnostics for Tte SPEDM.....	109

LIST OF TABLES

Table 3.1: The Interest of Some Federal, State, and Local Players in Governing the MRG	58
Table 3.2: Descriptive Statistics SMBEs of Actors	66
Table 3.3: OLS Regression Models Predicting FPGI.....	77
Table 4.1: Summary of Independent Variables ^a And Expected Impact on the Dependent Variable.....	95
Table 4.2: Propensity for Government Policy Actors to Be Connected—Political Homophily	103
Table 4.3: Exponential Random Graph Model (ERGM) Parameter Estimates	105

CHAPTER I: INTRODUCTION

1.1 Background: Collaborative Policy Networks in Governing Social-ecological Systems

The tragedy of the commons (Hardin, 1968) is *ipso facto* a tragedy of governance. The Global Water Partnership (GWP), for instance, describes the water crisis as “...mainly a crisis of governance” (Global Water Partnership, 2002, p. 17). A growing concern in environmental policy is to identify factors motivating self-interested actors to *supply* the institutions needed to save the commons (Lubell, Schneider, Scholz, & Mete, 2002; E. Ostrom, 1990; Edella Schlager, 1994; Schneider, Scholz, Lubell, Mindruta, & Edwardsen, 2003; Scholz & Stiftel, 2005). The governance/institutional tragedy is seen as the second order collective action dilemma (Bates, 1988; E. Ostrom, 1990).¹ This tragedy needs to be solved in order to address the first order dilemma—imminent tragedy facing the commons. At the frontier of water governance research, therefore, are the development and testing of theoretical and empirical factors influencing the supply of different institutional arrangements to deal with the second order collective action dilemma (Berardo & Scholz, 2010; Feiock & Scholz, 2009; Lubell et al., 2002; Schneider et al., 2003; Scott, 2015).

¹The undersupply of institutions to avert the second order collective action dilemma relates to transaction cost and benefits (see detailed discussion on this on page 145 of Schneider et al., 2003)

Collaborative policy networks remain central in recent inquiries into addressing the second order collective action dilemma.² Policy is seen here as the conscious change in institutional rules to engender systematic changes in outputs and outcomes capable of meeting targeted social needs (Lubell, Scholz, Berardo, & Robins, 2012, p. 355). Changes in institutional rules (macro-level) and the decision-making rules (micro-level) of individuals are, however, embedded within a complex web of social relationships (Granovetter, 1985). Borrowing from network theory and methods, policy networks have emerged as a “meso-level” concept to interrogate relationships between “institutional rules (both formal and informal) and individual behavior (citizens, politicians, or organizations)” within the complex web of social relationships (Evans, 2001; Lubell et al., 2012; Rhodes, 1997). Environmental policy networks, for example, are an emerging network governance structure fostering collaboration and cooperation among autonomous actors to address the second order collective action dilemma (Bodin & Crona, 2009; Lin, 2001; Lubell et al., 2002; Schneider et al., 2003). The central question, however, is and has always been: *what conditions must exist for autonomous actors to form collaborative policy networks?*

In addressing different dimensions of the above question, different frameworks, theories and methods have been advanced. In her seminal piece, Ostrom’s (1990, p. 25) key proposition³—self-organized and self-governing individuals can solve the collective action dilemma—has been crucial in current conceptual, theoretical and methodological advances in dealing with the second order collective action dilemma. Some of these

²Collaborative governance and policy networks are often treated as synonyms (see Ansell & Gash, 2008, p. 547).

³She uses this proposition to reject the premise and prescriptions of the three theoretical orthodoxies—tragedy of the commons, prisoners dilemma, and collective action dilemma—as the “only way” of analyzing institutional supply in governing the commons (E. Ostrom, 1990, p. 13).

frameworks and theories include the institutional analysis and development (IAD) framework (E. Ostrom, 1990, 1999b), the Common Pool Resource theory (E. Ostrom, Gardner, & Walker, 1994), and the institutional collaborative action (ICA) framework (Feiock & Scholz, 2009; Feiock, Steinacker, & Park, 2009)⁴. While acknowledging the relative superiority of the IAD framework and the CPR theory (Edella Schlager, 2007; Edella Schlager & Blomquist, 1996), the applicability of this framework to the *urban commons* has been questioned (Dagan & Heller, 2001; Garnett, 2011; Harvey, 2011).⁵ Harvey (2011, p. 102), for instance, succinctly looks at the Ostrom framework as suffering from “... [an] unanalyzed ‘scale problem’...” Analyzing the factors that condition the emergence of collaborative policy networks at the *urban scale* is still an underexplored area in the literature. This dissertation seeks to add to the dearth of knowledge in this area.

1.2 Study Overview: Polycentric Ecology of Urban Water Policy Games

1.2.1 Setting: The Urban Water Commons/Watershed

The ‘urban’ is treated as the big container constituted by many “commons” such as the “water commons.” The urban water commons and urban watershed is used interchangeably in this dissertation. The commons idea is used narrowly here to refer to the establishment of collective property claims over certain resources within the urban (e.g. land, water, housing, etc.) through their sustained use and appropriation (Blomley, 2008; Gillespie, 2016). Eizenberg notes the limitation of the contemporary use of the word commons because existing commons are only “live relics of the ideal of the commons; they are never complete and perfect and may even have components that contradict the ideal

⁴ See detailed description of these and other frameworks and theories in Sabatier (2007)

⁵ See Garnett (2011) for detailed discussions on the urban and liberal commons.

type' (Eizenberg, 2012, p. 765). The urban water commons as used in this dissertation, however, helps to convey the specificity of the resource in the urban being studied, the multiplicity of collective property claims that are often made over this resource, and the scale dilemma associated with this urban resource.

In studying certain aspects of the urban, such as the environmental commons, especially the water and air commons, scholars must confront the 'scale dilemma'—what is the appropriate scale to study water resources in a particular geographic space? For example, water resources are studied at the watershed, problem-shed or policy-shed scales (see detailed discussions on these in Cohen & Davidson, 2011; Griffin, 1999; Islam & Repella, 2015). The problem here is that there are often asymmetries of these scales, where the problem affects an extensive—multi-jurisdictional—geographic scope (extensive problem-shed) but policies are often made by individual jurisdictions (non-extensive policy-shed) (Cohen & Davidson, 2011; Islam & Susskind, 2012). Hence, the choice of scale must hence blend scientific and political reasoning (Blomquist & Schlager, 2005).

The urban watershed scale offers a blend between scientific and political reasoning, which also reflects the scale where the watershed, the problem-shed and the policy-shed scales approximately converge (cf. Grimm, Grove, Pickett, & Redman, 2000; Kaushal & Belt, 2012). It is defined as the "...drainage units entirely or substantially within metropolitan regions, not major rivers that flow through or past cities like the Hudson at New York or the Mississippi at St. Louis and New Orleans." (Platt, 2006, p. 29). The U.S. Geological Survey has a four tier classification system and the last category "Cataloguing Units or HUC-8" provides the drainage of networks at the urban-metropolitan scale (ibid). Even though these designated urban watersheds have clearly defined boundaries, there is a

multi-scalar collective property claims over each of these urban watersheds—making it a multi-scale, geopolitical arena whereby policy, politics and science converge to define the wicked or complex nature of problems characterizing the urban watershed (see also Islam, Gao, & Akanda, 2010; Rittel & Webber, 1973). This dissertation views the urban watershed/commons as the ideal “policy space” (E. Ostrom, 1990, p. 142) to study the outcomes from a collective-choice process—interorganizational collaborations to govern the urban water commons.

1.2.2 Governing the Urban Water Commons as a Polycentric Ecology of Water Policy Games

“...man is both a game-playing and a game creating animal, that his capacity to create and play games and take them deadly seriously is of the essence...” (Long, 1958, p. 252)

In this dissertation, the study of interorganizational collaboration in governing the urban water commons is situated within two theoretical constructs—the “ecology of games” (Long, 1958, p. 251; Lubell, 2013) and polycentric governance (McGinnis, 2015; E. Ostrom, 1990, 2010a; V. Ostrom, 1999[1972]; V. Ostrom, Tiebout, & Warren, 1961). It seeks to properly contextualize (by hypothesizing and testing) the role of polycentric governance within the ecology of games framework. To achieve this, the dissertation concerns itself with three questions, which are answered by the three papers/essays forming the next three chapters of the dissertation. These questions include:

1. What does it mean to conceptualize the governance of social-ecological systems (e.g. the urban water commons) as a polycentric governance system—i.e. what is a polycentric urban water governance system?
2. How could a polycentric urban water governance framework be enacted methodologically?

3. How is interorganizational collaboration in governing the urban water commons shaped by polycentric governance?

The ecology of games considers governance as the concurrent operation of multiple policy games at different points in time (Long, 1958; Lubell, 2013). A policy game comprises the interactions among policy actors as they participate in a policy institution—a rule-governed collective decision-making process (Lubell, 2013, p. 538). A policy game is populated by policy actors participating in a policy institution or “collective-choice rules” that creates “operational rules” in dealing with a policy issue (e.g. water supply or pollution) in a geographically defined policy system (Lubell, 2013, p. 540; E. Ostrom, 1990; Scharpf, 1997b). A policy system is a geographically defined territory (e.g. urban watersheds) comprising multiple policy issues (e.g. water supply, and flood hazards), multiple policy institutions (e.g. conserving water resources, hazard mitigation planning, and regional transportation planning) and multiple actors (e.g. private and public organizations or individual at local, state or national levels) (Lubell, 2013). The policy system can be defined at any geographical scale but there is the need to account for cross-scale interaction (*ibid*). This proposed dissertation considers the urban watershed scale as its policy system.

A policy institution is constituted of formal rules and informal norms at the meso-level that determine the patterning of interactions among policy actors within the urban policy system (Lubell, 2013; Lubell, Robins, & Wang, 2014). At the policy institution level, policy actors collectively decide to operationalize macro-level/constitutional rules to govern micro-level or operational rules (policy issues) such as water supply, water pollution, traffic congestion, etc. (Lubell, 2013; E. Ostrom, 1990). Policy actors, such as

individuals or organizations, have a variety of interest or stake (e.g. appropriation and political interests) in the decisions made at the policy institution level (Lubell, 2013; Lubell et al., 2014). Therefore, they interact with other policy actors as they participate in a policy institution to gain information, credibility, and political influence (Berardo & Scholz, 2010) as well as gain legitimacy, social acceptance, and improve social status (Edelman, 1985; Long, 1958). The participation of policy actors in a policy institution implies that they are “playing a policy game” (Lubell, 2013, p. 540). Hence, the urban commons as an ecology of games simply considers the interactions of multiple games—e.g. banking, government/politics, etc.—and actors within the urban commons, where each game is structured by rules and strategies, all producing an unintended but functional system for the urban ecology.

Polycentricity is a key feature of the ecology of games framework (Lubell, 2013; Lubell et al., 2014). Polycentric governance refers to a self-governing system constituted by “(1) many autonomous units formally independent of one another, (2) choosing to act in ways that take into account of others, and (3) through processes of cooperation, competition, conflict, and conflict resolution” (V. Ostrom, 1994a). Lubell (2013, p. 538) argues that the ecology of games could be looked at as “a *theory[emphasis in original]* of polycentric governance that extends E. Ostrom’s (1991, 2007) Institutional Analysis and Development (IAD) *framework[emphasis in original]*.” In using the ecology of games framework to study the governance of the San Francisco Bay (SF Bay) water resources, Lubell et al. (2014, p. 5), concludes that the S.F. Bay is “appearing polycentric.” This conclusion gives room to further interrogate issues such as 1) the form and constituents of governing system that ‘appears’ to be polycentric, and 2) the analytical and/or policy

relevance (if any) in characterizing a governing system as appearing polycentric. The former issue is both empirical and methodological in nature. The latter questions the extent to which polycentric governance could be *generalized* as a key institutional prescription to govern and promote resilient social-ecological systems (see Chaffin, Gosnell, & Cosens, 2014; Cosens & Williams, 2012; Folke, 2007; Folke, Hahn, Olsson, & Norberg, 2005). This dissertation wrestles with these two and other issues.

1.3 Significance of Research

This dissertation offers theoretical and methodological contributions to the ongoing discourse on collaborative policy networks in governing social-ecological systems. Theoretically, Lubell et al. (2014) and Bodin and Crona (2009) note that there is no consensus on what types of network structures and social-ecological conditions affect governing arrangements in different contexts. Specifically, despite frequent citation to this fact, the role of polycentricity in ensuring effective governance of coupled social and ecological systems (e.g. the urban water commons) is under-theorized within the ecology of games framework. This dissertation conjoins multiple theoretical lenses to (re)conceptualize and develop a novel analytical framework to think about and analyze how polycentricity shapes network structures (e.g. interorganizational collaboration) in urban watershed governance.

Beyond theory, the paper also makes methodological contributions, especially in response to the call of moving beyond the normative and descriptive focus of polycentrism (e.g. Green, 2007; Lubell, 2013). This is achieved through 1) the use of social network theory and analysis to methodologically engage polycentricity in urban water governance from a novel analytical perspective, and 2) the conjoining of multiple hypotheses to test

how different factors (e.g. bridging and bonding social capitals, social-ecological risks, and polycentricity) shape interorganizational collaboration within the urban ecology of water policy games. The latter contribution, in other words, offers a “supersynthesis” (Cairney, 2013, p. 2) or a multi-theoretic lens in studying complexity in governing social-ecological systems (Lubell, 2013; Edella Schlager, 2007).

In addition to the novel ways of thinking about and methodologically engaging polycentric governance within the ecology of games framework, the use of the Middle Rio Grande (MRG) urban watershed as proofs of concept can help policy makers, practitioners and scholars in the following ways. Specifically, the analyses and narratives presented in this dissertation can help local policy makers within the MRG to understand how the pattern of interorganizational collaboration within this urban watershed could potentially reveal 1) the level of trust organizations have for each other, 2) the specific organizations that could help foster greater collaboration, enhance information dissemination, and also help resolve conflicts between organizations, and 3) the extent to which the MRG could be effectively governed if organizations reach out to strategic partners (i.e. reaching out to different types of organizations operating at different governing scales). Again, the analysis and narratives embodied in the proofs of concept could also allow scholars and policy makers to replicate this study in other contexts (e.g. the use of different geographic locations and/or the use of different social-ecological systems such as forest resource systems) to support natural resource governance and conservation efforts.

1.4 Outline of Chapters

The dissertation is presented in five cohesive chapters including both introduction and conclusion chapters. The introduction chapter serves as the roadmap by providing the context and thematically-linked research questions that animates this dissertation.

The second chapter develops a theoretical framework of polycentric water governance by explicating its key tenets. This chapter offers a synthesized conceptualization of polycentricity in the areas of political economics, planning, and social-ecological networks. It puts into conversation three theoretical paradigms to excavate the conceptual pillars to study the polycentricity of urban water governance in the United States. These paradigms are the polycentric governance literature, the PUR concept championed by European urban planning scholars through projects like the POLYNET, and the social-ecological network analysis (SENA) framework. This synthesis is crystallized into five rules to study the polycentricity of coupled social-ecological systems such as urban water resources. Although the chapter restricts itself to water governance in the U.S., its embodied ideas could be translated to other social-ecological systems.

The third chapter uses these key tenets to develop both theoretical and empirical models of polycentric water governance. This chapter uses the five rules in chapter 2 to develop both theoretical and empirical models to study the polycentricity of urban water governance. It uses the Middle Rio Grande (MRG) urban watershed in New Mexico, USA, as a case study. Four indices are developed to measure the level of political, market, nonprofit, and overall polycentricity in governing this urban water commons. The findings indicate that the governance of the MRG urban watershed is a predominantly monocentric governing system with elements of polycentricity. These findings also suggest that

polycentric water governance could also primarily be about the politics of power and resource distribution, the reconfigurations of actors' positionalities as they align themselves and their interests strategically. This raises both empirical and conceptual concerns as to the role of polycentric governance in actors' strategic access to power and resources in governing the urban water commons.

The fourth chapter uses the overall index to model the role of polycentricity in governing the urban water commons. This chapter provides a means to address the concerns raised in the third chapter: the role of polycentric governance in actors' strategic access to power and resources in governing the urban water commons. It conceptualizes the governance of the MRG urban water commons as a constellation of policy actors and policy institutions, constituting a polycentric ecology of water policy games. The exponential random graph models (ERGMs) is used to explain inter-actor (organizational) collaborations within the Middle Rio Grande (MRG) urban water commons. The chapter finds that a polycentric ecology of urban water policy games implies two non-mutually-exclusive conditions. Firstly, there is a core-periphery (centralized) collaborative policy network *segmented* into a chain of smaller cohesive (decentralized) subgroup areas. This is referred to in the chapter as the *Lubell-Robins-Wang polycentric hypothesis*. Secondly, policy actors make strategic decisions to connect with other policy actors within different sectors and at different governing scales. Policy-wise, the findings suggest that traditional hierarchical institutional structures can resolve problems in governing the urban water commons, if policy actors across multiple governing scales and sectors collaborate.

The conclusion chapter provides summary and synthesis of the chapters by delineating the theoretical, methodological and policy contributions of these cohesive essays.

CHAPTER II: (RE) MAPPING POLYCENTRICITY: THE POLITICAL ECONOMY, SPATIALITY, AND NETWORK OF POLYCENTRIC WATER GOVERNANCE

2.1 Introduction

Polycentrism is treated as a governance or spatial concept—polycentric governance (from a political economy standpoint) or polycentric urban regions (from an urban/spatial planning standpoint). Polycentric governance or a “polycentric political system” implies the existence of multiple decision-making centers that are formally autonomous of each other and operate under certain sets of rules (Aligica & Tarko, 2012; McGinnis & Ostrom, 2012; E. Ostrom, 2010a; V. Ostrom, 1999[1972]; Polanyi, 1951). The concept of polycentric urban region (PUR) considers a network of functionally interconnected settlements (Burger & Meijers, 2012; Green, 2007; Hall & Pain, 2006b; Vasanen, 2012). The underlying similarity between polycentric governance and PUR lies in the fact that scholars seek to interrogate, both conceptually and empirically, the logic behind and the implications of the network of multiple equipotent focal points (i.e. multiple decision-making centers or multiple urban centers).

This chapter provides a synthesized conceptualization of polycentric governance in watershed governance. It puts into conversation three theoretical paradigms to excavate the conceptual pillars of polycentric governance. These paradigms are represented in the polycentric governance literature mostly by the Bloomington School of Political Economy (Vincent and Elinor Ostrom, and their associates), the PUR concept championed currently by European urban planning scholars through projects like the POLYNET (Peter Hall and Kathy Pain and their associates), and the social-ecological network analysis (SENA) framework (Bergsten, Galafassi, & Bodin, 2014; Bodin & Tengö, 2012; Rathwell & Peterson, 2012; Sayles, 2015; Schoon, Baggio, Salau, & Janssen, 2014). This synthesis is crystallized into five rules upon which robust methodological engagement and empirical testing of polycentric water governance could be pursued in future research. Although this chapter restricts itself to water governance, its embodied ideas could be translated to other coupled social and ecological systems.

The chapter is structured into four main sections not including the introduction. The first section provides a brief literature context of water governance within the United States (U.S.). The second section offers both historical and theoretical overview of polycentrism by drawing on the work of Polanyi (1951) and the Bloomington School—the Polanyi-Bloomington School. The third section maps out the conceptual pillars of polycentricity in governing social-ecological systems like the urban water commons. First, two rules are developed by dissecting and integrating the key ideas embodied in the literature on polycentric governance by the Polanyi-Bloomington School and the PUR literature. Second, these rules are built upon by developing three additional rules based on the central ideas in the SENA literature. The fourth section synthesizes these five rules into a

conceptual map of polycentric water governance. Policy network and social network scholars in general will find that this conceptual mapping easily lends itself to different methodological approaches like social network analysis. The chapter closes with some observations on operationalizing the rules for methodological analysis.

2.2 Governing the Urban Water Commons in the United States

Over 2000 watersheds in the contiguous United States are located within or experience the effects (e.g. urban runoff) of urban areas. The urban watershed is treated here as the big container constituted by many “commons” such as the “water commons.” Platt (2006, p. 29) defines urban watersheds in the U.S. as the “...drainage units entirely or substantially within metropolitan regions, not major rivers that flow through or past cities like the Hudson at New York or the Mississippi at St. Louis and New Orleans”. These urban lands generally make up about 3 percent (61million acres) of the total U.S. land area (Nickerson, Ebel, Borchers, & Carriazo 2011). Denser urban regions in the east have more intensified urban uses (see Figure 2.1 below). The commons idea is used narrowly here to refer to the establishment of collective property claims over certain resources within the urban (e.g. land, water, etc.) through their sustained use and appropriation (Blomley, 2008; Gillespie, 2016).⁶The urban water commons as used in this paper helps to properly convey the specificity of the resource in the urban watershed being studied, the multiplicity of

⁶ Eizenberg notes the limitation of the contemporary use of the word commons because existing commons are only “live relics of the ideal of the commons; they are never complete and perfect and may even have components that contradict the ideal type” (Eizenberg, 2012, p. 765).

collective property claims that are often made over this resource, and the scale dilemma associated with this urban resource. I will discuss the scale dilemma later in this paper.

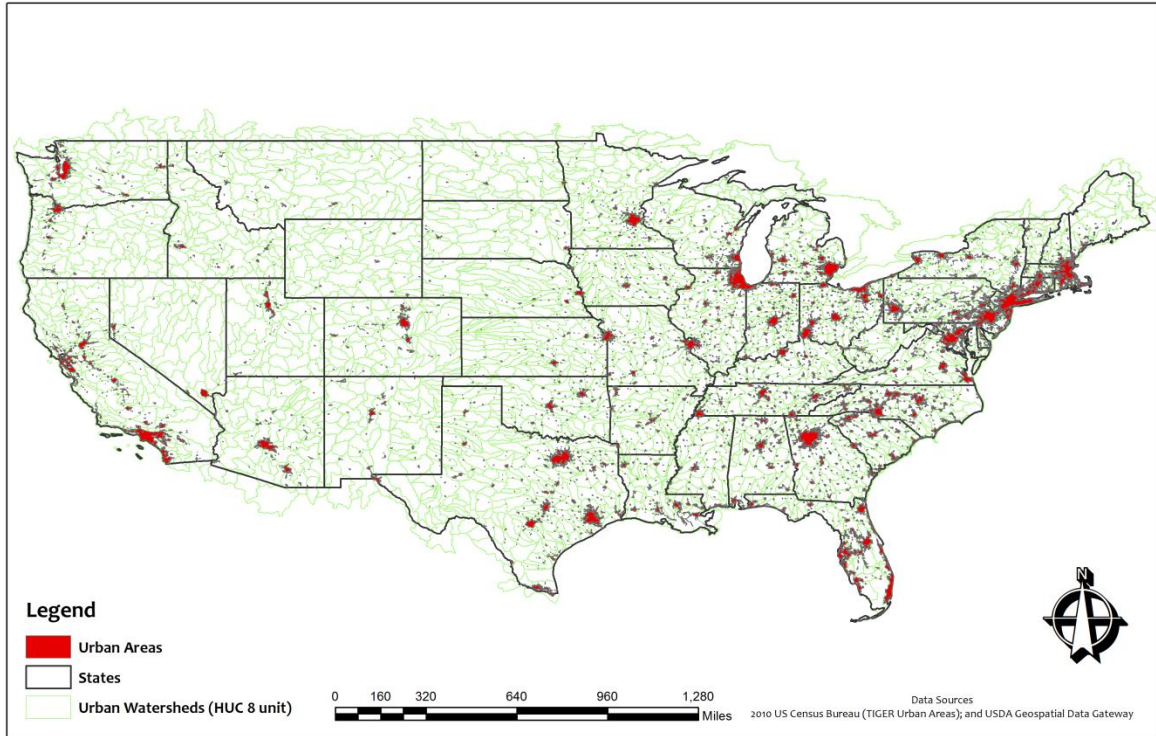


Figure 2.1: Urban Watersheds in the United States

Water governance generally refers to the various actors and systems (politico-economic and administrative systems) in place to regulate the use and management of water resources (Baumgartner & Pahl-Wostl, 2013; Rogers & Hall, 2003). This definition is situated within the broader environmental governance definition, which looks at the formal and informal rules and practices guiding actors’ use of social-ecological systems (Chaffin et al., 2014; Pahl-Wostl, 2009). The governance of water resources and other social-ecological systems is based upon theories of collective action (Rogers, MacDonnell, & Lydon, 2009). Water, as a “fugitive resource”—its supply engenders natural monopolies and its use also generates to externalities (Rogers et al., 2009, p. 225)—requires institutions capable of 1) minimizing transaction costs among actors, and 2) effective monitoring and

enforcement of common rules to punish defectors and free-riders (Schneider et al., 2003). The creation of institutions capable of addressing these issues is increasingly needed as the mode of water governance keeps shifting in the U.S. and in other countries. In the U.S., water governance has shifted from strong centralized bureaucratic control in the 1960s and 1970s to decentralization and privatization in the 1980s and 1990s to the currently network governance and community involvement (Pahl-Wostl & Knieper, 2014).

There are variously constructed institutional prescriptions in governing social-ecological systems such as the urban water commons. Reviewing the literature on water governance and adaptive (co-) management, Huitema et al. (2009) presents four institutional prescriptions—polycentric governance, public participation, experimentation, and bioregional approach (see also Pahl-Wostl, Holtz, Kastens, & Knieper, 2010). Participation, seen either narrowly as ‘stakeholder participation’ or broadly as ‘public participation’ simply refers to when the public or stakeholders are willing and able (e.g. have the desired participation channels) to make inputs in decisions (DeCaro & Stokes, 2013; Huitema et al., 2009; Mostert, 2003; Reed, 2008). Experimentation in governance, as a critique of the ‘rational planning model’ (see Lindblom, 1959; van Gunsteren, 1976), privileges incremental institutional arrangements or “piecemeal engineering” (Popper, 1985[1944], p. 309) based upon experiential or trial and error learning (Collingridge, 1992; Huitema et al., 2009). The bioregional approach supports the creation of “unitary”, “strong”, or higher-level (centralized authority) institutional arrangement at the river basin level (Dinar et al., 2005; Mitchell, 1990; E. Schlager & Blomquist, 2000, pp. 3-4). I will discuss polycentric governance in detail in later sections of the paper.

The above four institutional prescriptions are not mutually exclusive; they overlap, support, and/or constrain each other (Huitema et al., 2009). Specifically, as an umbrella institutional arrangement, polycentric governance, discussed by resilience and adaptive governance scholars, recognizes the mutually constitutive nature of all four institutional prescriptions (Chaffin et al., 2014; Cosens & Williams, 2012; Folke, 2007; Folke et al., 2005). For instance, public participation is key in developing a polycentric governance system for social-ecological systems (Dietz, Ostrom, & Stern, 2008; Folke et al., 2005; Lundqvist, 2004); the nesting of multiple centers of power supports institutional diversity and redundancy in power relations, which are needed characteristics for an adaptive governance system to still function in times of crises or disturbances (Chaffin et al., 2014).

More importantly, the above institutional prescriptions are generally in response to the limits of the economic theory of politics (Rogers et al., 2009). The economic theory of politics was first critiqued by Downs (1957), which later became the bedrock in developing what became known as the ‘rational choice’ or ‘public choice’ governance model (see Brennan & Buchanan, 1984; Keating, 1995). Drawing on works like Dahl and Lindblom (1953), Downs (1957) constructs a politico-economic model of governance whereby citizens and local governments *respond efficiently* (not rationally as used by economists) to the “exigencies of life in an imperfectly informed world” (Downs, 1957, p. 149). There is also the ‘polis model’ by Stone (2002), which draws on Maass (1951) to explore the nexus between group (public interest) and atomized (self-interest) political mobilizations. Finally, there is also polycentric governance model, the focus of this paper and other works on governing water resources (e.g. Dietz et al., 2008; E. Ostrom, 1990), which draws on Polanyi (1951).

While normative claims have been made about the public choice model (e.g. Brennan & Buchanan, 1984; Buchanan, 1979), and the polis model (e.g. Boland & Baumann, 2009; Skutsch, Vickers, Georgiadou, & McCall, 2011), Huitema et al. (2009) note that we still cannot make normative claims about the polycentric governance model. The definition and conceptualization of polycentricity seem nebulous (Davoudi, 2007; Green, 2007); hence, its robust methodological engagement and empirical testing are also constrained. The remaining sections of the paper provides a foundation for epistemological/methodological approach to polycentrism by weaving together different perspectives on polycentricity to 1) synthesize the current understanding, 2) use this synthesis to excavate the conceptual pillars of polycentricity in the form of rules, and 3) conceptually map polycentricity for future methodological interrogation.

2.3 The Political Economy of Polycentric Governance: A Brief Historical-Theoretical Context

The literature on polycentric governance or what V. Ostrom (2008b) refers to as the “*compound republic*” problematizes state-market and public-private goods dichotomies. Samuelson (1954) argues for an optimal institutional form to distribute public and private goods. Public goods are nonexcludable (no one can be exempted from enjoying them) and nonrivalrous (a person using it does not prevent another from using it). Hence, these goods are best provided by the state to minimize externalities. Private goods are the opposite of public goods—excludable and rivalrous—hence, the market is hypothetically the best institutional arrangement for providing these goods. Ostrom (2010) notes that this dichotomy and the resultant institutional arrangements (state and market) support the arguments that 1) a hierarchical government or the Leviathan is needed to ensure that self-

seeking individuals contribute to the efficient supply of public goods such as security (Ostrom, 2010, citing Hobbes, 1960[1651]; Wilson, 1885), and 2) there is efficiency and less chaos when a metropolis, for instance, is governed by a single rather than multiple governmental units (Ostrom, 2010, citing Frie sema, 1966; Gulick, 1957). We will refer to this state-market, hierarchical government argument as the monocentric government argument (MGA).

Scholars (e.g. see Williamson, 1975, 1986) exposed the analytical flaws within the public-private and state-market dichotomies including the logic that hierarchical and fewer number of governmental institutions offers the optimum institutional form. We will sketch the flaws in the MGA by focusing on what should be the optimum scale of producing urban public goods and services. This begins with the logic of the *reformers*, who in the 1960s posited that there were many governments but not enough government, leading to overlap and duplication of jurisdictional functions (Aligica & Boettke, 2009; McGinnis, 1999; E. Ostrom, 2000; V. Ostrom & Ostrom, 1965). The multiplicity of political units in the metropolis, or what Lind (1997, p. 7) refers to as “horde of Lilliputian governments,” structured metropolitan governance into an “organized chaos” or a “crazy-quilt pattern” (V. Ostrom et al., 1961, p. 831). Scholars of the Bloomington School, however, argued that metropolitan governance comprised of multiple agencies (government, quasi-government, and private organizations) at multiple governing scales offers the optimum scale in the efficient production of different urban public goods and services (McGinnis, 1999; V. Ostrom et al., 1961).

The Bloomington School’s position against the MGA was rooted in two arguments. First, the Bloomington School marshalled an intellectual argument against monocentric

government by building on Polanyi's seminal manuscript, "The Logic of Liberty" (1951). Polanyi (1951) centrally argued that progress in any organizational system (e.g. the scientific community) is achieved when the system has a polycentric organization. Polycentric organization allows the existence of multiple opinions, supports individual freedom, and allows people to make their personal contributions, and promotes progress through a trial-and-error evolutionary process as individuals interact freely (Aligica & Tarko, 2012; Polanyi, 1951). Here, Polanyi's (1951) polycentrism argument draws closer to Hayek's (1945) logic that the Pareto optimum of goods and services cannot be achieved through a monocentric authority—neither command-control-strategy nor market strategy—because there is imperfect information in both the command-and-control and market systems (see also Downs, 1957).

The second argument also deals with the multidimensional nature of goods and services. The monocentric metropolitan government could provide a bundle of Pareto optimum goods and services if all goods and services could be boxed into the Samuelson (1954) public-private goods dichotomy. Buchanan (1965), however, introduced a third kind of good—club goods—engendered as a result of private associations (club) providing nonrivalrous goods and services for their members only (nonrivalrous but excludable goods and services). E. Ostrom (1991) added a fourth type of good—common-pool resources (e.g. forest systems and urban water resources)—which represent those goods and services which are rivalrous (subtractable) but difficult to exclude (see E. Ostrom, 1972 for detailed discussion on goods, (dis)economies of scale, and metropolitan governance). These four different types of goods pose a governance riddle: *what governance/institutional arrangements suit the management of goods and services which are neither purely*

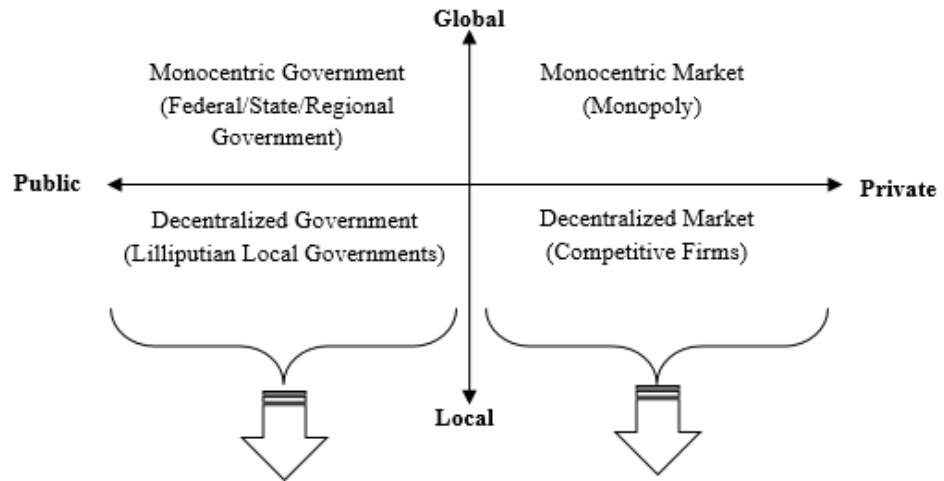
excludable nor purely subtractable? Polycentric governance is an attempt to unravel this riddle.

Through intergovernmental arrangements (e.g. collaborative and participatory decision making), a polycentric governance system emerges as a constellation of multiple decision-making centers coordinated by multiple and different decision-making powers to induce efficiency and self-correcting mechanisms (V. Ostrom & Ostrom, 1965). McGinnis (2015, p. 5) looks at polycentric governance as consisting of (1) multiple decision-making centers with overlapping jurisdictions, (2) formal and informal collaborations through the interactions of these decision-making centers, and (3) generation of a social order from these interactions, which is capable of ensuring democratic self-governance and capturing efficiencies at all aggregation scales. It is not self-evident that large scale government (monocentric government system) leads to economies of scale, and multiple governments within the metropolis are less efficient and chaotic. The evidence rather suggests that, “polycentric arrangements, generally, outperformed cities that had only one or two large departments” (McGinnis, 1999; E. Ostrom, 2000; E. Ostrom, Parks, & Whitaker, 1978; V. Ostrom, 1999[1972], p. 148). Further, the evidence suggests, noted V. Ostrom (1999[1972]) and McGinnis (1999, p. 52), that a predominantly polycentric governance system may contain elements of monocentric government and vice versa; that is, polycentric and monocentric government systems are two sides of the same coin. Again, the evidence also suggests that there is a “systemic logic” to polycentric governance in that “islands of polycentric order” (e.g. market polycentrism, and judicial polycentrism) influence each other (Aligica & Tarko, 2012, p. 247; V. Ostrom, 1999[1972]).

The governance of social-ecological systems (such as water resources) fits the polycentric governance arrangement rather than the state-market institutional arrangement (E. Ostrom, 2010a). Social-ecological systems are governed by diverse and often multi-scalar institutional arrangements (market, government, quasi-market, and quasi-governmental institutions) designed by policy actors who face complex motivational and payoff structures (see Folke et al., 2005; Folke, Pritchard, Berkes, Colding, & Svedin, 2007). But what does it mean specifically to describe water governance as polycentric? The next sections of the paper wrestle with this question.

2.4 Conceptualizing the Political Economy of Polycentric Governance

The framework in Figure 2.2 below illustrates key points in the discussion above. The first part of the framework, the four quadrants, is adapted from Pahl-Wostl and Knieper (2014). In these four quadrants, we see the state-market dichotomy represented as either being monocentric or decentralized. This first quadrant presents an often misunderstood logic in the Polanyi-Bloomington School argument: polycentricity is not the antithesis of monocentricity. The solution to the multiple decentralized governments or firms, as argued by the MGA scholars (e.g. Christenson & Sachs, 1980; Horan & Taylor, 1977; Jones, 1942), was to propose an institutional arrangement—monocentricity—diametrically opposed to a decentralized arrangement. This ‘black or white’ logic is what the Polanyi-Bloomington School rejects. As shown in the second part of the framework, the matrix presents the inherent complexity in the thinking of the Polanyi-Bloomington School scholars. If the answer to the complicated governance riddle earlier posed does not lie in a binary oppositional logic, then, we could combine and experiment with multiple institutional arrangements.



		Public		Private	
		<i>Local</i>	<i>Global</i>	<i>Local</i>	<i>Global</i>
Public	<i>Local</i>	Decentralized Government	Mix of Monocentric and Decentralized Governments (Partial Polycentrism)	Mix of Decentralized Market and Government (Partial Polycentrism)	Mix of Monocentric Market & Decentralized Government (Purely Polycentrism)
	<i>Global</i>	Mix of Monocentric and Decentralized Governments (Partial Polycentrism)	Monocentric Government	Mix of Monocentric Government & Decentralized Market (Purely Polycentrism)	Mix of Monocentric Market and Government (Partial Polycentrism)
Private	<i>Local</i>	Mix of Decentralized Market and Government (Partial Polycentrism)	Mix of Monocentric Government & Decentralized Market (Purely Polycentrism)	Decentralized Market	Mix of Monocentric and Decentralized Market (Partial Polycentrism)
	<i>Global</i>	Mix of Monocentric Market & Decentralized Government (Purely Polycentrism)	Mix of Monocentric Market and Government (Partial Polycentrism)	Mix of Monocentric and Decentralized Market (Partial Polycentrism)	Monocentric Market

Key

- Diametrically opposed institutions
- Involves different governing scales (decentralized and centralized)—Partial polycentrism
- Involves different sectors (public and private)—Partial Polycentrism
- Involves both different governing scales and sectors (Purely Polycentric)

Figure 2.2: Conceptual Framework of Polycentric Governance

The four by four matrix section of the framework presents an alternative way of thinking about the four quadrants. There are four institutional arrangements expected: 1) a purely monocentric or decentralized institutional arrangement (diametrically opposed institutional arrangements); 2) an institutional arrangement involving organizations at different governing scales (mix of decentralized and centralized); 3) an institutional arrangement involving organizations within different sectors (mix of public and private); and 4) an institutional arrangement involving organizations at different governing scales and within different sectors (mix of decentralized-centralized and public-private). The fourth outcome, which involves different governing scales (monocentric and decentralized) and within different sectors (public and private), as noted by McGinnis (1999) and Aligica and Boettke (2009), is what the paper terms as the zone of pure polycentrism. The second and third institutional outcomes are not purely polycentric but contain elements of polycentrism—mix of governing scales or mix of sectors (partial polycentrism).

In the matrix, there is only a 25% chance of having these diametrically opposed institutions (the first expected institutional arrangement) compared to the 75% chance of having combinations of institutional arrangements that have elements of both monocentric and decentralized institutional arrangements. This, perhaps, is a more accurate representation of how societies in the U.S. especially are governed: governance is not purely monocentric or decentralized but a melting pot of both. The probability of having partial polycentrism (second and third outcomes) is 50% and the probability of having a purely polycentric system (the fourth outcome) is also 25%. In other words, conceptually, the probability of having a purely polycentric or diametrically opposed (monocentric or decentralized) institutional arrangements are lesser than having a system containing

elements of both. This could help illustrate the point that the governance of U.S. societies is neither purely polycentric nor purely monocentric or decentralized. It is more of an imperfect (partial) polycentric governance system; the nesting of multiple institutional arrangements that sometimes looks like a largely monocentric system within a polycentric system and vice versa (see V. Ostrom (1999[1972]) and McGinnis (1999, p. 52). We will expand on some of these key points in the next section of the paper as we excavate the conceptual pillars (or the rules) of polycentricity in water governance or other social-ecological systems.

2.5 The Conceptual Pillars of Polycentric Water Governance

2.5.1 The Political Economy and Spatiality of Polycentrism: European Spatial Planning School Meets Bloomington School

Some scholars have explored the concept of polycentric development or PUR or polynucleated urban landscape (e.g. Batty, 2001b; Davoudi, 2003; Green, 2007; Hall & Pain, 2006b; Parr, 2004). The interest in polycentric development was influenced by the increasing number of city centers (e.g. the city-suburb spatial forms), which shifted the conversation from the monocentric city model or the core-periphery model to the emerging PUR (Copus, 2001; Green, 2007). The history of modern planning, argued by Green (2007), shows that the discourse on polycentric urban region in planning could be traced back to scholars like Ebenezer Howard (1898), Patrick Geddes (1968[1915]), Lewis Mumford (1938), and Hall (1984). PUR has been used to describe places like the Greater London and south-east England in the United Kingdom (Geddes, 1915/1968, pp. 27–28), Radburn, Hamburg, and Köln in Germany (Mumford, 1938, p. 490), and Randstad in Holland (Hall, 1984; Meijers, 2005).

The link between polycentric governance and polycentric urban region can be seen in terms of two interrelated issues—the normative versus analytical dimensions of polycentrism, and the functional versus morphological dimensions of polycentrism. First, both the polycentric governance and the polycentric urban region scholars have advocated making polycentricity analytically relevant. This requires separating the normative and analytical aspects of polycentrism. Green (2007, p. 2079) argued that polycentrism, for some, has become an “ism” that must be achieved. The need to explore the analytical relevance of polycentrism is not to negate the use of polycentrism in the normative sense. However, because of definitional ambiguity of polycentricity some scholars have argued that more empirical tests are needed (Lieberman, 2011); hence, normative evaluations of polycentricity become tenuous at best (Bailey & Turok, 2001; Mostert, 2012; Turok, 2005). In other words, we must explore the analytical relevance of polycentricity through robust empirical tests and use such findings to inform normative claims about polycentricity.

Second, exploring the analytical side of polycentrism means that one needs to deal with the morphological and functional aspects of polycentrism. Through projects like the EU-funded POLYNET (Hall & Pain, 2006b), scholars interested in PUR have expanded the literature to include the morphological and functional aspects of polycentrism, developing and offering robust empirical tests of polycentricity as a spatial concept. We will focus on and adapt some of the works by these polycentric urban region scholars, specifically the works of Green (2007), Burgess et al. (2012), and Vasanen (2012), as a means to develop and empirically test polycentric governance.

Green (2007), based on what he terms “functional polycentricity,” attempts to define and measure polycentricity based on its morphological and functional aspects. The

morphological aspect of polycentrism refers to the multiplicity of adjacent centers (urban centers) within a given territorial space (Burger & Meijers, 2012; Green, 2007; Vasanen, 2012). In terms of polycentric governance, we can look at *morphological polycentric governance* as also the plurality of adjacent decision-making policy actors within given territorial and decision-making spaces at the constitutional, policy, and/or operational levels. For instance, in urban water governance, we are interested in the various adjacent policy actors within 1) the policy space of urban water governance (i.e. the number of actors involved in urban water decisions), and 2) the specific urban territorial space where these decisions are made (e.g. the Middle Rio Grande urban watershed, New Mexico (MRG)). Following the lead of Green (2007), from this morphological conception of polycentrism, we could state, as the first rule, that for polycentric governance to exist:

Rule 1: There must be more than one policy actor within specified policy and territorial spaces.

Morphological polycentrism, however, only captures the existence of adjacent policy actors without capturing the functional relationships (e.g. policy actors' collaboration or partnership with each other) (Burger & Meijers, 2012). The existence of adjacent nodes (e.g. urban centers or policy actors) within specified policy and territorial spaces, whereby these nodes are relatively equal in their absolute importance, only captures the *topography (location)* of polycentrism (Green, 2007, p. 2083). But in polycentric governance discourse especially, the adjacency of nodes (policy actors) is not only topographical but also functional/topological (Green, 2007). For instance, in studying urban water governance in the MRG, we may identify policy actors like the City of Santa Fe and the Valencia Soil and Water Conservation District (VSWCD) as adjacent nodes

within the specified policy space of urban water governance and the specified territorial space of the MRG. However, the City of Santa Fe and the VSWCD are also adjacent (located topographically) because of they have a functional (e.g. collaboration or partnership) relationship. Hence, morphological polycentricity becomes: 1) a representation of an implicit functional relationships among policy actors; and 2) a necessary but insufficient condition for polycentric governance. This way, polycentric is separated from terms like ‘multicentric’ or ‘multinuclear’ (Burger & Meijers, 2012, p. 1133). Again, following the lead of Green (2007), we could state that for polycentric governance to exist:

Rule 2: There must be functional linkages between policy actors (e.g. collaboration or partnerships) so that there is no polycentric governance in the absence of such a functional linkage.

Taken together, Rules 1 and 2 explain the point that functional polycentrism builds on morphological polycentrism to account for the absence of absolute importance of certain specific nodes in a polycentric system (governance or urban regions) (Burger & Meijers, 2012). In effect, functional polycentric governance (Rule 2) encapsulates morphological polycentric governance (Rule 1); henceforth, *functional polycentric governance* and polycentric governance will be used interchangeably in this chapter.

2.5.2 The Network of Polycentrism: SENA Meets European Spatial Planning School and Bloomington School

In polycentric governance, we are interested in a policy actor's degree of connectedness to the system. In other words, since polycentrism is a scalable concept, our basic unit of analysis is the policy actor, but not the entire region occupied by multiple policy actors. We can then scale a policy actor's degree of connectedness (polycentric index) to the sub-group (e.g. market polycentrism or political polycentrism) and to the overall group (combination of all sub-group polycentrisms). This approach adopts a methodological logic akin to the bottom-up approach of analyzing urban systems (Coombes, Green, & Openshaw, 1986; Davoudi, 2008). Vasanen (2012) used such a logical approach to compute the connectivity of individual centers to the whole urban system. Privileging the policy actor, not the entire region occupied by multiple policy actors, is based on Polanyi's (1951) argument for the connectivity and autonomy of individuals within a polycentric organization (see also V. Ostrom, 2002, p. 440). In other words, a policy actor's polycentric index represents an individual's maximum level of connectedness within a polycentric organization without compromising the policy actor's autonomy. We will explore what this further by drawing on the literature on social-ecological network analysis (SENA) framework, complemented by the work of McGinnis (2005, 2015) and Hooghe and Marks (2001; 2003).

SENA helps to address the central features of polycentric governance—multi-scale and multi-type/multi-sector (McGinnis, 2005)—by connecting social and ecological units in governing natural resources (Bodin & Crona, 2009; Sayles, 2015). SENA has been used,

both conceptually and empirically, to investigate scale or social-ecological mismatch⁷ within multi-ecological units (Bergsten et al., 2014; Rathwell & Peterson, 2012; Sayles, 2015). We can think of social-ecological scale-mismatch as the misfits or incongruences between governing boundaries and natural resources systems as a result of the multiplicity of institutional arrangements often involved in governing coupled social-ecological systems like urban water resources (Crowder et al., 2006; Folke et al., 2007; Sayles, 2015). Examining social-ecological mismatch within the Puget Sound watershed, WA, U.S.A., Sayles (2015) built a SENA framework for multi-level governance.

Two node types are needed to build a SENA framework—social nodes, and ecological nodes. Social nodes generally refer to the policy actors (individuals or institutions) involved in governing the natural resource system. In a multi-level governance framework, these social nodes are classified into local nodes and higher-scale nodes (regional nodes). These regional nodes operate at the regional, state and federal/national policy levels. Although these higher order nodes implicitly imply jurisdictional hierarchy in the social-ecological system (Ernstson, Barthel, Andersson, & Borgström, 2010; Rathwell & Peterson, 2012), the multi-level SENA framework defines these nodes based on the spatial extent within which these organizations work (Sayles, 2015). The work of these higher order nodes spatially overlaps the ecological nodes. For example, the U.S. Bureau of Reclamation (USBR) and U.S. Army Corps of Engineers (USACE) may work respectively in the Valencia Soil and Water Conservation District (VSWCD) and the Santa Fe Soil and Water Conservation District (SSWCD) in New Mexico. But the work of the USBR and the USACE are not spatially restricted to only these two soil and water

⁷ Scale-mismatch and socio-ecological scale mismatch are used interchangeably throughout this paper.

conservation districts, hence, we designate these two social nodes as regional nodes not based on hierarchy but based on the spatial extent of their operation. In simple terms, regional social nodes are connected to more than one ecological node while local social nodes are connected to only one ecological node.

This distinction between hierarchy and spatial extent is very important in polycentric governance because it clarified the debate between McGinnis (2015) and Hooghe and Marks (2001; 2003). Hooghe and Marks (2001, 2003) define two institutional arrangements—Type I and Type II institutional arrangements. Type I institutions offer a neat model of federalism where multipurpose governance units are arranged in a hierarchy with non-overlapping jurisdictions. Type II consists of an institutional arrangement of special purpose governance agencies that are cross-jurisdiction (e.g. water districts). These cross-jurisdictional multi-purpose governance units are established to “fill in the gaps” that often open up in the Type I institutional arrangement (McGinnis, 2015, p. 7). Although it could be analytically useful to categorize institutions as being either Type I or Type II institution, McGinnis (2005) averred that these categories ignore a system-level (polycentric) analysis of institutional arrangements (V. Ostrom, 2002); and therefore, fail to capture how policy networks develop based on multiple contacts among different organizations at different governing scales and within different sectors. So far, our discussion of social and ecological nodes under SENA has touched on the multiple governing scale aspect of polycentrism without addressing the multiple sectors aspect. Later, we will modify the SENA framework to include the different sectors aspect of polycentrism.

The ecological nodes are both spatial and aspatial jurisdictional designation—that is, in coupled social-ecological systems like urban water resources, an ecological boundary should consider both the natural watershed and the administrative boundaries. However, previous studies have only looked at the spatial jurisdictional designation (i.e. natural watershed or forest boundary) of these ecological nodes. For instance, Sayles (2015) defined the ecological nodes based on the small watershed boundaries in the Puget Sound watershed—these boundaries are classified as the HUC 10 boundary level by the U.S. Geological Survey. Again, Bodin and Tengö (2012) define the ecological nodes based on the boundary of forest patches within a rural village in Madagascar. In the U.S. context, however, the Soil and Water Conservation District (SWCD) is one such ecological unit that aligns the natural watershed and administrative boundaries. Therefore, the SWCDs will serve as the ecological nodes in this discussion.

The two node types—social and ecological—serve as the basis to assess whether policy actors (local or regional nodes) classified under the various ecological units have ties or edges that help to address the social-ecological scale-mismatch within the system. These ties or “scale bridging edges” are classified into three types—local-local edges (between two local nodes within different ecological units), local-regional edges (between a local node and a regional node), and regional-regional edges (between two regional nodes) (Sayles, 2015). These three edges show the extent to which different social nodes bridge the social-ecological scale-mismatch within a polycentric governance system. Multiple configurations of these scale-mismatch bridging edges/ties (**SMBEs**) could exist within a given network system, which could point to the existence of polycentrism within monocentricity and vice versa (McGinnis, 1999; V. Ostrom, 1999[1972]). For instance, a

network with many local-local, local-regional, and regional-regional edges indicates that social-ecological scale-mismatch is occurring at both local and regional levels even while these levels are connected. This configuration implies a high-degree of functional polycentric governance, but it does not preclude some degree of—albeit minimal—monocentric configurations within the network (e.g. instances where some local and/or regional social nodes are isolated or have few edges). We will therefore formulate another rule for functional polycentric governance:

Rule 3: In a functional polycentric governance system, there must exist at least two node types—social nodes (local and regional) situated within at least two ecological nodes/units—to allow for at least three basic node-edge configurations to bridge scale-mismatch—local-local, local-regional, and regional-regional.

It should be noted that the local-local edge between two local social nodes within the same ecological unit is not a scale bridging edge under the SENA framework; hence, it is excluded from the analysis (see also Sayles, 2015). This has two interrelated implications: 1) In a SENA framework with 8 social nodes for instance, the maximum edges possible within the network are less than that expected in a regular network with eight nodes; and 2) social nodes do not have to be connected to everyone to have a perfectly connected system because local-local edges within the same ecological unit are excluded in the computation. These implications, especially the second, offers a methodological avenue to illustrate Polanyi's (1951) argument that some level of individual autonomy is needed in polycentrism (see also V. Ostrom, 2002).

For instance, assume an eight-node network—4 local social nodes (S_{ALN1} , S_{ANL2} , S_{BNL3} , S_{BNL4}), 2 regional social nodes (R_1 and R_2) and 2 ecological units (A and B).

Regional nodes R_1 and R_2 have cross-jurisdictional working operations within ecological units A and B. Local social nodes S_{ANL1} and S_{ANL2} are functionally connected to (operate within) ecological unit A, and local social nodes S_{BNL3} and S_{BNL4} operate within ecological unit B. Local social node S_{ANL1} has a perfect functional connection within this network if it is connected to S_{ANL2} , S_{BNL3} , and S_{BNL4} (perfect local-local SMBEs) and R_1 and R_2 (perfect local-regional scale-mismatch bridging ties). In methodological terms, if we conceptualize autonomy narrowly as a local social node's ability to function while not being connected to one of the possible connections within the system, then, A_1 is not autonomous in the above instance. However, as explained earlier, the SENA framework excludes edges between social nodes within the same ecological units (i.e. an edge between S_{ANL1} , and S_{ANL2} in this example). Hence, S_{ANL2} could still have a perfect connection within the network (connecting to S_{BNL3} , S_{BNL4} , R_1 , and R_2) while having some level of autonomy (not having a connection to S_{ANL2}). We will capture this autonomy argument in this additional rule:

Rule 4: In a functional polycentric governance system with perfect functional connections, the maximum edges possible to bridge scale-mismatch within the network are less than what's expected in a regular network (Expected SMBEs $< \frac{n^2-n}{2}$, where n = social nodes) to allow local social nodes to have some degree of autonomy.

We will further modify the SENA framework to operationalize functional polycentric governance by incorporating into it the multi-sector nature of polycentric governance highlighted by McGinnis (2005) and the Polanyi-Bloomington School in general. In functional polycentric governance, we are interested in both the multi-scaling

and the multi-sectoral nature of functional connections among social nodes (McGinnis, 2005). The SENA framework categorizes these social nodes based on scale (local-regional) but it does not categorize them according to their sectors of operations—e.g. political, market, and nonprofit social nodes. The relevance of this sector-based categorization lies in the argument that polycentric governance is about multiple organizations operating within different sectors (Aligica & Tarko, 2012; McGinnis, 2005; V. Ostrom, 1999[1972]). These multiple sectors constitute themselves as “islands of polycentric order” (e.g. market and political polycentric orders) that nonetheless influence each other (Aligica & Tarko, 2012, p. 247). For instance, we can think of market polycentrism or polycentric order within the SENA framework as constituted by political social nodes with SMBEs within different ecological units. We could represent the multi-sector argument of polycentrism as our final rule:

Rule 5: In a functional polycentric governance system, social nodes constitute more than one island of polycentric order within which social nodes form SMBEs.

2.6 Mapping the Multidimensionality of Polycentric Water Governance

Figure 2.3 below presents a conceptual mapping of polycentric water governance by integrating the five rules earlier discussed. It essentially incorporates the multi-sector and multi-scale argument of polycentrism into the SENA framework. We will increase our hypothetical eight-node network example above to a network of 13 nodes to explain the five rules discussed above. Here, the local (S_{ALN1} , S_{ANL2} , S_{ANL3} , S_{ANL4} , S_{BLN1} , S_{BNL2} , S_{BNL3} , S_{BNL4}) and regional (R_1 , R_2 , and R_3) social nodes are categorized according to their organizational types such as political nodes, market (business) nodes, and nonprofit nodes. We will restrict ourselves to these three sectors in this paper. These social nodes and their

functional linkages shown in Figure 2.3 below satisfy the first and second rules: there must exist multiple policy actors with functional linkages between them within specified policy and territorial spaces.

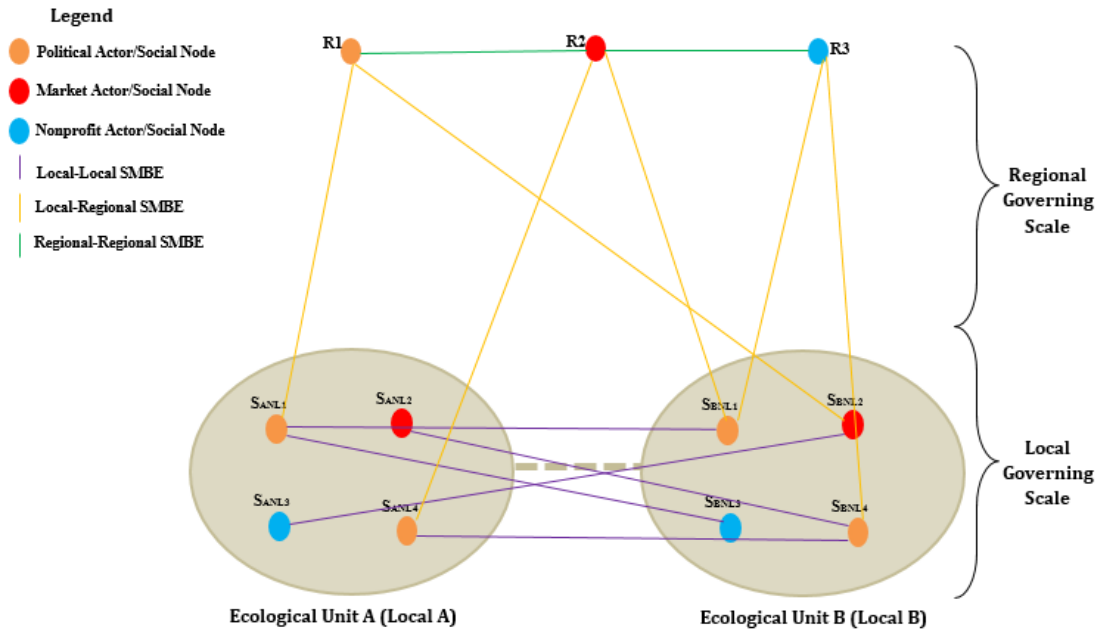


Figure 2.3: Conceptual Mapping of Functional Polycentric Governance

The third rule is also satisfied because these social nodes are functionally connected to (operate within) two ecological units—ecological units A and B. This allows for the three node-edge configurations—local-local, local-regional, and regional-regional—stipulated in the third rule. The fourth rule states that the maximum edges expected in a perfectly connected (perfect polycentric governance system) is less than what’s expected in a regular network. This is also satisfied because there are no edges between two local social nodes within the same ecological unit (e.g. S_{ANL1} and S_{ANL2} or S_{BNL1} and S_{BNL2}). Finally, categorizing the social nodes as political, economic/market, and nonprofit nodes

helps to constitute these social nodes into three islands of polycentric order (political, economic/market, and nonprofit polycentric orders).

2.7 Conclusion

This paper sought to excavate the conceptual pillars to study the polycentricity of the urban water commons. A brief context of water governance in the U.S. is first provided. The context of U.S. water governance portrays the involvement of multiple political-economic and administrative systems constituted by overlapping institutional arrangements—polycentric governance, public participation, experimentation, and bioregional approach (Huitema et al., 2009). The paper then zooms in on what constitutes the polycentricity of governing social-ecological systems (e.g. urban water resources) since polycentrism is regarded in the literature as a key governing characteristic of coupled social-ecological systems (Berardo & Lubell, 2016; Dietz et al., 2008; Folke et al., 2005; Lundqvist, 2004). Here, the historical-theoretical contours of polycentric governance is mapped to present the debate between the MGA and Bloomington School scholars on what is an optimum institutional arrangement. From this historical-theoretical landscape, the paper surmises that 1) polycentricity is not the antithesis of monocentricity, 2) polycentricity involves the co-constitution of actors at multiple governing scales within multiple sectors, and 3) conceptually, the probability of having a purely polycentric or diametrically opposed (monocentric or decentralized) institutional arrangements are lesser than having a system containing elements of both.

The paper expands on the above three points to delineate five conceptual pillars, in the form of rules, constituting polycentric water governance in the U.S. These include 1) existence of multiple policy actors, 2) presence of functional linkages between these policy

actors, 3) policy actors comprise of social nodes embedded within ecological nodes, 4) social nodes are relatively autonomous of each other—they form ties which bridge governing scales but the maximum SMBEs for each social node is less than what's expected in a regular network, and 5) social nodes operate within multiple sectors—*islands of polycentric order*. The paper then integrates these conceptual pillars (rules) to develop a conceptual mapping of polycentric water governance. Although this conceptually mapping is restricted to the polycentricity of urban water governance in the U.S., its embodied ideas could be translated to other coupled social and ecological systems.

Two issues remain in moving forward with the ideas presented in this paper. The first relates to how to operationalize methodologically these rules (conceptual mapping) for an empirical testing of polycentric governance. Tools and methods in social network analysis could offer promising approaches to operationalize the rules methodologically. The second issue, both conceptual and empirical in nature, relates to how the operationalized rules could be used to 1) analyze whether polycentric governance is a cause or effect of other prevailing social-ecological factors, and 2) make normative claims about polycentrism. This paper synthesizes the literature on polycentrism and delineates the conceptual foundations to guide future studies in wrestling with the above and other interesting issues in the polycentricity of governing urban water resources in the U.S.

CHAPTER III: THE POLYCENTRICITY OF URBAN WATERSHED

GOVERNANCE: A METHODOLOGICAL APPROACH

3.1 Introduction

Polycentric governance is a key institutional prescription to govern and promote resilient social-ecological systems (Chaffin et al., 2014; Cosens & Williams, 2012; Folke, 2007; Folke et al., 2005). This paper brings together the theoretical efforts of polycentric governance (PG) in the political science area (e.g. Aligica & Tarko, 2012; V. Ostrom, 1999[1972]) and polycentric urban region (PUR) in the planning area (e.g. Davoudi, 2003, 2007), and develops a methodology to test empirically the polycentricity of urban watershed governance. Polycentric governance or “polycentric political system” implies the existence of multiple decision-making centers that are formally autonomous of each other and operate under certain sets of rules (Aligica & Tarko, 2012; McGinnis & Ostrom, 2012; E. Ostrom, 2010a; V. Ostrom, 1999[1972]). Polycentric urban region considers a spatial network of functionally interconnected settlements (Burger & Meijers, 2012; Green, 2007; Hall & Pain, 2006b; Vasanen, 2012).

The empirical testing of polycentrism (the idea underlying both PG and PUR) has advanced at different paces within the literature. In the 1970s, 1980s, and 1990s especially, scholars from the Bloomington School of Political Economy (Vincent and Elinor Ostrom, and their associates) provided rigorous empirical support for PG. For instance, numerous studies on public service delivery (e.g. police protection services) in U.S. urban and rural areas support the argument that a mix of institutions (small- and medium-sized), through intergovernmental arrangements, are effective in public service delivery (McGinnis, 1999; E. Ostrom et al., 1978; V. Ostrom, 2008a, 2008b).

Since the early 2000s, spatial planners and analysts have increasingly studied the interconnectedness of European cities using innovative and theoretically-grounded analytical methods such as agent-based models and social network theory and analysis (Batty, 2001a, 2001b; Governa & Salone, 2005; Meijers, 2005; Parr, 2004). Particularly, the EU-funded POLYNET project (Hall & Pain, 2006b), marked a significant juncture in the spatial analysis of polycentrism. From this project, Green's (2007) seminal paper on 'Functional Polycentricity' borrowed from the literature on social network theory and analysis (Wasserman & Faust, 1994) to develop a theoretically-grounded method in analyzing networked European cities (i.e. polycentric urban regions). Burger and Meijers (2012) and Vasanen (2012) have also explored the social network theory and analysis dimension to spatial polycentricity.

This chapter is built upon the existing literature and explores a social network theory and analysis dimension of PG. The paper studies the polycentricity of urban water governance using the Middle Rio Grande (MRG) urban watershed in New Mexico, USA, as the case study. Specifically, it develops three sub-indices and an overall index of

polycentricity to: 1) determine whether the governance of the MRG could be characterized as a polycentric governance system; 2) examine whether actors operating within different sectors (e.g. political, economic/market, and nonprofit sectors) in a polycentric governance system—what Aligica and Tarko (2012) refer to as “islands of polycentric orders”—do or do not influence each other, and 3) establish the relationships between the polycentric indices and other network graph statistics and discuss what these relationships mean to the study of polycentric water governance.

3.2 Mapping the Theoretical Landscape of Polycentricity in Urban Water Governance

The ‘theory of polycentrism’ has been explicated extensively in the literature (e.g. Aligica & Tarko, 2012; McGinnis, 1999, 2015; E. Ostrom, 2010a; V. Ostrom, 1999[1972]). This section will not recapitulate the discussions and contestations in the literature. The goal here is briefly excavate the theoretical pillars to guide the methodological enactment of polycentrism in governing urban watersheds. In other words, what does it mean, theoretically and empirically, to describe the governance of social-ecological systems as polycentric?

3.2.1 Polycentricity as the Multiplicity and Functional Connectivity of Actors

Polycentricity implies the collective functioning of multiple, linked equipotent centers. To avoid cooperation paralysis, as Polanyi (1951) argued, the Pareto optimum outcome is achieved through a trial-and-error evolutionary process as multiple autonomous decision-making centers (e.g. individuals and organizations) interact freely (see also E. Ostrom, 2005). Without going in-depth into the philosophical exegesis of polycentrism (see in-depth discussion in works like Aligica, 2014; Aligica & Tarko, 2012), the

discussion here points two foundational premises about polycentricity: 1) free, autonomous, and/ or ‘equally powerful’ entities (individuals, organizations/firms, spatial centers); and 2) the interactions or linkages among these entities. These premises foreground the theoretical foundation upon which polycentricity is discussed in this paper.

Polycentricity emerges from interactions. To borrow a key logical construct of relational/post-structural geographies, e.g. actor network theory and assemblage theory (Cresswell, 2013; Farias & Bender, 2009; McFarlane, 2011; Murdoch, 2006), polycentricity could be seen as an emerging *relational space* shaped constantly by the multiplicity of actors’ interactions. To put it differently, the discourse on polycentricity can only begin upon the premise that an observed group of actors are linked/connected. For instance, in spatial planning, interactions between autonomous territorialities (e.g. cities, regions or countries) could be in the form of commuting patterns or commodity flows between places. In governance terms, we could think of interactions between organizations or actors to comprise of interorganizational exchanges in service delivery or support. Consequently, Green (2007, p. 2101) in his seminal paper proposed a “formal definition” of polycentricity as a collection of “functionally connected and balanced” cities, firms, or people (see also Hall & Pain, 2006a; Hall & Pain, 2006b).

The recognition of the functional connections between autonomous entities forces us to consider the topography and topology of polycentricity. Figure 3.1 illustrates the difference (see an alternative illustration in Green, 2007). Topography considers the physical shape formed by considering where the autonomous are located (see the left side of Figure 3.1). Topology considers the connectedness of these autonomous entities regardless of their physical location (see the right side of Figure 3.1). From the figure,

actors A, B, and C hypothetically represent the various government and nonprofit agencies working in location X. On the left side of the figure, these actors have been arranged according to where their offices are located. This is a topographical representation. On the right side of the figure, these actors have been represented to show who they are connected to (e.g. who they collaborate with in terms of technical assistance, funding, etc). They have been topologically represented because who they are connected to, not where they are located, is relevant here.

This difference between topology and topography is important for polycentric governance because the relationship between actors—e.g. federal agencies like the United States Army Corps of Engineers (USACE) and local governments—is constructed based on the exchanges (e.g. technical and financial) between them and is not about where these agencies are physically located. Therefore, the mere presence, concentration and proximity of multiple governmental and non-governmental agencies within a particular geographic space do not necessarily constitute polycentric governance. In other words polycentricity is not necessarily morphological but functional in nature (Green, 2007; Hall & Pain, 2006a, 2006b).

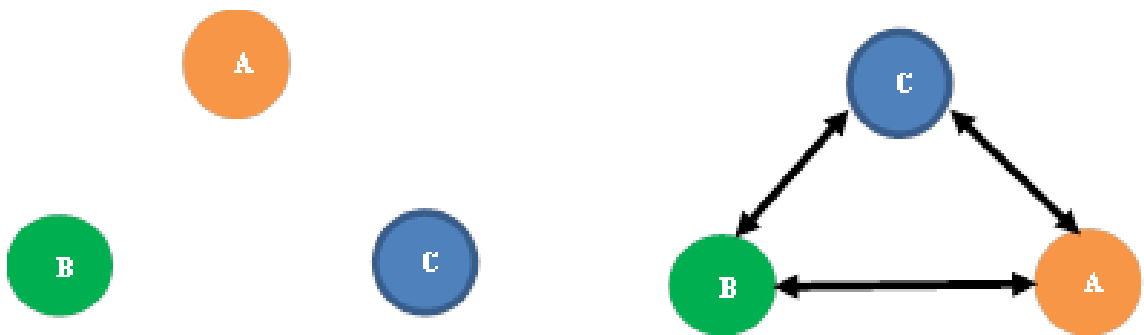


Figure 3.1: Illustrating the Topography and Topology of Polycentrism

3.2.2 Polycentricity as the Mix of Actor Types (Sectors) and Governing Scales

It is a necessary but insufficient condition to define polycentricity in terms of multiple actors and the functional connections between them. McGinnis (2005, p. 8) assert that “a polycentric system of governance is multi-level, multi-type, and multi-sector in scope” (see also E. Ostrom, 2010a, 2010b). To empirically explore this, we need to know the types of actors and the governing scale at which they operate, and the heterogeneity of an actor’s connections (i.e. an actor’s connectedness to other types of actors who operate at different governing scales).

First, the theoretical pillar of multiplicity of different types of actors relates to the argument that polycentricity is shaped by multiple “pulsating polycentric domains” (Aligica, 2014; Aligica & Tarko, 2012, p. 247). Polycentric domain/sector or “island of polycentric order” (Aligica & Tarko, 2012, p. 247) could simply been seen as the policy or decision arena in economy, law, or politics, within which multiple centers of decision making interact through competition and/or cooperation (Aligica, 2014; Aligica & Tarko, 2012; McGinnis, 2015). The interactions within and between these multiple domains (re)generate and transform the entire system to create what V. Ostrom (1999[1972], p. 57) refers to as the “polycentric order.” A polycentric order is thus defined as “where many elements are capable of making mutual adjustments for ordering their relationships with one another within a general system of rules where each element acts with independence of other elements” (V. Ostrom, 1999[1972], p. 57). Therefore, we could conceptualize polycentric governance as involving different types of actors (e.g. political, market, nonprofit, judicial) whose activities creates and recreates polycentric order within and between these polycentric domains—e.g. political polycentric order, market polycentric

order, and judicial polycentric order. The polycentric order within these polycentric domains shapes and is also shaped by the polycentric order of the entire governance system (Aligica, 2014, p. 51; McGinnis, 2015; Nagendra & Ostrom, 2012; V. Ostrom, 1999[1972]).

Second, the theoretical pillar of governing scales speaks to Ostrom's (1990, p. 90; 2005, 2010a) "nested enterprises" and its relationship to the theory of collective action. Folke et al. (2005, p. 449) note that polycentric governance involves "nested quasi-autonomous decision-making units operating at multiple scales." Polycentric governance as a nesting of enterprises is when governance activities are organized in multiple layers involving local and higher organizational levels with clearly demarcated jurisdictional boundaries (Folke et al., 2005; Lundqvist, 2004; E. Ostrom, 1990). The theory of collective action (Olson, 1965) or what E. Ostrom (1990) refers to as the Olson's Dilemma was a challenge of the group theory hypothesis. The group theory hypothesis argued that individual with a common interest will voluntarily act to pursue such an interest (Bentley, 1949; Truman, 1958). Olson (1965, p. 2), however, argued that rational, self-interested individuals will free-ride and not act to achieve their common interest unless they are coerced to do so. This logic of collective action has often driven scholars to offer two oppositional institutional prescriptions—the *coercive state (Leviathan) approach* by proponents like Ophuls (1973) and Hardin (1978) vs. the market (privatization) approach by adherents like Demsetz (1983) and Welch (1983).

The nesting of enterprises as the alternative to these two oppositional institutional prescriptions is based on two critiques. In the case of environmental problems, the empirical support for collective action theory shows mixed results regarding the free-rider

problem—some cases support the free-riding hypothesis and other cases do not (Agrawal, 2002; Poteete, Janssen, & Ostrom, 2010; Edella Schlager, Blomquist, & Tang, 1994). E. Ostrom (2010b) calls for an update of the collective action theory by revising the ‘rational theory’ of human behavior (Camerer, 2003; Fehr & Leibbrandt, 2011) to incorporate different social-ecological contexts that shape individuals’ norms and values of trust and reciprocity (Poteete et al., 2010; Rothstein, 2005). Individuals do not possess perfect information and are ‘intendedly but boundedly’ rational actors who make and correct their decisions based on experience and experimentation, and the continuous gathering and analysis of information (Cox, Friedman, & Gjerstad, 2007; E. Ostrom, 1998; Edella Schlager & Blomquist, 1996; Simon, 1955). Next, E. Ostrom (1990, 2000) debunked these oppositional institutional prescriptions by arguing that scholars 1) underestimated the ability of individuals to self-organize and self-govern, and 2) assumed that collective action dilemma could be resolved through panacea—one-size-fit-all institutional arrangement. In reality, we see a more complex nesting of enterprises—“polycentric public economies” (E. Ostrom, 2000, p. 33)—whereby large-, medium-, and small-scale institutional arrangements are necessary components of an effective governing system (E. Ostrom, 2010b, p. 552).

The complex nesting of enterprises constitutes an institutional mix of what Schneider et al. (2003) refer to as the “vertical-boundary spanning” (centralized) and “horizontal-boundary spanning” (decentralized) governing structures.⁸ These boundary spanning institutional arrangements reveal cross-jurisdictional mechanisms within a polycentric governance system: 1) instances where actors operate (have offices and/or are

⁸ The vertical-boundary spanning also refers to command-and-control or adversarial institutional arrangement (Hecl, 1978; John, 1994; Weber, 1998).

solely responsible for the execution of a project) within multiple local politico-juridical or boundaries, and/or 2) instances where actors are connected to other actors in different localities. In both instances, we see a complex matrix of relationships involving nonlocal (e.g. state or federal) and local actors (vertical-boundary spanning), and local-local and nonlocal-nonlocal actors (see also Pahl-Wostl & Knieper, 2014). Polycentric governance as an integrative matrix of institutional relationships is sustainable because these institutions offer complementary support: 1) vertical-boundary spanning (hierarchical) institutional arrangement provides less costly avenue for monitoring collective agreements and conflict resolution among actors especially in large social-ecological systems, and 2) horizontal-boundary spanning (decentralized) institutional arrangement ensures self-governance, collective-choice arrangements, and congruence between appropriation and provision rules especially in small- and medium-sized social-ecological systems (McGinnis, 2005; E. Ostrom, 1990, 2005, 2010a).

The complementary support provided by the mixed of institutional arrangement in a polycentric governance system is also explored by Sarker (2013) using a concept he refers to as the “state-reinforced self-governance” (see also DeCaro, Chaffin, Schlager, Garmestani, & Ruhl, forthcoming). The next sub-section of the paper uses the social-ecological network approach (SENA) framework to synthesize the above-discussed theoretical pillars of polycentrism multiplicity of actors and functional connectivity, and mix of actor types (sector) and governing scales. This synthesis will be used to engage a methodological approach in studying the polycentricity of urban water governance by constructing polycentric governance indices.

3.3 (Re) Casting the Theoretical Pillars of Polycentric Governance within the SENA Framework: Synthesis and Methodological Approach

3.3.1 Synthesizes of the Theoretical Pillars through the SENA Framework

The social-ecological network analysis (SENA) framework examines spatial mismatch or spatial fit in environmental governance—the incongruences between governance boundaries and natural resource systems (Cumming, Bodin, Ernstson, & Elmqvist, 2010; Cumming, Cumming, & Redman, 2006; Gunderson & Holling, 2002; Sayles, 2015). The misalignment between the scale of ecological processes and the scale of institutions contributes to the mismanagement of natural resources and also affects the resilience of both human and ecological systems (Bodin, Crona, Thyresson, Golz, & Tengö, 2014; Cumming et al., 2006; Folke et al., 2007). Cumming et al. (2006) have identified three forms of scale mismatches: spatial mismatch (misalignment between the spatial scales of management and ecosystem processes); temporal mismatch (misalignment between the temporal scales of management and ecosystem processes); and functional mismatch (misalignment between the functions of management such as consumption and the functions of ecosystems).

This paper considers spatial scale mismatch. Henceforth the use of scale mismatch refers to spatial mismatch. Spatial mismatch manifests in ways such as when upstream and downstream water management and land use control cannot be achieved due to the absence of a large governance boundary to manage the entire watershed, and, conversely, when the governance boundary of a watershed is too large and hence disrupts local self-governance, collective-choice arrangements, and congruence between appropriation and provision rules (Sabatier, Foucht, Lubell, Trachtenberg, & M. Matlock, 2005; Sayles, 2015). These two

oppositional manifestations highlight the polycentric governance dilemma: how are institutional enterprises nested through vertical- and horizontal-boundary spanning connections between actors to bridge scale mismatches (i.e. realign the boundaries of governance and ecological processes) (see also Folke et al., 2005; Guerrero, McAllister, Corcoran, & Wilson, 2013).

This section of the paper adapts the SENA framework to weave a conceptual framework that integrates the existing discussions of polycentrism that involves multiple autonomous actors with functional connections, operating at different governing levels and within different sectors. The SENA framework analyzes the structural patterns formed in environmental governance processes as a result of the connection between social and ecological units (Bodin & Crona, 2009; Cumming et al., 2010). A key structural pattern analyzed in this paper is the emergence of polycentric governance in urban watersheds. Scale mismatch bridging edges (SMBEs), an analytical tool within the SENA framework (Bodin & Tengö, 2012; Sayles, 2015), becomes useful to analyze the structural pattern of polycentric urban water governance.

Scale mismatch bridging edges considers the multiplicity of connections between governance and ecology. An analysis of SMBEs begins with the basic analytical units within a SENA framework—social nodes (actors) and ecological nodes (the geo-political boundaries of the ecological process) (Bodin & Tengö, 2012). Social nodes are the policy actors (individuals or institutions) involved in governing ecological systems. As shown in Figure 3.2, in a multi-level governance framework, these social nodes are classified into local nodes and regional nodes. Regional nodes operate at the regional, state and federal/national policy levels and are defined based on the spatial extent within which these

organizations operate (Sayles, 2015). Based on the Figure 2, local (S_{ANL1} , S_{ANL2} , S_{ANL3} , S_{ANL4} , S_{BNL1} , S_{BNL2} , S_{BNL3} , S_{BNL4}) and regional (R_1 , R_2 , and R_3) social nodes are categorized according to their organizational types such as political nodes, market (business) nodes, and nonprofit nodes. These classified social nodes and their functional linkages respond toward the earlier discussions about theoretical pillars of polycentric governance: multiplicity of actors and functional connectivity, and mix of actor types (sector) and governing scales.

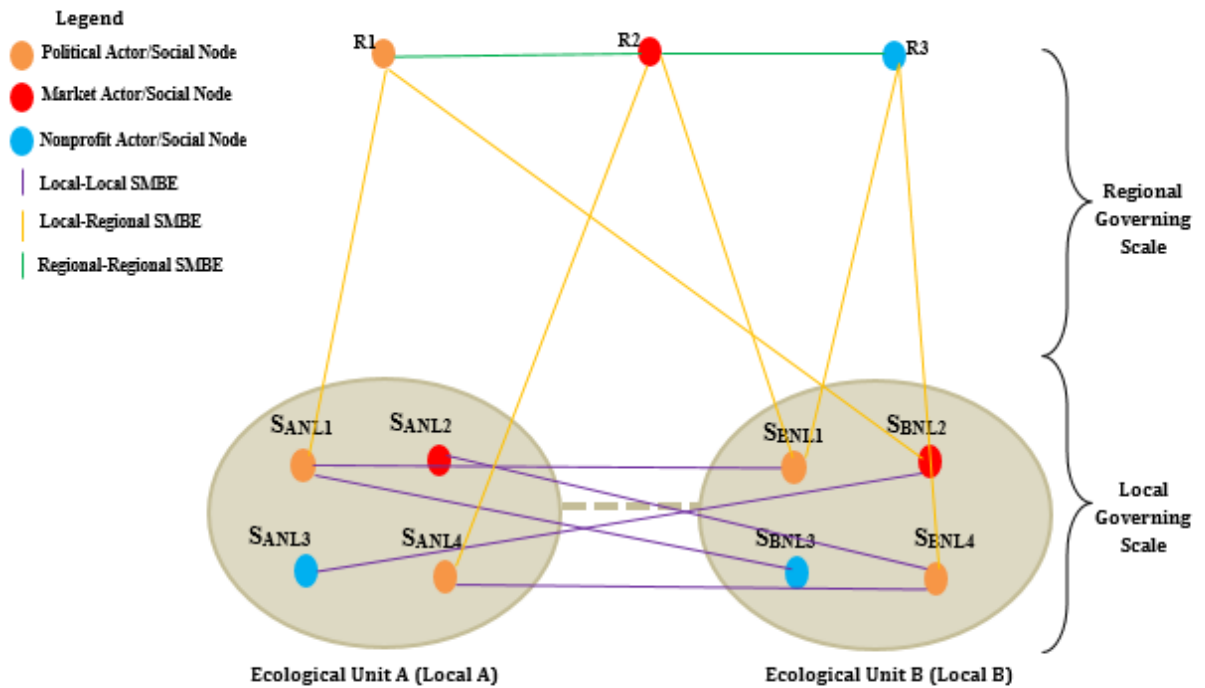


Figure 3.2: Conceptual Mapping of Polycentric Governance

The ecological nodes, shown as ecological units A and B in Figure 2, consider both the ecosystem boundary (i.e. the watershed boundary in the case of this paper) and the administrative boundaries. The Soil and Water Conservation District (SWCD) in the

United States is one such ecological unit that aligns the natural watershed and administrative boundaries.

The two node types—social and ecological—form three node-edge configurations— local-local, local-regional (we can also have regional-local based on the direction of the connection), and regional-regional. These node-edge configurations or scale mismatch bridging edges (**SMBEs**) show the extent to which different social nodes connect to different actors within different localities and at different governing scales. The SENA framework has two key analytical advantages for analyzing the polycentricity of a governing system.

Firstly, node-edge connection between two local social nodes within the same ecological unit is excluded from the analysis because it is not considered a SMBE (see also Sayles, 2015). This means that the maximum edges needed by a social node to connect bridge scale mismatches (perfect scale-bridging connections) within a network are less than what's expected in a regular network (Expected SMBEs $< \frac{n^2-n}{2}$, where $n =$ social nodes). To put it simply, actors do not have to be connected to everyone to have a perfectly connected system (i.e. network where actors have all the expected SMBEs). This offers a methodological avenue to illustrate, albeit narrow and simplistic, Polanyi's (1951) argument that some level of individual autonomy is needed in polycentrism. For instance, in Figure 2, for local social node S_{ALN1} to have a perfect functional connection within this network it needs to form SMBEs to S_{BNL1} , S_{BNL2} , S_{BNL3} , and S_{BNL4} (perfect local-local SMBEs) and R_1 and R_2 (perfect local-regional scale mismatch bridging ties). Hence, S_{ANL1} could still have a perfect connection within the network (connecting to actors in ecological

unit B and regional actors) while having some level of autonomy in this system (not having a connection to actors in ecological unit A).

Second, the SENA framework helps us determine an actor's connectivity (aggregate SMBEs) within the islands of polycentric order (political, market and nonprofit) and within the entire governance system. In other words, since polycentrism is a scalable concept, our basic unit of analysis is the actor. We can measure an actor's degree of connectedness by induces (e.g. political polycentric index, market polycentric index, nonprofit polycentric index, and overall functional polycentric governance index index). This approach adopts a methodological logic akin to the bottom-up approach of analyzing urban systems (Coombes et al., 1986; Davoudi, 2008). Vasanen (2012) used such a logic approach to compute the connectivity of individual centers to the whole urban system. The conceptual basis for privileging actor level over a system level functional polycentric governance index is based on Polanyi's (1951) argument that a polycentric organization implies the connectivity of individuals without comprising their autonomy (see also V. Ostrom, 2002, p. 440). In other words, an actor's overall polycentric index (functional polycentric governance index), represents its maximum level of connectedness within a polycentric organization without compromising its autonomy. The next section builds on this idea to develop an actor's polycentric indices—political polycentric index (PPI), market polycentric index (MI), nonprofit polycentric index (NPI), an overall functional polycentric governance index (FPGI).

3.3.2 Constructing Polycentric Governance Index

We will construct three sector specific indices and an overall index of polycentricity (FPGI). We have to first identify a network or a graph of multiple nodes connected to each other. These nodes are the policy actors involved in governing an urban watershed. These nodes can be classified into two groups—ecological nodes and social nodes. The ecological nodes are those policy actors representing the geo-political boundaries of the urban watershed, such as soil and water conservation districts (SWCDs). The social nodes are the other policy actors in the network. Next, we group the social nodes connected to only one ecological node as local social nodes, and those connected to multiple ecological nodes as regional social nodes. For example, a nonprofit organization located within a SWCD is a local social node, and the EPA is a regional social node. Local social nodes are further grouped according to their corresponding ecological units. For example, local 1 refers to all social nodes connected to ecological unit 1. All the regional social nodes belong to the same category. We further classify social nodes according to their type of institution—political, market, or nonprofit—for both local and regional nodes. The above steps are summarized in the following representations:

i: Index of local social nodes;

j: Index of regional social nodes; and

k: Index of sector (=1, for political sector; =2, for market sector; =3, for nonprofit sector).

After identifying the network and classifying the social (actors) and ecological nodes, we can define scale mismatch bridging edges (*SMBEs*) and use that to compute the four indices. Four groups of *SMBEs* are defined as:

LLP_i^k : Local-local type- k *SMBE* for the local social node i = The number of links between local social node i and all the local type- k social nodes in the other ecological units;

LRP_i^k : Local-regional type- k *SMBE* for the local social node i = The number of links between each of the local social nodes and all the regional type- k social nodes;

RRP_j^k : Regional-regional type- k *SMBE* for the regional social node i =The number of links between regional node j and other regional type- k social nodes; and

RLP_j^k : Regional-local type- k *SMBE* for regional social node i =The number of links between regional node j and other local type- k social nodes;

With the above *SMBEs* defined, we calculate political, market, and nonprofit polycentric indices for a local social node i ($PI_i^1, PI_i^2, and PI_i^3$) and for a regional social node j ($PI_j^1, PI_j^2, and PI_j^3$) using equations 1 and 2 below:

$$PI_i^k = \frac{\text{Actual Total } LLP_i^k \text{ and } LRP_i^k}{\text{Expected Total } LLP_i^k \text{ and } LRP_i^k} \quad (1)$$

$$PI_j^k = \frac{\text{Actual Total } RRP_j^k \text{ and } RLP_j^k}{\text{Expected Total } RRP_j^k \text{ and } RLP_j^k} \quad (2)$$

We calculate the *FPGI* for a local social node i ($FPGI_i$) and for a regional social node j ($FPGI_j$) using equations 3 and 4 below:

$$FPGI_i = \frac{\sum_{k=1}^3 \text{Actual Total } LLP_i^k \text{ and } LRP_i^k}{\sum_{k=1}^3 \text{Expected Total } LLP_i^k \text{ and } LRP_i^k} \quad (3)$$

$$FPGI_j = \frac{\sum_{k=1}^3 \text{Actual Total } RRP_j^k \text{ and } RLP_j^k}{\sum_{k=1}^3 \text{Expected Total } RRP_j^k \text{ and } RLP_j^k} \quad (4)$$

An index is expected to vary between 0 and 1, with higher value indicating higher level of polycentricism.

3.4 Case Study of the Middle Rio Grande (MRG) Urban Watershed, New Mexico

We use the MRG urban watershed to test the proposed methodological approach of functional polycentric governance. The Middle Rio Grande (MRG) watershed or basin is located in central New Mexico (NM) and covers approximately 3,060 square miles. The MRG watershed is part of the Rio Grande River, which is over 1,900 miles long, and flows from the San Juan Mountains, near Creede, CO into the Gulf of Mexico. The Rio Grande River forms the border between Mexico and Texas, which makes it a “successive and contiguous” international and national watercourse (Benson, Llewellyn, Morrison, & Stone, 2014, p. 201). The MRG extends from the Cochiti Dam to the Elephant Butte Reservoir in central New Mexico (see Figure 3.3 below). It encompasses nine soil and watershed districts— Valencia SWCD, Ciudad SWCD, Socorro, SWCD, Santa Fe-Pojoaque SWCD, Sierra SWCD, Coronado SWCD, Claunch-Pinto SWCD, Doña Ana SWCD, and Lava SWCD—all spanning seven main counties—Santa Fe, Sandoval, Bernalillo, Valencia, Socorro, Tarrant, and Cibola. It is also home to six Native American pueblos—Cochiti, San Felipe, Santo Domingo, Santa Ana, Sandia, and Isleta.

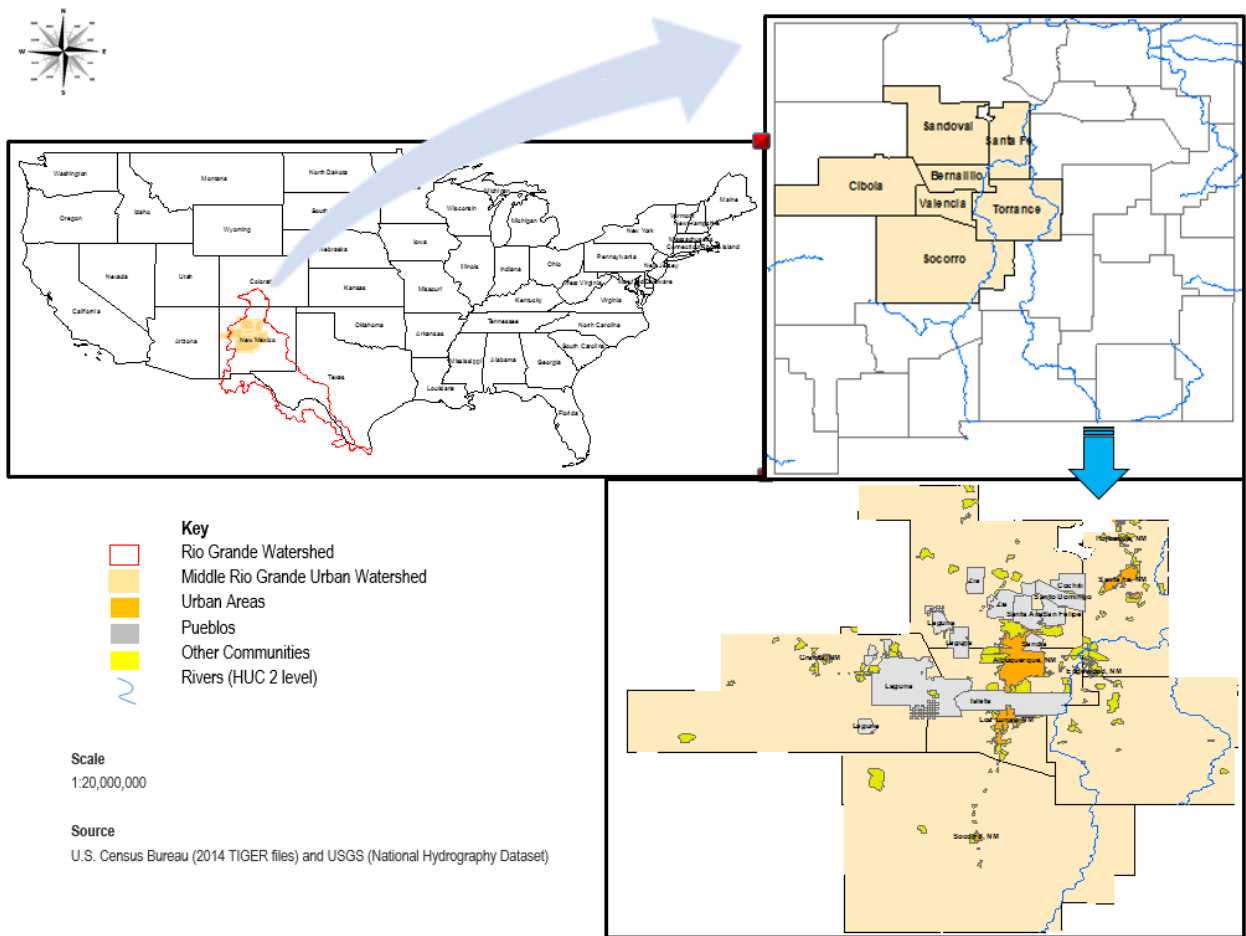


Figure 3.3: The MRG Urban Watershed in Context

The MRG urban watershed is ideal to study polycentric water governance. The MRG involves multiple inter-state compacts such as the: Animas-La Plata Project Compact (1968), Canadian River Compact (1950), Colorado River Compact (1922), Costilla Creek Compact (1946), La Plata River Compact (1925), Pecos River Compact (1948) Rio Grande Compact (1939), and the Upper Colorado River Basin Compact (1949) (Buynak & Oglesby, 2014). Benson et al. (2014) note that the multi-jurisdictional nature of this water commons and the extensive amount of public lands in this area have led to the presence of many policy actors, especially federal and state government agencies, within the Rio Grande and its associated watersheds like the MRG. Table 3.1 presents some of the policy

actors and their interests/roles in the governance of the Rio Grande and its associated watersheds like the MRG). Some scholars have characterized this watershed as experiencing a “rigidity trap;” that is, these actors “become highly connected, self-reinforcing, and inflexible” (Benson et al., 2014, p. 223; Carpenter & Brock, 2008). This is partly because of the high presence of multiple internal and external actors (e.g. federal and state actors) and legal agreements. This suggests hierarchy (monocentricity) in governing the MRG urban watershed. However, as E. Ostrom (2000, 2010b) notes, monocentric governance does not negate the presence of polycentricity within a governign system. A predominantly polycentric governance system may contain elements of monocentric government and vice versa (McGinnis, 1999, p. 52; V. Ostrom, 1999[1972]). The methodological approach developed in this paper will empirically test whether the MRG has monocentric governing system with elements of polycentricity.

Table 3.1: The Interests of some Federal, State, and Local Players in Governing the MRG

Policy Actor	Type	Interest/Responsibility
The International Boundary and Water Commission	International	Interest in ensuring the implementation of the treaty between the United States and Mexico in the use of the Rio Grande
US, Canada and Mexico	National	Interested in securing their water rights granted in the various compacts governing the Rio Grande
States like Colorado, New Mexico, and Texas	U.S. States	Interested in securing their assigned apportionment of water from the Rio Grande
U.S. Army Corps of Engineers (USACE)	Federal Agency	Interested in fulfilling its mandates related to flood control operations through projects like dam construction in the MRG (Abiquiu and Cochiti reservoirs)
Bureau of Reclamation (USBOR)	Federal Agency	Interested in fulfilling its mandates related to operating the two water storage and delivery projects in the MRG (the Chama and El Vado Reservoir projects)
U.S. Fish and Wildlife Service (USFWS)	Federal Agency	Interested in the implementation and enforcement of the Endangered Species Act (ESA)
U.S. Forest Service (USFS)	Federal Agency	Interested in managing most of the public lands in the upland forest areas upstream of the MRG
Bureau of Indian Affairs (USBIA)	Federal Agency	Interested in ensuring that the pueblo communities within the MRG receive their allocation of water under the tribal water agreements
NM Office of the State Engineer (NM OSE)	State Agency	Interested in administering water in accordance with the prior appropriation doctrine in New Mexico

Policy Actor	Type	Interest/Responsibility
New Mexico Inter-state Stream Commission (NM ISC)	State Agency	Interested in ensuring that New Mexico obliges with and obtains its rights under the various interstate compact agreements
Cities, Counties, and Soil and Water Conservation Districts (SWCDs) such as Albuquerque City, Santa Fe City, Rio Rancho City, Bernalillo County, Sandoval County, etc.	City and county level political jurisdictions	Interested in managing the recreational open-space along the riparian corridor (the Bosque) of the Rio Grande River as well as land use management decisions and impacts on water quality and quantity in MRG
Albuquerque-Bernalillo County Water Utility Authority (ABCWUA)	City and county level political jurisdictions	Interested in drinking water projects in the MRG
Middle Rio Grande Conservancy District (MRGCD)	A quasi-municipal political subdivision	Interested in fulfilling its mandates of constructing dams and levees to drain the historic floodplain for agricultural use and to deliver water to the MRG district
Pueblo communities in MRG	Local political jurisdictions	Interested in securing their “Prior and Paramount” rights to water
Environmental Groups	National, State and local agencies	Their interests and belief vary (e.g. from water resource protection to forest conservation). However, all these interests broadly seek for the conservation of the environmental commons in the MRG.

Source: Compiled from Benson et al. (2014)

3.5 Data and Analysis

The study employed the archival snowball network sampling approach in gathering network data (Burt, 1975, 1983; Carley & Hummon, 1993; Wasserman & Faust, 1994). Over a period of six months, data on policy actors (i.e. organizations) involved in water and environmental conservation activities in the MRG as well as their collaborators within were collected using the snowball network sampling method. The snowball network sample is comprised of nominated zones—e.g. first-order zone, second-order zone, etc. (Wasserman & Faust, 1994). Figure 3.4 below illustrates how the archival-based snowball network sampling was employed in this research.

In the first step, the U.S. Environmental Protection Agency’s (EPA) databases on urban watershed collaborative partnerships served as the initial point to locate policy actors within the study area—the MRG urban watershed. For the second step, the websites of,

and archival documents (e.g. academic documents, action/strategic plan and memorandum of understandings) related to each organization (identified in *step one*) were examined to record the characteristics of these organizations—e.g. whether they are a nonprofit or government (political) organization—and their past and present project/policy/funding collaborators. Steps three and four entailed the same process utilized in step two to identify the related partners until the list was exhausted.

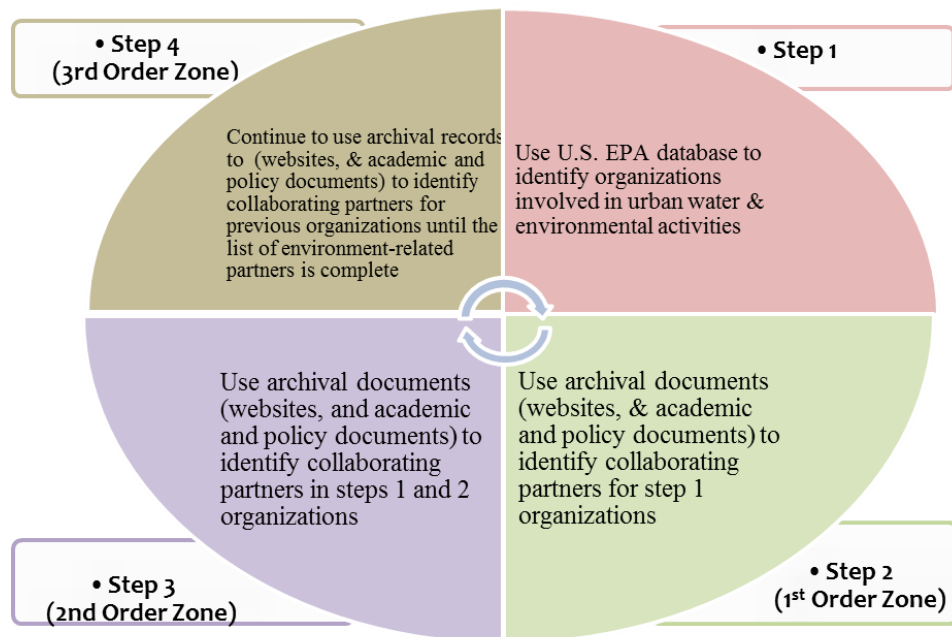


Figure 3.4: Framework for the Archival Snowball Network Sampling Used

In all, more than 700 websites and archival documents (e.g. online newspaper articles, academic documents, government documents, annual reports, grant databases, budget documents, memorandum of understandings, and action/strategic plans) were collected through this network snowball approach using google search and LexisNexis. However, the study limited itself to collaborations occurring within the past 10 years, which reduced the number of websites and archival documents analyzed to 473.

Collaboration tie/link between two actors (organizations) was measured as a non-directional relationship (cannot distinguish relationship from A to B and vice-versa). Partly informed by Lubell's (2004a) coding parameters, the presence of a collaborative tie between two actors (e.g. A and B) was determined as a yes (1) or no (0) if:

- 1) A is a project partner (or listed as a partner) of B or vice versa;
- 2) A provides financial assistance (listed as a financial donor, corporate sponsor, and/or grantor) to B or vice versa;
- 3) A and B have joint implementation agreement (JIA) and/or memorandum of understanding (MOU);
- 4) A and B share logistics and personnel (including volunteering); and
- 5) A and B have a shared permitting or regulatory activities.

The above listed were coded to analyze the websites and archival documents. The study adapted the coding scheme approach by Campbell, Quincy, Osserman, and Pedersen (2013) This coding scheme is designed to improve reliable coding of in-depth qualitative data (e.g. analyzing an entire government annual report) and also for single coder projects, especially when a single knowledgeable person in the subject matter is required to determine subtle meanings in the text being analyzed (ibid). Reliability deals with this issues of stability (i.e. do codes change over time?), accuracy (i.e. were gold standard schemes used), and reproducibility or inter-coder reliability (i.e. will different coders code the data the same way?) (Krippendorff, 2004; Popping, 2010). The use of Lubell's (2004a) coding parameters, with some few additional parameters, helped to ensure consistency in the coding (the stability issue), and also minimize inaccuracies in measuring a collaboration

tie. The few additional parameters were added based on the inputs and advice from the author's research committee members.

Multiple approaches were adopted to ensure the reliability of the data and the analysis conducted even though this was a single coder project and required a relatively simple coding approach to collect network data (i.e. absence or presence of a collaboration tie between two organizations if any of the above coding parameters were present). After developing the coding parameter, the author sampled 40 of the data records already obtained—this included 5 websites, 1 grant database, and the rest were online newspaper articles, academic papers and annual reports of some already identified organizations based on the first 1 outlined in Figure 3.4 above. The author solicited the assistance of a colleague to help assist in assessing the inter-coder reliability in analyzing the data (see also Campbell et al., 2013). Both the author and his colleague analyzed the data independently using the coding parameters.

Two interrelated errors were seen by comparing the adjacency matrix (which actors have a collaboration tie between them) obtained by the author and his colleague. A total of 21 actors were obtained in one matrix and 24 actors were obtained in the other. This evidently also affected the adjacency matrices obtained—a pair of actors had a missing collaboration tie in one matrix and not the other matrix. These errors were mainly the result of ambiguities in the organizational names (and sometimes acronyms) as well as duplicates in the list of organizations because some data records used a department or project to represent a larger organization while other data records used the name of the large organization. For example, sometimes Bosque del Apache National Wildlife Refuge and Friends of Bosque del Apache were used interchangeably even though the former is a

project by the U.S. Fish and Wildlife Service and the latter is a nonprofit group established to support the project.

These errors were remedied by ensuring consistent use of organization names and acronyms. Again, even though the use of the NVivo qualitative data software made it easier to code and analyze the 40 sample of data records, it also made it easier to catch some of these and other potential errors. Hence, since the coding parameters were relatively simple and easy to use, and most of the data records involved looking at a specific part of an organization's website (e.g. finding the "corporate sponsor" or "partners" section on the website), the author analyzed the data manually to help reduce the above mentioned and other potential errors that could have been missed by using NVivo.

The data was prepared, analyzed (e.g. network clustering and centrality analysis, and bivariate and multivariate regression analysis) and presented using multiple software programs including R and its network analysis packages such as the sna and statnet suites in R (Butts, 2008; Handcock, Hunter, Butts, Goodreau, & Morris, 2003), and the Cytoscape software (Shannon et al., 2003). The preliminary analyses were compared with both published (some have been cited in the chapter) and unpublished scholarly works to have a general sense of potential inaccuracies. These preliminary analyses were also shared with a researcher who has studied this site to also determine potential inaccuracies.

3.6 Results and Discussion

The network data collected constitute political, market, and nonprofit actors or social nodes involved in governing the MRG urban watershed. Figure 3.5 presents the network graph of the MRG urban watershed governance. These are nine soil and water conservation districts (ecological units/nodes), 82 local social nodes (actors who operate within one

ecological unit), and 109 regional nodes (operate within more than one ecological unit). The dominance of regional nodes (57 percent of total social nodes) points to the multiplicity of multi-jurisdictional actors (e.g. federal government actors) within this urban watershed as noted by Benson et al. (2014). There are more nonprofit actors (54 percent) operating within this urban watershed, compared to 34 percent political actors and 12 percent market/business actors. These imply that characterizing the governance of this watershed as polycentric largely depends on actors/social nodes possessing more local-regional, regional-local, and regional-regional SMBEs connected to the nonprofit and political actors. Hence, the multiplicity of social nodes covering multiple ecological units alone does not make the governance of the MRG polycentric. We need to understand the SMBEs of these actors across the multiple sectors that these actors operate within.

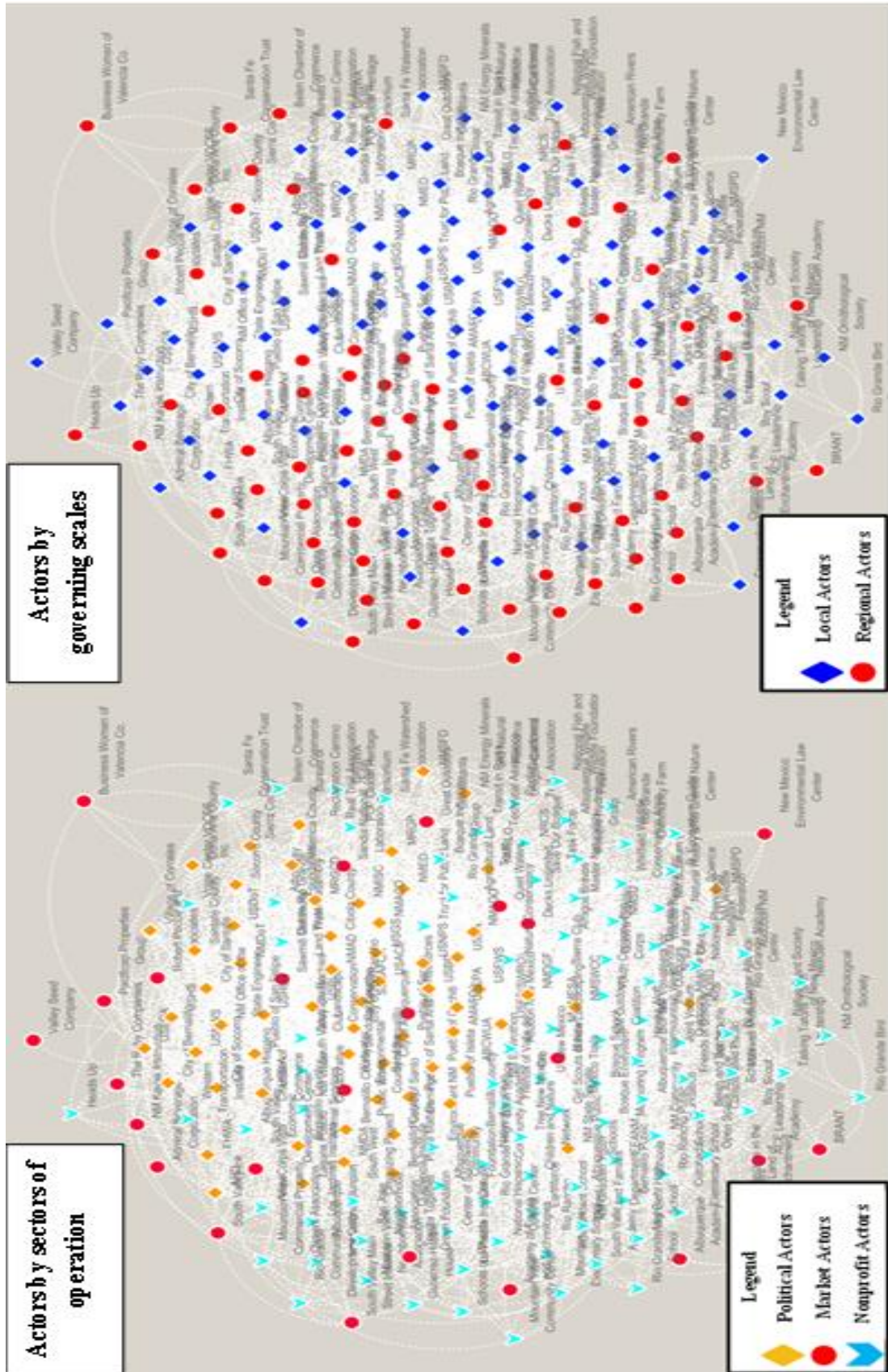


Figure 3.5: Policy Network in Governing the Middle Rio Grande Urban Watershed

3.6.1 Determining the Polycentricity of Governing the MRG

Table 3.2 below presents the descriptive statistics of the SMBEs of actors within the different sectors. Three findings are discussed from the descriptive statistics and Figures 3.6 and 3.7 below to provide empirical support that the governance of the MRG urban watershed could be characterized as largely monocentric with some minimum level of polycentricity. Firstly, polycentric governance is a multi-scale issue (McGinnis, 2005; E. Ostrom, 2000; V. Ostrom et al., 1961). On the average, actors within the MRG have more SMBEs between local and regional actors (average of 3.1 for local-regional and 4.3 for regional-local) and between regional actors (average of 2.3). This is visually represented in Figure 3.6 below. This figure presents a two-set map of the SMBEs between local and local actors and local and regional actors (the local and regional actors combines both local-regional and regional-regional SMBEs). On the maps, regional actors are located outside (non-jurisdictionally bounded western part) of the nine ecological units because these actors operate in two or more ecological units.

Table 3.2: Descriptive statistics SMBEs of actors

Scale mismatch Bridging Edge	Political Polycentric Order		Market Polycentric Order		Nonprofit Polycentric Order		Total (FPG)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Local-local	3.2	4.6	0.2	0.4	1.3	2.3	1.6	3.2
Local-Regional	4.7	5.3	0.5	1.1	4	3.8	3.1	4.2
Regional-Regional	3.8	4.8	0.2	1	2.8	4.7	2.3	4.2
Regional-Local	7.0	6.8	1	1.3	4.8	6.4	4.3	6
Total	7.8	9.2	0.7	1.4	5.3	5.1	13.8	13.7

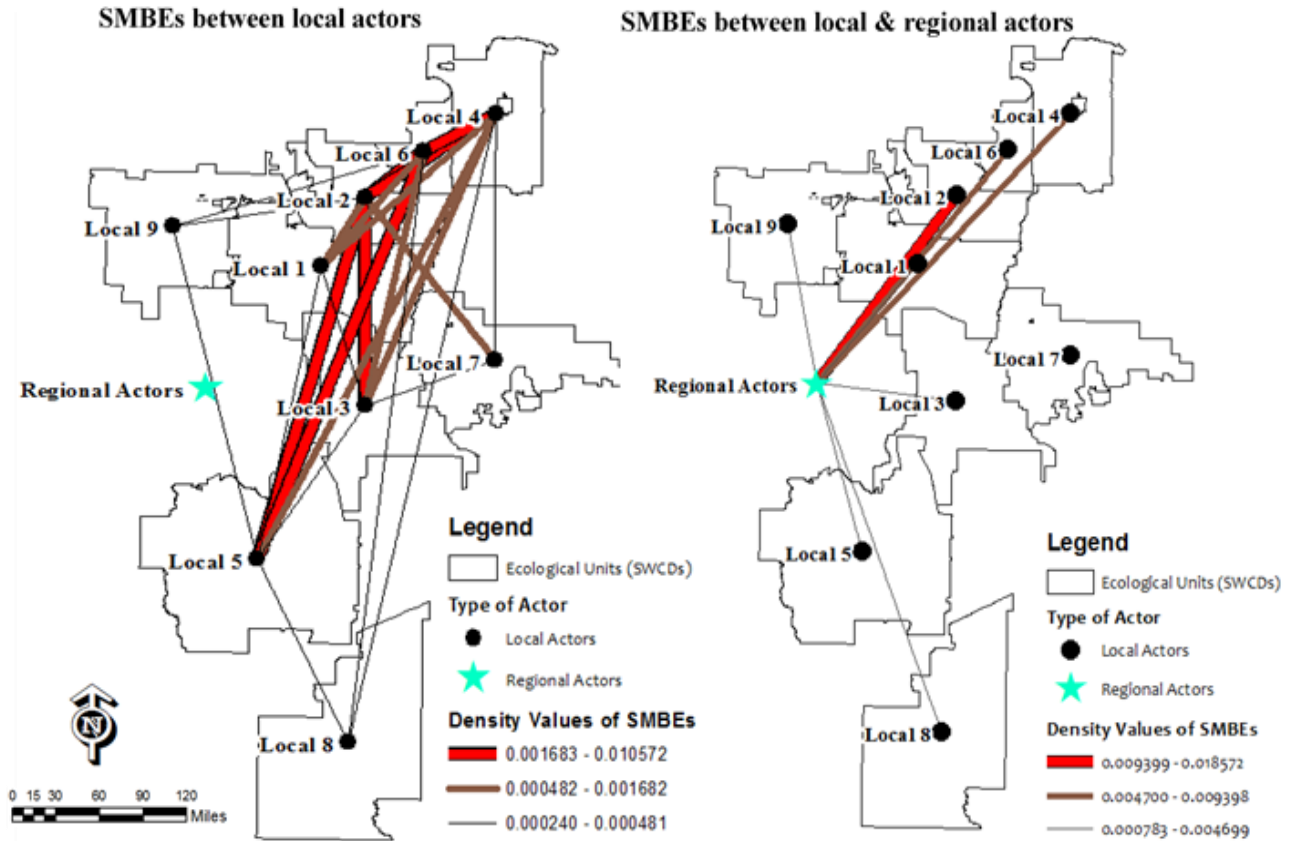


Figure 3.6: Density of SMBEs based on the governing scales of actors

The map on the left side of Figure 6 shows that the density (intensity) of local-local SMBEs is high for local 2, local 3, local 4, local 5, and local 6 actors. Most of these ecological units are within the densely populated urban centers in New Mexico (e.g. Albuquerque and Santa Fe). The MRG River also flows directly through most of these ecological units. This map, therefore, shows that local actors within these five ecological units are reaching out more to each other (high density SMBEs) in the governing of the MRG. The map on the right also shows that local 2 and regional actors are reaching out more to each other (high density SMBEs between these two actors). The local 2 ecological unit is within Albuquerque, which is the most densely populated urban center in NM.

Sayles (2015), using the SENA framework, opines that the absence (or the presence of a minimum number) of SMBEs between local and regional actors demonstrates that local and regional actors are disconnected. This means that to describe the governance of the MRG as polycentric, in addition to witnessing high density local-local SMBEs, there should also be *no disconnection* between the actors—that is, there should be observed density SMBEs between local and regional actors. From analyses and discussions above (see Table 3.2 and Figure 3.6 above) we see, albeit minimally, that 1) local actors within different ecological units are reaching out to each other, and 2) there is no disconnection between local and regional actors in governing the MRG.

Polycentric governance is also a multi-sector issue (Aligica & Tarko, 2012; McGinnis, 2015; V. Ostrom, 1999[1972]). We must consider the actors within these islands of polycentric order to identify the number of scale mismatch bridging connections formed between these actors and other actors within the network. Table 3.2 indicates more local-regional and regional-regional SMBEs (average of 4.2 edges) within the political polycentric order than the nonprofit polycentric order (average of 3.9 edges). This is visually represented in Figure 3.7. There are high-density (red) and moderate-density (brown) lines in all the three maps but there are more of these lines in the first map (Political SMBEs). In other words, actors form more SMBEs with political actors than with nonprofit and market actors.

Even though there are more nonprofit actors (54 percent) than political actors (34 percent), there are more political SMBEs in governing the MRG urban watershed. This finding, perhaps, points to an inherent characteristic of polycentric governance that our methodology did not explicitly capture: the power and resource capability of actors (see

Bulkeley, 2005; Huitema et al., 2009; McGinnis, 2011). The designation of a political polycentric order was an implicit categorizing of actors with political and some resource capabilities; but it does not fully address the power and resource capability dimension of polycentric governance. Again, we see that high density SMBEs in all three maps are formed between local 2 and regional actors. As earlier noted, the local 2 ecological unit is very important within the MRG because it is located in the most populated urban center in NM (Albuquerque) with significantly more actors involved in governing the MRG.

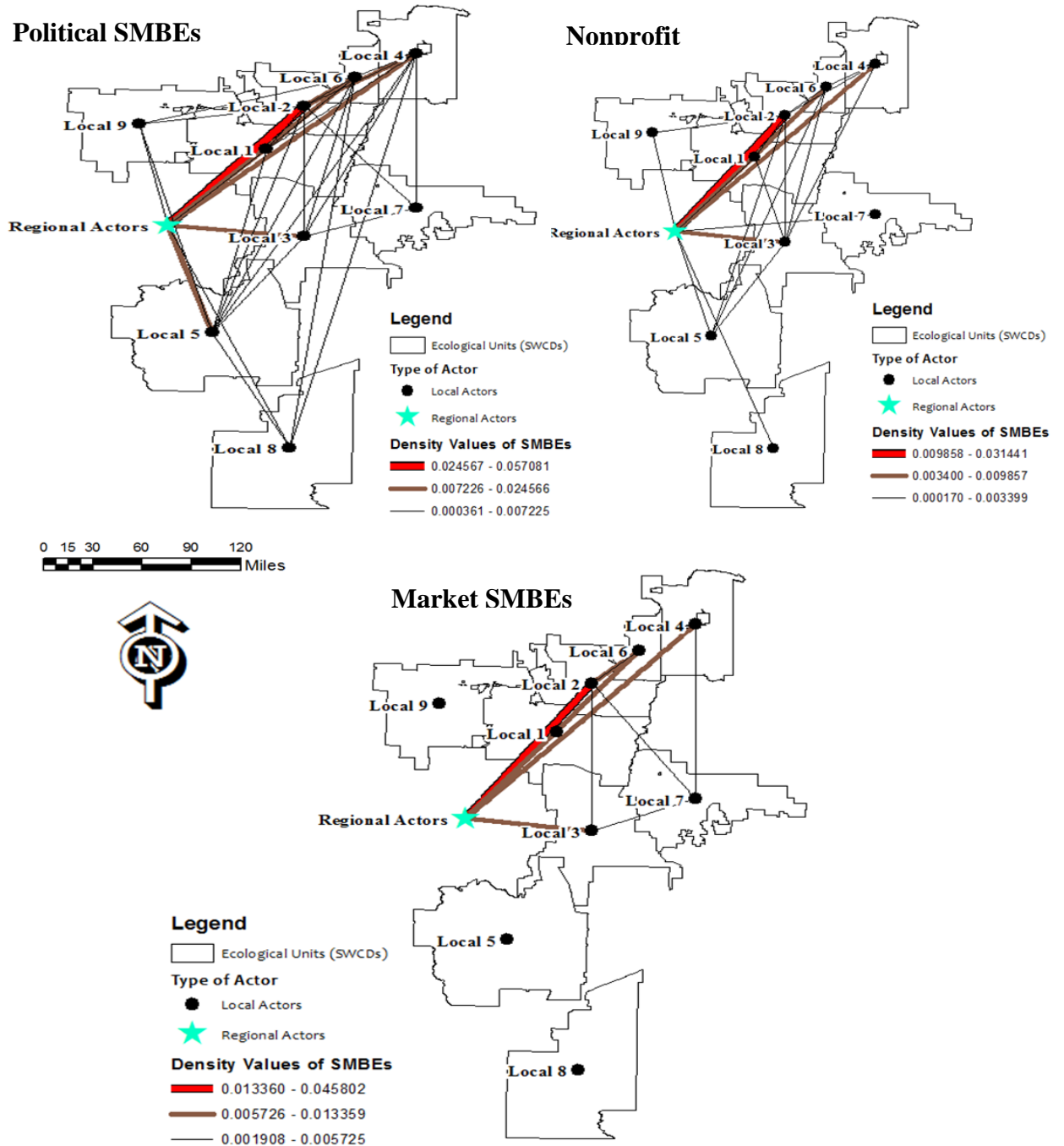


Figure 3.7: Density of SMBEs based on the sectors and governing scales of actors

Finally, even though we see some traces of polycentrism—SMBEs across multiple governing scales and sectors—among actors, the MRG urban watershed governance could be characterized as minimally polycentric within a largely monocentric government

system. Figure 3.8 shows that not all SMBEs are present within this policy network. On the average, only 15 percent, 4 percent, and 7 percent of the expected total scale mismatch bridging edges for the political (PPI), market (MI), and nonprofit (NPI) political orders respectively are present. This means that actors, on average, are exposed to only 15 percent political actors, 4 percent market actors, and 7 percent nonprofit actors working within different ecological units (soil and water conservation districts) and at different scales (regional scale).

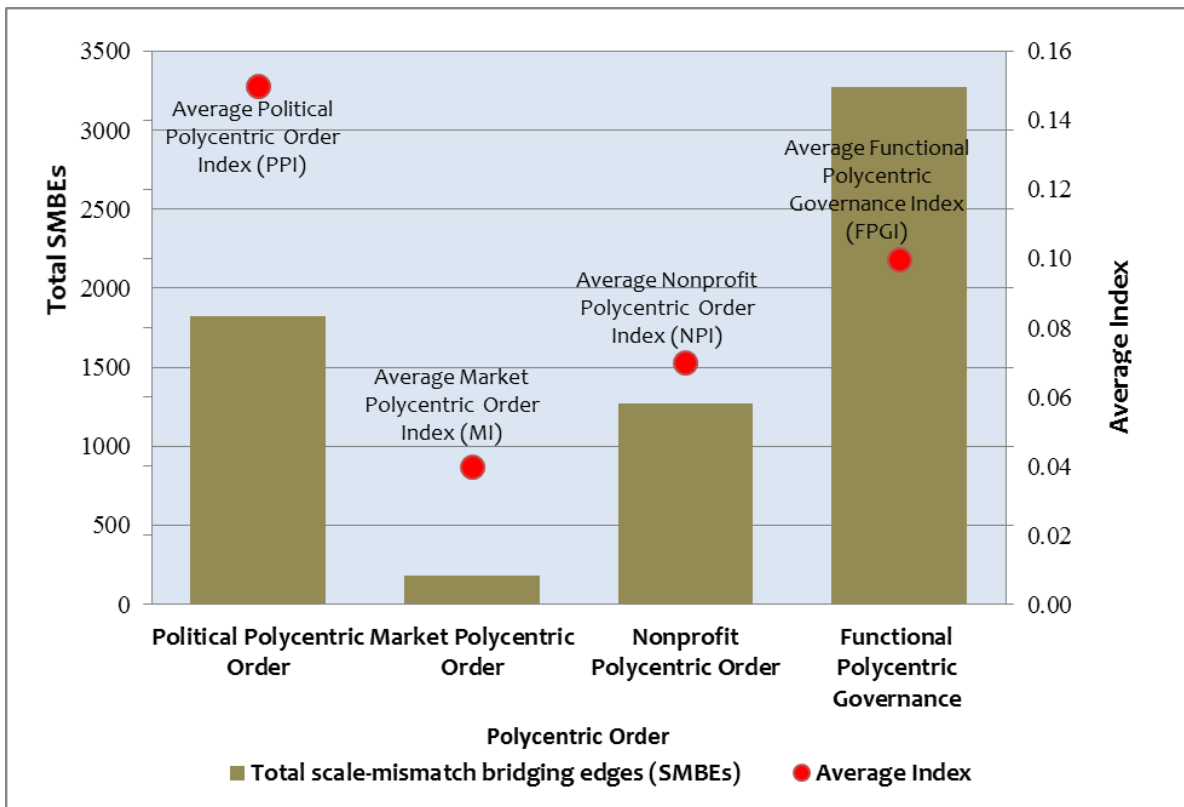


Figure 3.8: Total SMBEs and Average Polycentric Governance Indices

The three-set map shown in Figure 3.9 indicates the most polycentrically connected actors within the three islands of polycentric order. About 25 percent (47) actors have a PPI of 20 percent or more (see appendix 1 for these actors). In other words, these actors have SMBEs which connects them to 20 percent or more of the political actors within the

MRG. The number of actors having an NPI and MI is less. This brings to light the role of politics (power, resources, etc.) in the discourse around polycentric governance (Huitema et al., 2009; McGinnis, 2011). The polycentricity of urban water governance may above all be about the politics of resources and power distribution and asymmetries therein; and the resultant constant reconfigurations of actors' positionalities as they align themselves and their interests strategically. There is still more empirical research to be done in this area.

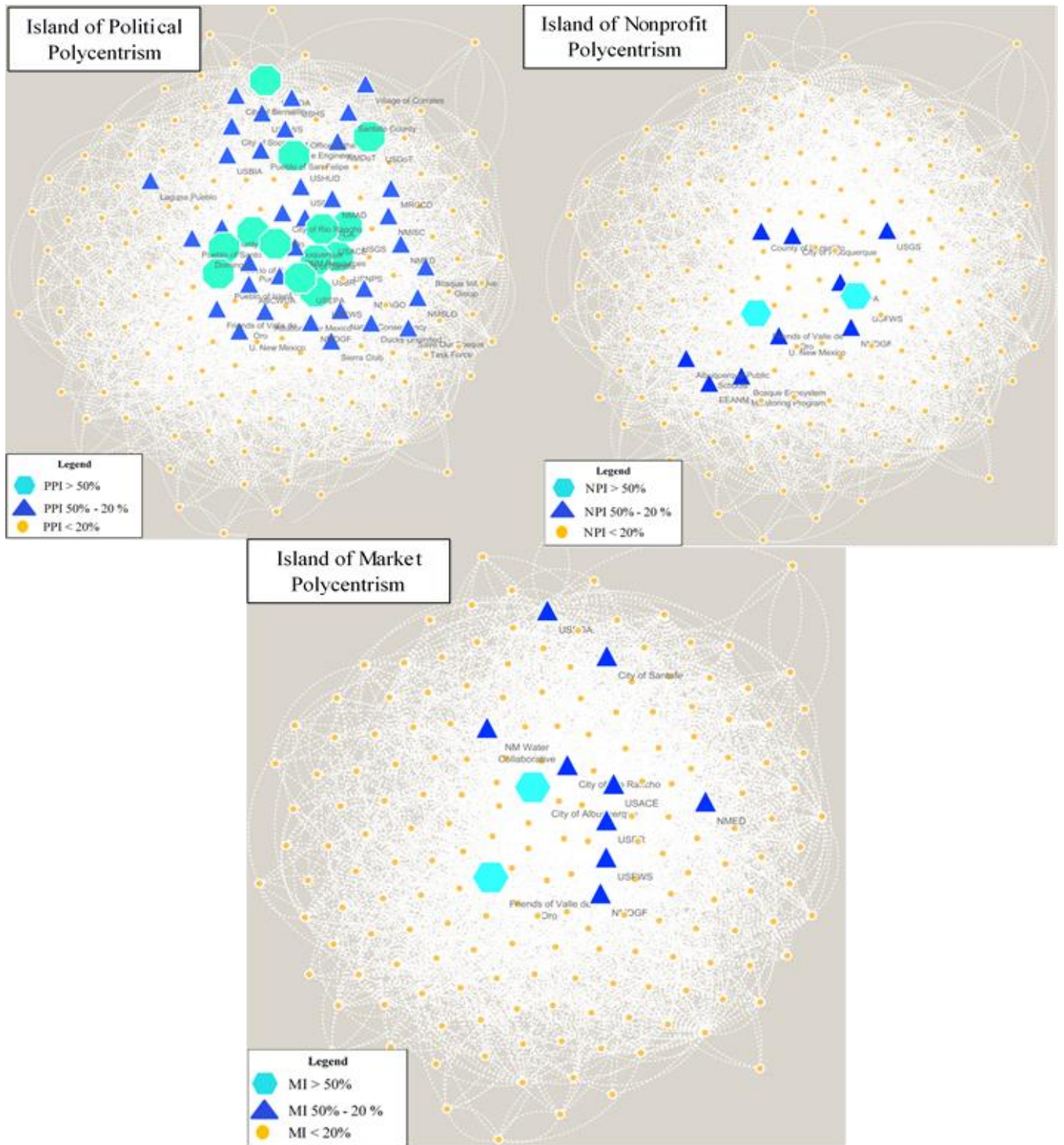


Figure 3.9: Actors' Level of Polycentric Connectedness in the Islands of Polycentric Order

The bivariate analysis of the PPI, MI, and NPI, presented in Figure 3.10 below also shows significant positive relationships (p values < 0.01). The coefficient of determination is high for MI and NPI (R^2 of 0.5) and approximately 0.3 for both PPI-NPI and PPI-MI. This implies, for instance, that NPI explained about 50 percent of the variance in the MI. To put it differently, we can partly (50 percent) understand the pattern of actors' SMBEs to market actors by studying the pattern of actors' SMBEs to nonprofit actors. Since it is a bivariate analysis, the opposite explanation also holds. We can infer, albeit cautiously, that this provides an evidence to the argument that these islands of polycentric orders often influence each other in polycentric governance (Aligica & Tarko, 2012; McGinnis, 2015). Again, it should be noted that the coefficient of determination is comparatively lower when PPI is involved. This could indicate that connectedness of political actors is less influenced by the other two types actors (or islands of polycentric orders).

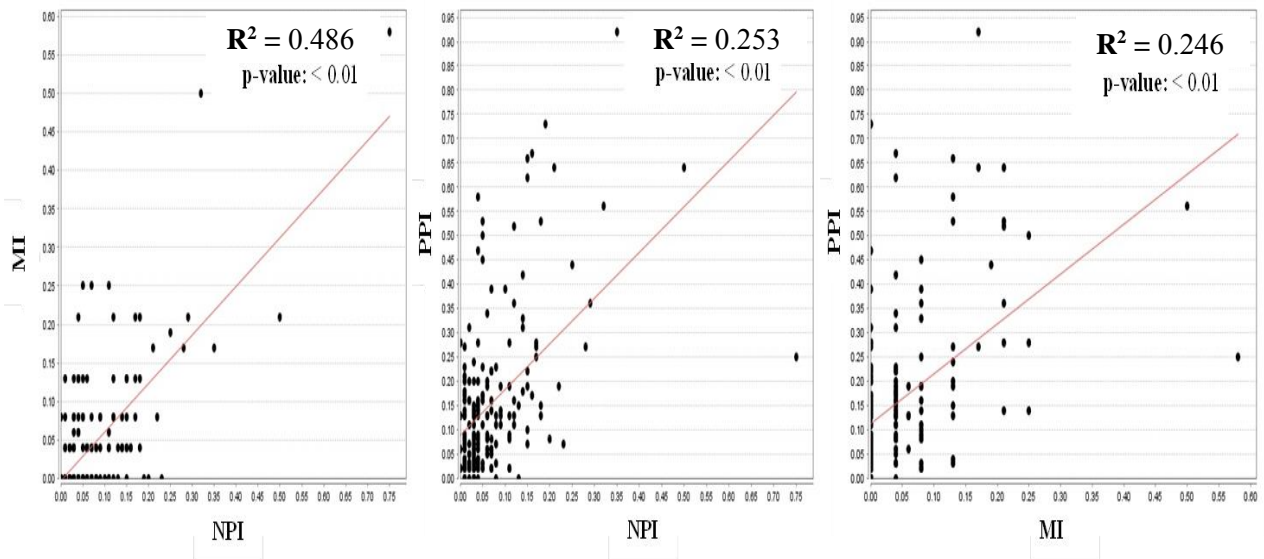


Figure 3.10: Bivariate Analysis of the PPI, MI, and NPI Indices

Since correlation does not necessarily imply causation, the results here serve only as prima facie evidence of the possible reinforcements among these polycentric orders. Again the relationships between these indices (islands of polycentric order) could be nonlinear (contrary to what the bivariate analysis shows) and could also be mediated by multiple factors. Therefore, the nature and degree to which these different polycentric orders influence each other still require further empirical interrogation.

Based on the three indices (PPI, NPI, and MI), actors involved in governing the MRG urban watershed, on average, have a functional polycentric governance index of 0.1 (see Figure 3.11 and appendix 2 for ranking of actors based on their FPGI). To put it differently, the functional connections formed by actors in governing the MRG urban watershed exposes them to only 10 percent (average) of all actors working within different sectors (political, economic/market, and nonprofit) and ecological units (soil and water conservation districts) and at different scales (regional actors). This finding could explain why scholars within the MRG urban watershed have characterized the watershed as rigid and inflexible despite the presence of multiple actors (Benson et al., 2014, p. 223; Carpenter & Brock, 2008). Therefore, we could characterize the governance of the MRG urban watershed as minimally polycentric circumscribed within a largely monocentric governance system.

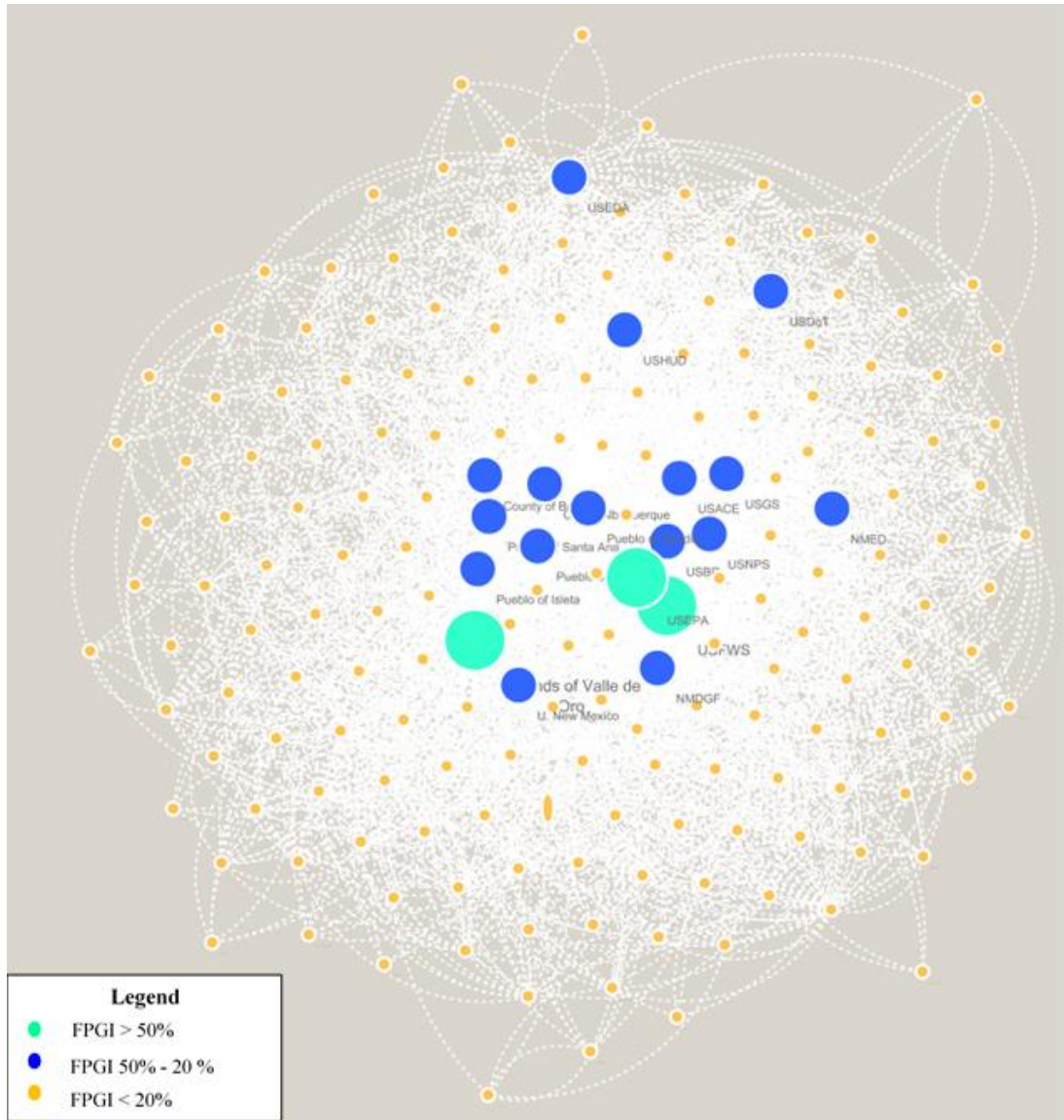


Figure 3.11: Actors' overall level of polycentric connection (FPGI)

3.6.2 (Re) interpreting Polycentric Water Governance in Terms of Social Network Analysis

We develop an ordinary least squares (OLS) model (Table 3.3 below) to explore the relationships between the FGPI and some network graph statistics to identify some implication(s) for functional polycentric governance. We include two measures for actor centrality within a network—closeness centrality and betweenness centrality—and two

measures for actor clustering within a network—clustering coefficient and topological coefficient. All four of these measures are a ratio coefficient measured from zero to one. The closeness centrality of a social node or actor measures how close an actor is to the other actors within the network; it also reveals how fast information spreads within the network (Newman & Girvan, 2004; Wasserman & Faust, 1994). The betweenness centrality of a social node presents a political view of network flow by indicating the degree of control an actor has over the other actors within the network (Anthonisse, 1971; Brandes, 2008; Newman, 2005; Wasserman & Faust, 1994). The clustering coefficient of an actor (n) is the ratio of the number of connections between n and its neighbors and the maximum number of possible connections that could exist between n and its neighbors (Newman & Girvan, 2004). The topological coefficient extends the clustering coefficient further by measuring the extent to which actor n shares neighbors with other actors in the network (Newman & Girvan, 2004).

Table 3.3: OLS regression models predicting FPGI

Variable	Full Model	Parsimonious Model ¹
Constant	-0.409	-0.408
Closeness Centrality	1.099***	1.096***
Betweenness Centrality	1.637***	1.643***
Clustering Coefficient	-0.004	-
Topological Coefficient	-0.159***	-0.164***
Full Model Summary		Parsimonious Model Summary
$n = 191$		$n = 191$
$R^2 = 0.85$		$R^2 = 0.85$
Std. Error = 0.0368142		Std. Error = 0.036719
F = 271.027***		F = 363.232655***
<i>Significance: $p < 0.01$***</i>		
Coefficients of variables shown are unstandardized regression coefficients		
¹ Parsimonious model results are produced using backward selection		

Our discussion here will focus on the parsimonious model but we will touch briefly on the full model. In the full OLS model, all variables, except the clustering coefficient,

have significant relationships (p -value < 0.01) with the functional polycentric governance index (FPGI). Backward selection was used to develop the parsimonious model. All three variables—closeness centrality, betweenness centrality, and topological coefficient—have significant relationship with the FPGI; together, they explain 85% of the variance of the FPGI. Both the full and parsimonious models reveal that an actor's degree of centrality is positively related to its FPGI; the opposite holds for an actor's degree of clustering within the network. This has two interconnected implications for polycentric governance.

Firstly, an actor's multiple connections (clustering) within a network of actors do not mean necessarily that it is connected polycentrically within a governance system. Polycentric governance is not only about how many are connected to an actor, but more importantly about the heterogeneity of who are connected to (Aligica & Tarko, 2012; McGinnis, 2005; V. Ostrom, 1999[1972]). Hence, reiterating, despite the presence of multiple actors within the MRG, its governance framework is still rigid and inflexible (Benson et al., 2014, p. 223; Carpenter & Brock, 2008) because connections formed within this watershed are less heterogeneous (multi-scale and multi-sector), thus making the governance framework more monocentric than polycentric.

Secondly, the positive relationships between an actor's FPGI and its closeness centrality and betweenness centrality drums home the point that polycentric governance is about political influence (closeness centrality) and ease of information dissemination (betweenness centrality). We earlier touched on how our method accounts for, albeit implicitly, political power in polycentric governance. However, political power, resources, and information in polycentric governance call for in-depth conceptual and empirical

analyses beyond the scope of this paper (see some conceptual discussions on this issue in works like Hooghe & Marks, 2003; Huitema et al., 2009; McGinnis, 2011).

3.7 Conclusion

This paper has presented a methodological approach to studying the polycentricity of urban watershed governance. It excavated the theoretical pillars of polycentricity by synthesizing the works of the Bloomington School of Political Economy and the PUR research by spatial planners. These conceptual pillars define polycentricity as 1) the multiplicity and functional connectivity of actors, and 2) the mix of actor types (sectors) and governing scales. The paper re-interprets these theoretical pillars using the SENA framework. The SENA language and interpretation, specifically the concept of scale mismatch bridging edges (SMBEs), are used to develop a methodological approach in studying the polycentricity of the Middle Rio Grande urban watershed in New Mexico. The methodological approach involved developing three sub-indices—PPI, MI, and NPI—and an overall index—FPGI—to study the polycentricity of the MRG urban watershed governance.

Two key insights are highlighted in the paper regarding the polycentricity of the MRG's urban watershed governance. First, the governance of the MRG urban watershed is characterized as a predominantly monocentric governing system with elements of polycentricity. Empirically, this implies that the expected density of connections between local-local actors and local-regional actors was very low. This is also reflected in the low average FPGI score of actors (10 percent). In fact, the presence of more federal, state and other regional government actors within the MRG urban watershed, as noted by Benson et al. (2014), requires that both local and regional government actors should do a better job

of reaching out to each other in governing this watershed. This outreach should include more localities, rather than focusing on actors within the densely populated areas (like the Albuquerque area) because the density of SMBEs between local-local and local-regional actors were concentrated within very few localities.

Second, the analysis showed that polycentric governance is primarily about the heterogeneity of an actor's connections. Actors within the MRG urban watershed were more connected to political actors than with the market and nonprofit actors. The point and perhaps contention based on this finding is that polycentric water governance could above all be about the politics of power and resource distribution. Acknowledging the need for more empirical testing to ascertain the centrality of power and resource distribution in polycentric governance, this finding could support why some view polycentricism in a normative sense. Actors' strategic decision to connect with others within different sectors and at different governing scales could be the 'right move' to save the urban water commons. On the other hand, the fact that actors within the MRG urban watershed governance have connections to political, rather than market and nonprofit actors, re-echoes why this governing system is viewed as rigid and inflexible (Benson et al., 2014, p. 223; Carpenter & Brock, 2008). Actors possessing more heterogeneous connections (across multiple scales and sectors) make the MRG urban watershed governance more polycentric and perhaps more flexible and less rigid; however, will this guarantee actors' strategic access to power and resources? This could be a central question for future empirical studies.

CHAPTER IV: GOVERNING THE URBAN WATER COMMONS: INTER-
ORGANIZATIONAL COLLABORATIONS IN A POLYCENTRIC ECOLOGY OF
URBAN WATER POLICY GAMES

4.1 Introduction

The governance of social-ecological systems (e.g. urban water commons/resources) involves a constellation of policy actors and policy institutions⁹ (Lubell, 2013). Scholars have engaged different theoretical and methodological approaches to study the interactions of actors and institutions in governing coupled social and ecological resources. Mark Lubell and associates have invoked Norton Long's (1958) *ecology of games* (EG) as the theoretical lens to conceptualize and test empirically the activities of actors and institutions in managing water resources (e.g. Lubell, Henry, & McCoy, 2010; Lubell et al., 2014). Social network and social capital concepts and game theory are used to frame and test hypotheses about actors' collaborative behaviors in governing social-ecological systems. Scott and Thomas (2015) developed an empirical model to test whether the decision of actors to collaborate in governing water resources is subject to the 'law of diminishing marginal returns.

⁹ A policy institution is the venue or forum constituted of formal rules and informal norms at the meso-level that determines the patterning of interactions among policy actors (individuals or organizations), with interest or stake (e.g. appropriation and political interests) in the decisions made at the policy institution level (Lubell, 2013; Lubell et al., 2014). Actor or policy actor is used interchangeably in this paper. Again, collaborative groups and policy institutions are used interchangeably. Not all collaborative groups are necessarily policy institutions.

Even though the constellation of policy actors and institutions suggests polycentricity in governing social-ecological systems, empirical models have yet to explicitly test for the role of polycentrism in governing social-ecological systems. Polycentric governance or ‘polycentric political systems’ implies the existence of multiple decision-making centers that are formally autonomous operate under certain sets of rules (Aligica & Tarko, 2012; McGinnis & Ostrom, 2012; E. Ostrom, 2010a; V. Ostrom, 1999[1972]; Polanyi, 1951). For instance, numerous studies on public service delivery in urban and rural areas supported the argument that a mix of variously sized jurisdictions are effective in public service delivery through intergovernmental arrangements (McGinnis, 1999; E. Ostrom et al., 1978; V. Ostrom, 2008a, 2008b). In the case of coupled social and ecological systems, Lubell et al. (2014, p. 5) infer from their findings that the governance of the San Francisco Bay water resources is “appearing polycentric.”

This paper moves beyond the ‘appearance’ of polycentricity and develops an empirical model to explicitly explore how polycentric governance shapes inter-organizational collaborations in urban water governance. An index is created to operationalize polycentric governance, and is used to explicate the emergence of inter-organizational collaboration in governing the Middle Rio Grande (MRG) urban water commons. The next section reviews the literature, and proposes hypotheses about the role of polycentric governance in shaping the collaborative outcomes between actors in governing social-ecological systems. This is followed by a discussion of the method—exponential random graph model (ERGM), the study context and the data for the study. The descriptive statistics and results from the ERGM are then discussed. A brief summative section concludes the paper.

4.2 Polycentric Ecology of Urban Water Policy Games: Theoretical Context

Urban water governance can be conceptualized as the concurrent operation of multiple policy games within a defined geo-political arena (Lubell, 2013; Lubell et al., 2014). Policy games refers to the interactions of policy actors and their participation in policy institutions—a rule-governed collective-choice process with jurisdiction over one or more collective-action problems—to influence policies by gaining information, credibility, and political influence (Berardo & Scholz, 2010; Lubell, 2013). Figure 4.1 portrays a constellation of interdependencies in governing water resources.¹⁰ Policy actors (e.g. city/county governments, urban planning departments, and water coalition groups) participate in three policy institutions—urban government/politics, soil and water conservation (SWC), and environmental advocacy (EA). Policy institutions can have overlapping jurisdictions. For instance, in the urban ecology of water policy games (Figure 4.1), decisions on soil and water conservation are influenced by the zoning decisions of city/county governments as well as other regulatory controls by the soil and water conservation district (SWCD). Policy actors’ participation in these three policy institutions are considered as three on-going policy games.

¹⁰See Lubell (2013) for a different depiction of actors’ participation in institutions.

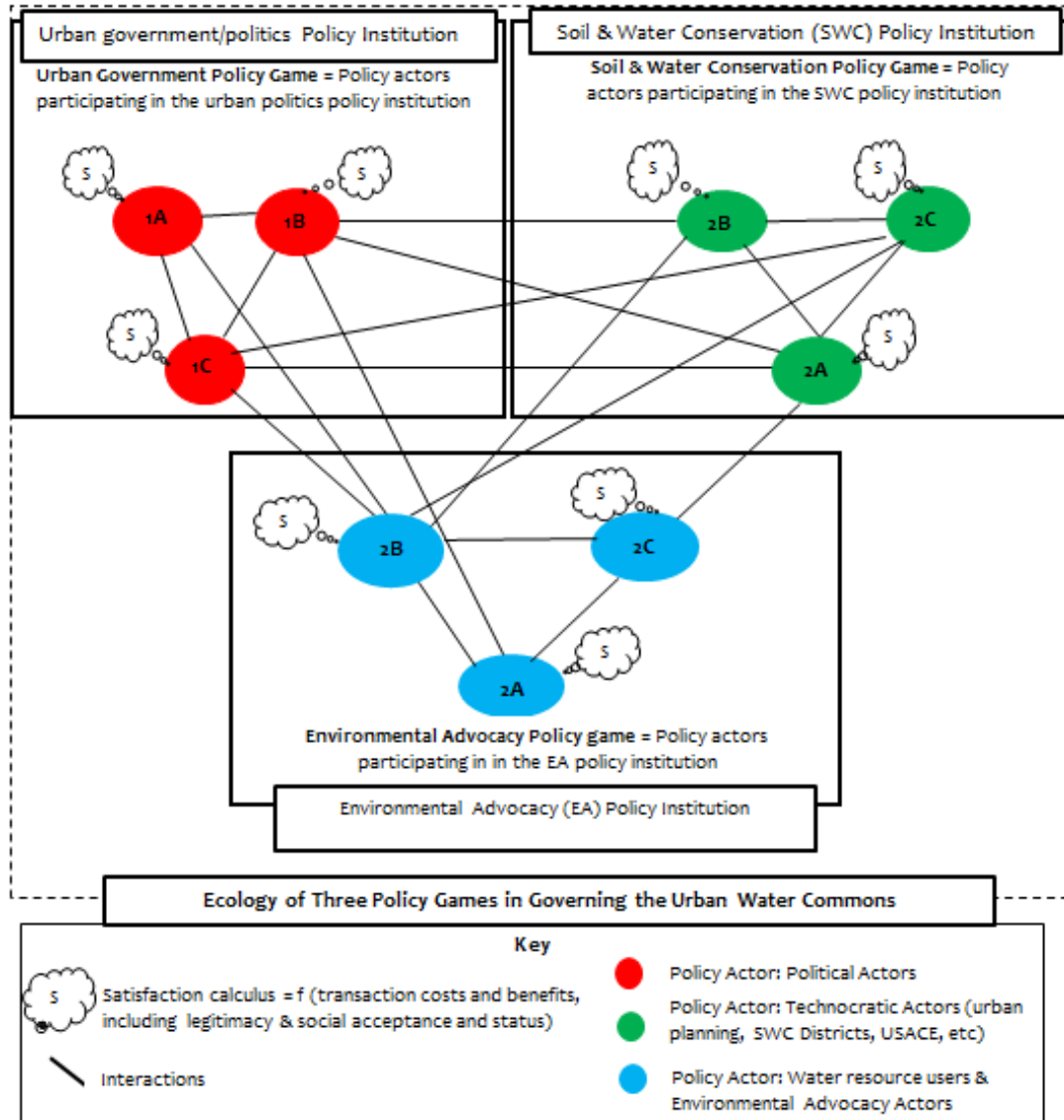


Figure 4.1: Ecology of Three Policy Games in Governing Urban Water Resources

The EG framework interrogates how actors solve collective-action problems through coordination and cooperation (Lubell et al., 2014). Coordination and cooperation in policy decisions is complex due to factors like political power and the multiple motivational and payoff structures facing policy actors (North, 1990, 2005; Scharpf, 1997a). The EG framework, hence, draws on multiple theoretical lenses to explicate factors that could explain the emergent collaborative policy networks within a given policy arena.

This paper draws on some of these theories to test a set of complementary hypotheses about how the MRG's policy network structure reveals supporting or hindering factors for collaboration and coordination among policy actors in governing this urban watershed. The subsequent discussions develop the theoretically-grounded hypotheses to be tested.

4.2.1 Centralization and Closure: Information, Trust, and Risks in Collaborative Policy Networks

Within the EG framework, collaborative policy networks¹¹ reveal the social capital structures that policy actors depend on to minimize transaction cost of coordination and cooperation (Ansell & Gash, 2008; Feiock & Scholz, 2009; Lubell et al., 2010; Margerum, 2011). Social capital is simply the “aggregate of the actual or potential resources which are linked to possession of a durable network of more or less institutionalized relationships of mutual acquaintance or recognition” (Bourdieu, 1985, p. 248). Several types of social capital are delineated in the literature—e.g. centralization or bridging, closure or bonding, and linking social capital (see Szreter, 2000; Szreter & Woolcock, 2004; Woolcock, 2001). This paper will limit itself to discussions of bridging and bonding social capitals.

Bridging social capital, often characterized as a star network (where one actor serves a central node or there is the absence of triadic relations among connected actors), is about relations of mutuality and respect among actors in a social network who see themselves as having different social identities (Coleman, 1988; Granovetter, 1973, 1985; Szreter & Woolcock, 2004). Centralization or bridging social capital in a policy network suggests that policy actors prefer more diverse contacts and access to outside information (Prell, 2012; Prell, Hubacek, & Reed, 2009). It is associated with coordination games, that

¹¹ Collaborative governance and policy networks are often treated as synonyms (see Ansell & Gash, 2008, p. 547).

is, when policy actors prefer to connect to few popular policy actors to gain easy access to information and roughly agree on a common strategy to deal with a problem (Lubell et al., 2014). Centralization, therefore, reveals a hierarchical policy network whereby few policy actors with the capacity and resources to coordinate emerge as the focal points (Carlsson & Sandström, 2008; Sandström & Carlsson, 2008). In their risk hypothesis, Berardo and Scholz (2010) found that policy actors in natural resource governance build bridging ties in low social-ecological risk situations—when the collective action problem is less complex and does not have far-reaching consequences. The paper test for the presence of centralization using the geometrically weighted degree (*GWD*) term using the *statnet* program. This is an anti-preferential attachment term which indicates the probability of policy actors forming bridging ties or connecting to more popular actors (that is when the *GWD* term is negative and statistically significant) (Hunter, 2007). It is expected that:

Hypothesis 1: The collaborative policy network in governing the MRG urban watershed is driven by high centralization if policy actors face low social-ecological risk situations.

Bonding social capital or transitive closure, seen as “closed” or triadic relations among actors (Actor A is connected to B, B is connected to C, and C is connected to A), is about trust and co-operation between social network members who often see themselves as having a shared social identity (Coleman, 1988; Szreter & Woolcock, 2004). Policy actors form bonding ties in dealing with cooperation games; that is, they form cohesive networks through building redundant and strong connections with other policy actors to create trust and security in relationships (Angst & Hirschi, 2016; Lubell et al., 2010; Lubell & Lippert, 2011). In natural resource governance, bonding ties are formed by policy actors

in high social-ecological risk situations—when the collective action problem is complex and policy actors have high incentive to be uncooperative (e.g. lie or cheat) (Berardo & Scholz, 2010; Burt, 2005; Coleman, 1988; Heckathorn & Maser, 1987). Forming bonding ties helps policy actors to gain multiple sources of credible information, monitor and sanction defectors, and solve complex collective action dilemmas in natural resource governance (Angst & Hirschi, 2016; Berardo, 2009). The presence of bonding social capital is tested for in statnet by using the geometrically weighted edgewise shared partner (GWESP) term—a statistically significant coefficient indicates the presence of transitive closure or bonding social capital within the network (Robins, Lewis, & Wang, 2012). This parameter simply illustrates the axiom that “my friend’s friend is my friend.” The geometrically weighted dyadwise shared partners (GWDSP) term is often added to the model to separate transitive closure from an accumulation of many connections by chance (Hunter, 2007; Snijders, Pattison, Robins, & Handcock, 2006). In other words, we need the GWDSP term to help accurately determine if we are properly capturing bonding social capital within the network. Based on the discussion of bonding social capital, it is expected that:

Hypothesis 2: The collaborative policy network in governing the MRG urban watershed is driven by high transitive closure if policy actors face high social-ecological risk situations.

Even though hypothesis 1 and 2 suggest that bridging and bonding social capital are mutually exclusive—the tradeoff argument by Berardo and Scholz (2010)—this may not be true in other social-ecological settings. Berardo (2009) found that both bonding and bridging social capitals are found in high-risk social-ecological situations. Lubell et al.

(2014) link the presence of both centralization and transitive closure to ‘polycentrism’ within a collaborative policy network. In-depth discussion on this will be offered in the polycentric governance section of this paper.

4.2.2 Actor Activities and Political Homophily

The attributes of policy actors also influence the probability of tie formation between actors in a policy network. Lubell et al. (2014, p. 1) refer to this as the “actor hypothesis.” Policy actors within an urban ecology of games solve collective action problems by using their resources and capacities—e.g. political, financial, information and technical—to coordinate and influence policy decisions (Ansell & Gash, 2008; Lubell et al., 2014; Scharpf, 1997a). Some policy actors with greater capacities and access to resources become more active (i.e. form more ties) within collaborative policy networks. In the case of the United States, Lubell et al. (2014) note the high activity of federal and state government actors often drives collaborative policy networks because these organizations have financial and technical/information resources, and delegated higher level political power to coordinate and influence policies. Borg, Toikka, and Primmer (2015) also find these outcomes in conservation governance networks in Finland. Further, Angst and Hirschi (2016) find this to be true in their dynamic network model of a regional park project in Switzerland. Therefore, in testing the actor hypothesis, it is expected that:

Hypothesis 3: The collaborative policy network in governing the MRG urban watershed is driven by federal and state government actors who have greater capacities and access to more resources and power to influence coordination and cooperation mechanisms in policy decisions.

Another dimension to the actor hypothesis is homophily. Homophily explains the tendency of tie formation between policy actors who possess similar attributional characteristics or belief systems (McPherson, Smith-Lovin, & Cook, 2001; Zafonte & Sabatier, 1998). Government actors are relatively more homogenous than non-government actors; they also have greater concentrations of resources (Lubell et al., 2014) than non-government actors in terms of their sources of technical and financial resources (e.g. access to public funds) and political power (i.e. statutes). These conditions potentially minimize conflict and transaction costs while concurrently fostering trust among these homogenous policy actors. In the United States, local government agencies are more likely to collaborate with state and federal government agencies than with nongovernment agencies to access technical and financial resources. Therefore, it is expected that:

Hypothesis 4: The collaborative policy network in governing the MRG urban watershed is driven by homophily of government actors (political homophily) to (re)distribute technical and financial resources among different levels of government.

4.2.3 Diminishing Marginal Returns in Collaborative Policy Networks

Interorganizational collaboration is influenced by policy actors' joint participation in collaborative groups. We can think of collaborative groups broadly as the policy institutions—forums or venues—that bring together policy actors to access resources and/or manipulate policy decisions (Scott & Thomas, 2015). Collaborative groups foster interorganizational collaborations among policy actors because they build credibility and rapport among participating policy actors (Emerson, Nabatchi, & Balogh, 2012; Scott & Thomas, 2015). These groups foster interorganizational collaborations because of

mechanisms like 1) principled engagement—participating policy actors can easily dialogue because they develop shared concepts, definitions and terminologies—and/or 2) increased capacity for joint action— participating policy actors get to know the capabilities, goals, motivations, and capabilities of other policy actors (Emerson et al., 2012). Principled engagement and increased capacity for joint action explain how participating policy actors in collaborative groups have lower transaction costs in finding suitable collaborating partners (Emerson et al., 2012; Scott & Thomas, 2015).

Scott and Thomas (2015), however, test the argument that the increased participation of policy actors in collaborating groups could lead to no or “diminished” capacity for policy actors to engage in interorganizational collaborations with member or non-member policy actors. This supports, empirically, the point that policy actors’ resource and cognitive capacity limits lead to payoff and strategy externalities as policy actors explore collaborative relationships within the confines of their limited abilities (see detailed discussion on these externalities in Bednar & Page, 2007; Lubell, 2013; Lubell et al., 2010; Margerum, 2007). It should be noted here that there is no test for policy actors’ co-participation in the same collaborative group as was done in Scott and Thomas (2015). The paper only adopts a generalist perspective to explore how policy actors’ participation in multiple collaborative groups or policy institutions influences collaboration ties. Based on this discussion, it is expected that:

Hypothesis 5a: The probability of collaborative relationships among policy actors in governing the MRG urban watershed increases as policy actors’ participate in policy institutions.

Hypothesis 5b: The probability of collaborative relationships among policy actors in governing the MRG urban watershed decreases as policy actors' participation in policy institution increases and exceeds a given threshold.

4.2.4 Segmentation and Polycentrism in Collaborative Policy Networks

Situating themselves within the EG framework, Lubell et al. (2014) lay an important methodological foundation for a robust test of how polycentric governance drives collaboration in policy networks. Firstly, they invoke the V. Ostrom (1994b, p. 225) definition of polycentrism being “a self-organizing system” composed of (1) many autonomous units that are formally independent of and influencing one another, and (2) processes of cooperation, competition, conflict, and conflict resolution. Secondly, they draw on V. Ostrom et al. (1961) to test the hypotheses that polycentric governance exhibits the concurrent existence of higher level institutions (centralization) and lower level institutions (decentralization) within the same governing system. Thirdly, like Berardo and Scholz (2010), Lubell et al. (2014) found that centralization (bridging social capital) and transitive closure/decentralization (bonding social capital) had statistically significant opposite signs within the same social-ecological system. In other words, the network exhibited a “core-periphery” structure due to popularity effect (negative GWD) and triangulation effect (positive GWESP) (Snijders et al., 2006). This core-periphery structure of negative GWD (centralization) and positive GWESP (decentralization) is also known as “segmentation” (Robins, Snijders, Wang, Handcock, & Pattison, 2007, p. 201). In this paper, the thesis that a segmented network is an evidence of a polycentric network will be referred to as the Lubell-Robins-Wang *polycentric hypothesis*.

A segmented policy network is *a necessary but insufficient condition* to describe a governing system as polycentric. Segmentation only describes the co-constitution of multiple governing scales within a policy network. Apart from governing scales, polycentrism also looks at the co-existence of *multiple sectors* (e.g. political, judicial, and market) within which policy actors operate at the different governing scales (Aligica & Tarko, 2012; McGinnis, 2005; V. Ostrom, 1999[1972]). These multiple sectors constitute themselves as “islands of polycentric order” (e.g. market and political polycentric orders) and they influence each other (Aligica & Tarko, 2012, p. 247). Taken together, discussions (ontological, epistemological and/or methodological) on the polycentricity of governing systems must, at a minimum, take into consideration some of the following—the autonomy of policy actors within the system, and policy actors’ operation at multiple governing scales—and within multiple sectors. In fact, the literature on Social-ecological Network Approach (SENA) also reveals that the concurrent existence of multiple governing scales in a network does not sufficiently tell us whether or not policy actors are adequately connecting to multiple policy actors at different governing scales (see Bergsten et al., 2014; Bodin & Tengö, 2012; Rathwell & Peterson, 2012; Sayles, 2015; Schoon et al., 2014). To put it differently, we must understand how many scale mismatch bridging edges (SMBEs) or connections policy actors possess.

Discussing all these debates and how they could help in a robust testing of polycentric governance exceeds the scope of this paper. This task is however addressed in the previous chapter where a scalable index—Functional Polycentric Governance Index (FPGI; see chapter 3) is developed. The FPGI is a policy actor level index ranging from 0 (not connected polycentrically) to 1 (fully connected polycentrically). It indicates the

degree of connectivity between a policy actor and other policy actors operating within different sectors and at different governing scales within the system. This index is included to test for two interrelated hypotheses on how polycentric governance drives interorganizational collaboration in the MRG's urban water policy network. The first hypothesis (hypothesis 6a below) tests the Lubell et al.'s (2014) segmentation argument, which as noted previously, is a necessary but insufficient condition for characterizing a governing system as polycentric. The second hypothesis (hypothesis 6b) tests whether the FPGI is a statistically significant driver of the observed MRG collaborative policy network. Therefore, it is expected that:

Hypothesis 6a: The MRG's collaborative policy network exhibits characteristics of a polycentric governing system if its collaborative policy network is segmented (negative centralization and positive decentralization coefficients)

Hypothesis 6b: The MRG's collaborative policy network is polycentric if, in addition to being segmented, it has a statistically significant functional polycentric index. (Note: the direction of the coefficient will determine if polycentric governance drives interorganizational collaboration within the MRG).

4.3 The Exponential Random Graph Models (ERGMs)

ERGMs are statistical models to explain how collaborative policy networks emerge, especially within the EG framework (Frank and Strauss (1986). An observed collaborative policy network is considered as a possible outcome of stochastic network processes (Lubell et al., 2014; Robins, Pattison, Kalish, & Lusher, 2007; Robins, Snijders, et al., 2007). Collaboration tie, the dependent variable, is defined as the probability that

two policy actors will collaborate. The ERGM uses a Markov-chain Monte Carlo (MCMC) fitting approach, and explore the influences of a set of independent variables on collaboration tie. These independent variables include both endogenous variables indicating structural characteristics of a network and exogenous variables related to actor and dyadic covariate effects (Prell, 2012; Scott, 2015). Table 4.1 below presents the set of independent variables and their expected sign of impacts to support different hypotheses.

A generalized ERGM can be presented as:

$$Pr(X = x) = \frac{1}{K} \exp \sum_Q \theta_Q Z_Q(x) \dots \dots \dots (1)$$

where,

$Pr(X=x)$ = Conditional odds ratio of observing a tie between two nodes (e.g. policy actors);

X = A social network;

Q = Network configuration of type Q comprising tie variables that are conditionally dependent given the rest of the network;

Z_Q = Set of graph statistics representing the network endogenous effects;

θ_Q = Vector of parameters corresponding to the graph statistics, and;

K = Normalizing constant.

In a social network, the formation and dissolution of collaborative ties not only depend on the network structural parameters, but also on exogenous attributes of policy actors and other dyadic covariates (Morris, Handcock, & Hunter, 2008; Robins, Elliott, & Pattison, 2001). To accommodate this, Equation (1) is modified as:

$$Pr(X = x|Y = y) = \frac{1}{K(\theta)} \exp \sum_{Q,\Lambda} \{\theta_Q Z_Q(x) + \theta_\Lambda Z_\Lambda(x, y)\} \dots \dots \dots (2)$$

where,

Y = A set of attribute variables

Λ = Variables of interactions between node attributes and network configuration (i.e. comprise of tie variables and nodal attribute variables)

θ_Λ = Vector of parameters for social selection configurations involving an interaction of network (x) and attribute (y) variables;

Z_Λ = Sufficient statistics for social selection configurations involving an interaction of network (x) and attribute (y) variables;

$K(\theta)$ = Normalizing constant.

Table 4.1: Summary of Independent Variables and Expected Impact on the Dependent Variable

Independent Variables	Hypothesis							
	1	2	3	4	5a	5b	6a	6b
Centralization (Bonding Social Capital)	+						-	
Triangulation (Bonding Social Capital)		+						+
Act. of Federal Gov't Actors			+					
Act. of State Gov't Actors			+					
Act. of SWCDs			-					
Act. of NPO Env't Actors			-					
Act. of Ed./Research Actors			-					
Political Homophily				+				
# Participation Groups					+			
#Participation (squared)						-		
Polycentric Governance								significant
Note:								
1. Dependent variable = collaboration tie between two policy actors								
2. + = positively correlated (probability of collaboration tie increases)								
3. - = negatively correlated (probability of collaboration tie decreases)								
4. Significant = statistically significant								
5. Act. = Activities								
6. NPO= Nonprofit								
7. Ed. = Education								
8. Env't = Environment								

4.4 Study Area

The Middle Rio Grande (MRG) watershed is part of the Rio Grande's watershed and is located in central New Mexico (NM), covering approximately 3,060 square miles. The MRG watershed extends from the Cochiti Dam to the Elephant Butte Reservoir in central New Mexico (Figure 4.2). The study area encompasses nine soil and watershed districts (Valencia SWCD, Ciudad SWCD, Socorro SWCD, Santa Fe-Pojoaque SWCD, Sierra SWCD, Coronado SWCD, Claunch-Pinto SWCD, Doña Ana SWCD, and Lava SWCD), and seven main counties (Santa Fe, Sandoval, Bernalillo, Valencia, Socorro, Torrance, and Cibola). It is also home to six Native American pueblos—Cochiti, San Felipe, Santo Domingo, Santa Ana, Sandia, and Isleta.

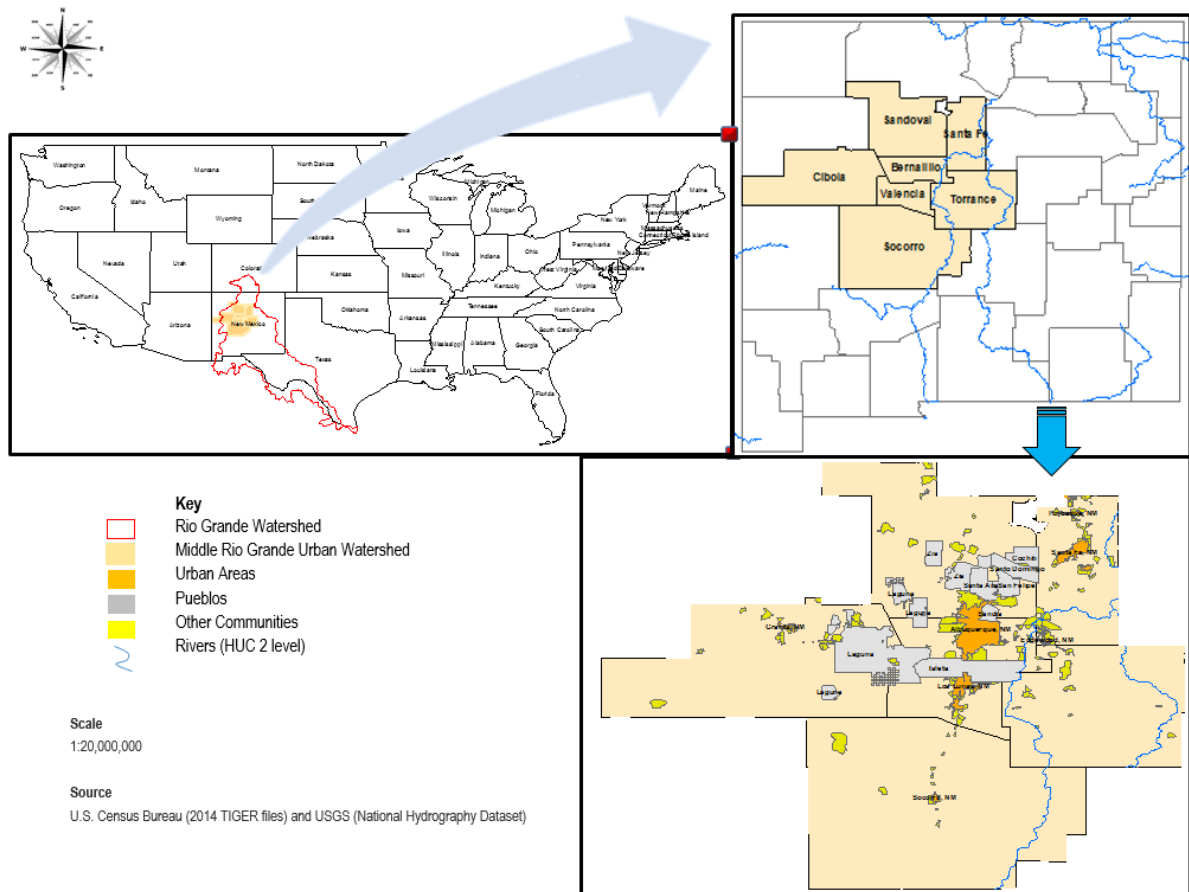


Figure 4.2: The MRG Urban Watershed

The MRG watershed involves multiple inter-state compacts such as the: Animas-La Plata Project Compact (1968), Canadian River Compact (1950), Colorado River Compact (1922), Costilla Creek Compact (1946), La Plata River Compact (1925), Pecos River Compact (1948) Rio Grande Compact (1939), and the Upper Colorado River Basin Compact (1949) (Buynak & Oglesby, 2014). The multi-jurisdictional nature of this water commons requires multiple players, both within and out of New Mexico, in governing the MRG. Policy actors, mostly federal and state government agencies, have a strong presence in the MRG partly due to the multi-state nature of the Rio Grande water commons, as well as the extensive amount of public lands in this area (Benson et al., 2014). These lands are owned and managed by agencies such as the U.S. Forest Service, Bureau of Land

Management, National Park Service, U.S. Fish and Wildlife Service, NM State Parks Division, and NM Forest Service (ibid). Internally, the MRG urban water governance is also controlled by tribal agreements between the federal government and the pueblos within (Benson et al., 2014). These pueblos have “prior and paramount” rights to water; that is, there exists the right for the pueblos to use the Rio Grande River to irrigate their lands within the Middle Rio Grande Conservation District (MRGCD) (Mann, 2007). The presence of multiple internal (state and local) and external (federal) actors and legal agreements/mandates make the MRG an ideal case study for polycentric governance.

4.5 Data Preparation

The study employed the archival-based snowball network sampling (Burt, 1983; Wasserman & Faust, 1994) to collect network data on policy actors and policy institutions involved in water and environmental conservation activities in the MRG. The U.S. Environmental Protection Agency’s (EPA) databases on urban watershed collaborative partnerships served as the initial point to identify policy actors within the study area. Next, the websites of these identified actors and archival documents (e.g. academic documents, action/strategic plan and memorandum of understandings) related to these actors were identified to collect data. Characteristics of these organizations collected, for instance, whether they are a nonprofit or government (political) organization and their past and present project/policy/funding collaborators. Steps three and four entailed the same process utilized in step 2 to identify the environment-related partners until the list could not be further expanded. The data was prepared using the Cytoscape software (Shannon et al., 2003).

In all, more than 700 websites and archival documents (e.g. online newspaper articles, academic documents, government documents, annual reports, grant databases, budget documents, memorandum of understandings, and action/strategic plans) were collected through this network snowball approach using google search and LexisNexis. However, the study limited itself to collaborations occurring within the past 10 years, which reduced the number of websites and archival documents analyzed to 473. Collaboration tie/link between two actors (organizations) was measured as a non-directional relationship (cannot distinguish relationship from A to B and vice-versa). Partly informed by Lubell's (2004a) coding parameters, the presence of a collaborative tie between two actors (e.g. A and B), which is the dependent variable, was determined as a yes (1) or no (0) if:

- 6) A is a project partner (or listed as a partner) of B or vice versa;
- 7) A provides financial assistance (listed as a financial donor, corporate sponsor, and/or grantor) to B or vice versa;
- 8) A and B have joint implementation agreement (JIA) and/or memorandum of understanding (MOU);
- 9) A and B share logistics and personnel (including volunteering); and
- 10) A and B have a shared permitting or regulatory activities.

Multiple approaches were adopted to ensure the reliability of the data and the analysis conducted even though this was a single coder project and required a relatively simple coding approach to collect network data (i.e. absence or presence of a collaboration tie between two organizations if any of the above coding parameters were present). After developing the coding parameter, the author sampled 40 of the data records already

obtained—this included 5 websites, 1 grant database, and the rest were online newspaper articles, academic papers and annual reports of some already identified organizations based on the first 1 outlined in Figure 3.4 above. The author solicited the assistance of a colleague to help assist in assessing the inter-coder reliability in analyzing the data (see also Campbell et al., 2013). Both the author and his colleague analyzed the data independently using the coding parameters.

Two interrelated errors were seen by comparing the adjacency matrix (which actors have a collaboration tie between them) obtained by the author and his colleague. A total of 21 actors were obtained in one matrix and 24 actors were obtained in the other. This evidently also affected the adjacency matrices obtained—a pair of actors had a missing collaboration tie in one matrix and not the other matrix. These errors were mainly the result of ambiguities in the organizational names (and sometimes acronyms) as well as duplicates in the list of organizations because some data records used a department or project to represent a larger organization while other data records used the name of the large organization. For example, sometimes Bosque del Apache National Wildlife Refuge and Friends of Bosque del Apache were used interchangeably even though the former is a project by the U.S. Fish and Wildlife Service and the latter is a nonprofit group established to support the project.

These errors were remedied by ensuring consistent use of organization names and acronyms. Again, even though the use of the NVivo qualitative data software made it easier to code and analyze the 40 sample of data records, it also made it easier to catch some of these and other potential errors. Hence, since the coding parameters were relatively simple and easy to use, and most of the data records involved looking at a specific part of an

organization's website (e.g. finding the "corporate sponsor" or "partners" section on the website), the author analyzed the data manually to help reduce the above mentioned and other potential errors that could have been missed by using NVivo. The preliminary analyses were compared with both published (some have been cited in the chapter) and unpublished scholarly works to have a general sense of potential inaccuracies. These preliminary analyses were also shared with a researcher who has studied this site to also determine potential inaccuracies.

4.6 Descriptive Statistics

Figures 4.3 and 4.4 present standard measures for centrality and clustering based on the type of policy actors. Degree centrality reports a policy actor's number of connections and a policy actor's eigenvector centrality shows its connections to well-connected policy actors—those with high degree (more collaboration ties). Betweenness centrality presents a political view of network flow by indicating the degree of control a policy actor has over others—i.e. the number of connections flowing through the policy actor (Anthonisse, 1971; Brandes, 2008; Newman, 2005; Wasserman & Faust, 1994). From Figure 4.3, the federal government, local government and environmental nonprofit policy actors play coordinating roles—are well-connected—within the MRG's collaborative policy network. Generally, with a median degree of 13 (average degree of 19), this collaborative policy network shown in Figure 4.5 below has a "fat tail" distribution—many low-degree policy nodes and few high-degree policy nodes—compared with a randomly simulated network of the same size (198 nodes/policy actors and density of 0.097).

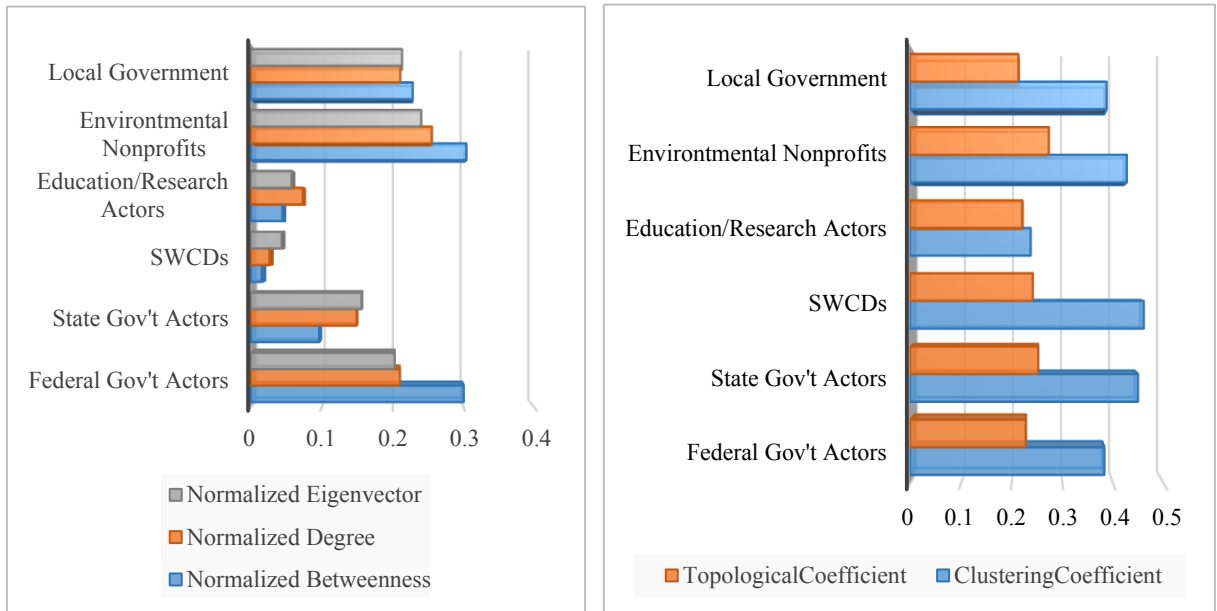


Figure 4.3: Centralization by Policy Actor Types Figure 4.4: Clustering by Policy Actor Types

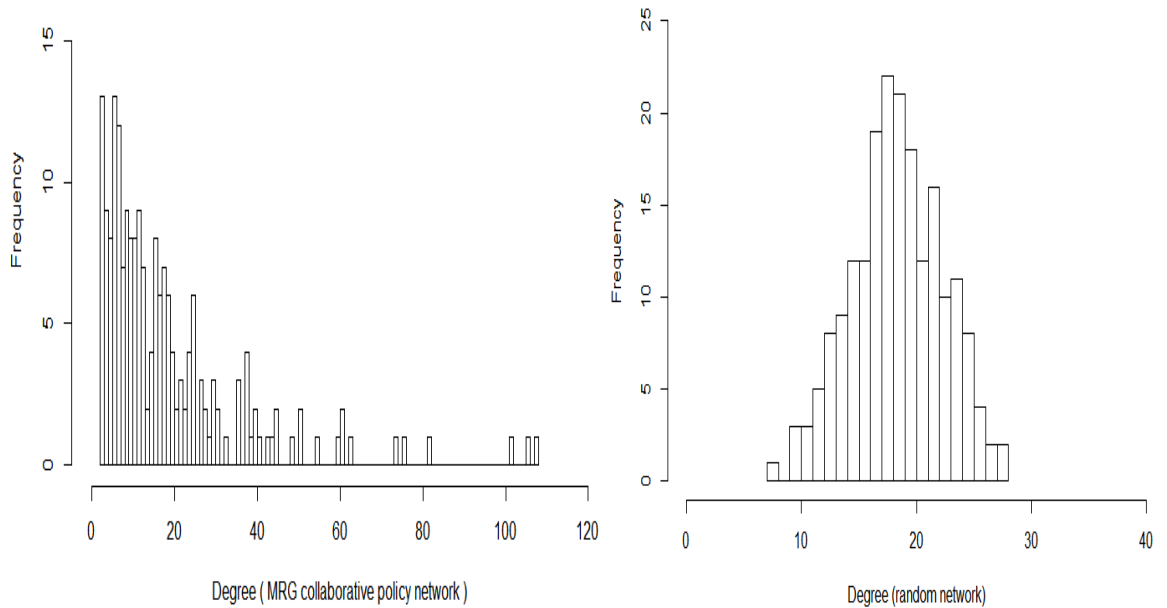


Figure 4.5: Comparing degree distributions for observed and randomly simulated network

The two standard measures of clustering in Figure 5 also show clustering within the MRG’s urban water policy network. The clustering coefficient of a policy actor (n) is the ratio of the number of connections between n and its neighbors and the maximum number of possible connections that could exist between n and its neighbors (Newman & Girvan, 2004). The topological coefficient extends the clustering coefficient further by measuring the extent to which policy actor n shares neighbors with other actors in the network (Newman & Girvan, 2004). The SWCDs, New Mexico’s state agencies, federal government agencies and environmental nonprofit organizations are highly clustered within the MRG urban watershed. This indicates the potential for transitive closure whenever these policy actors form collaborative relationships with other actors.

The paper also explore whether there is clustering among similar policy actors—homophily within the policy network, and use mixing matrices (Goodreau, Handcock, Hunter, Butts, and Morris (2008), as shown in Table 4.2, to examine the propensity for similar policy actors to be connected. About 50 percent of the total connected dyads (939 out of 1881) involve dyadic connections between government policy actors. This supports a propensity for government policy actors to be connected.

Table 4.2: Propensity for Government Policy Actors to be Connected—Political Homophily

		Government actors	
		<i>No</i>	<i>Yes</i>
Government actors	<i>No</i>	198	744
	<i>Yes</i>	744	939

4.7 The ERGM Results

Statnet is used to run ERGM analysis. Five ERGM models (Table 4.3) were built to fit the observed collaborative policy network in governing the MRG urban watershed. The ERGM, like the logistic regression, explains the probability of observed presence or absence of a collaboration tie between two policy actors. The odds of two policy actors having a collaboration tie is estimated by exponentiating the parameter coefficient to obtain a multiplicative effect on the odds ratio. The naïve model controls for the baseline odds of observing whether two randomly selected policy actors have a collaboration tie by using the observed density of the network. The parameter coefficient (-2.24) is exponentiated to obtain an odds of 0.11 to 1 of observing a tie between two policy actors. This naïve model assumes that collaborative decisions are uniformly distributed among policy actors and does not take into consideration the characteristics of these actors and the strategic decisions they often make in deciding who to collaborate with. The negative density parameter means that there are fewer observed collaboration ties than expected in random networks or there is less than 50 percent chance of forming any collaborating tie within this policy network.

Table 4.3: Exponential Random Graph Model (ERGM) Parameter Estimates

Parameters	Naïve Model	Strategic Decision Model (SDM)	Political Capacity Model (PCM)	Strategic Political Decision Model (SPDM)	Strategic Political-Economy Decision Model (SPEDM)
Density	-2.24***	-7.22***	-2.46***	-6.96***	-5.079***
Triangulation		1.81***	-	1.67***	0.33**
Multiple Connectivity		0.02***	-	0.002	-0.03***
Centralization		3.72***	-	5.46***	-0.78*
Act. of Federal Gov't Actors			0.86***	0.18***	0.07
Act. of State Gov't Actors			0.32***	-0.01	0.14**
Act. of SWCDs			0.10	0.08	0.93***
Act. of NPO Env't Actors			-0.20***	-0.01	0.02
Act. of Ed./Research Actors			-0.09	-0.01	0.05
# Participation Groups		0.14***		0.14***	0.08***
#Participation (squared)		-0.01***		-0.01***	-0.01***
Political Homophily				0.32***	0.25***
Polycentric Governance					0.10***
BIC	12,383	10,842	12,006	10,665	9,534
Degrees of freedom	1	6	6	12	13

Note:

1. Significance = ***p-value < 0.001; **p-value < 0.01; * p-value < 0.05
2. Act. = Activities
3. NPO= Nonprofit
4. Ed. = Education
5. Env't = Environment

The remaining four models take into account the structural characteristics of collaborative policy network and the attributes of policy within these actors. The “strategic decision model” (SDM), which is a slightly modified version of Lubell et al. (2014, p. 7), captures how collaboration decisions are mediated by network structure (bridging and bonding social capitals) and policy actors’ attributes (principled engagement and increased capacity for joint action). The SDM fails to accept hypothesis 1 (high centralization or bridging social capital drives collaboration ties) but accepts hypothesis 2 (transitive closure or bonding social capital drives collaboration ties), hypothesis 5a (policy actors’ participation in policy institutions or collaboration groups), and hypothesis 5b (collaboration ties decreases if the number of collaborative groups a policy actor participates in exceeds a threshold).

The SDM shows that collaboration ties within the MRG policy network is not driven by bridging social capital or highly centralized policy actors (positive and statistically significant GWD parameter) but by bonding social capital or policy actors forming transitive closure (positive and statistically significant GWESP parameter). For the GWESP, the SDM shows that two policy actors are more than 600% more likely to be connected if they share a common partner [$6.11 = \exp(1.81)$]. This characterizes the MRG's collaborative policy network as mainly a decentralized structure whereby policy actors build ties based on trust to address cooperation dilemmas in governing this urban watershed. # Participation Groups has a positive and significant impact. A unit increase in # participation groups increases by 15% [$\exp(0.14)$] the likelihood that the policy actor will collaborate with another policy actor. However, collaboration ties diminish, by a very small margin (the odds of observing a tie decreases by 1%), when the number of collaborative groups exceeds a certain threshold. This suggests that there could be an optimal size of urban water governance. This also provides some evidence of policy actors having less benefit if they already participate in multiple collaborative groups (Margerum, 2007). The Bayesian Information Criterion (BIC) shows that the SDM is better (BIC=10,842) than the naïve model (BIC=12,383).

The “political capacity model” (PCM), similar to Lubell et al. (2014, p. 7), explains how collaborative ties are driven by the activities of different policy actors. The ‘activities of local government actors’ is used as the reference group in this model. The result shows 1) two types of policy actors—Federal and state government actors—with significantly higher level of activity than local government actors, and 2) one type of policy actor—nonprofit environmental groups with significantly higher level of activity than local

government actors. The PCM accepts the actor hypothesis, framed in this paper as hypothesis 3, that collaboration ties in governing the MRG urban watershed is driven by federal and state government actor activities. These policy actors have greater capacities and access to more resources and power to influence coordination and cooperation mechanisms in policy decisions. The BIC of the DCM (12, 006), although better than that of the naïve model, performs poorly against the SDM.

The SDM and PCM are combined with the political homophily term to develop the strategic political decision model (SPDM). The SPDM controls for the types of policy actors, the types of collaboration ties they form (bonding and/or bridging social capitals), whether such collaboration ties are influenced by their participation in collaborative groups, and whether they consider it strategic to collaborate with similar policy actors. Like the SDM, the SPDM shows decentralization (positive and statistically significant GWD parameter), building bonding ties (positive and statistically significant GWESP parameter), positive and statistically significant term for the number of (#) participation groups, and negative and statistically significant term for the square of #Participation Groups. We see that only federal government actors have statistically significant higher levels of activity compared to local government actors. This suggests that strategic political decisions in collaboration are best made by federal governments which have relatively more access to greater capacities and access to more resources and power. Again, the SPDM also supports hypothesis 4 that political homophily drives collaboration ties in governing the MRG urban watershed. The SPDM is a better model of explaining the MRG's collaborative policy network because its BIC of 10,665 is better than that of the SDM, PCM, and the naïve model.

The final model includes the variable of interest, the functional polycentric governance term, to the SPDM to develop the strategic political-economy decision model (SPEDM). This is the best fitting model (with the lowest BIC) of the observed collaborative policy network in governing the MRG's urban watershed. The goodness-of-fit for this mode is shown in Figure 4.6. It tests for model degeneracy (Handcock, 2003; Kolaczyk, 2009). The three plots in Figure 6 show that the SPEDM is a good fit since simulated networks from this model closely matches the sparseness of the observed MRG collaborative policy network (shown as the solid line in all the three plots).

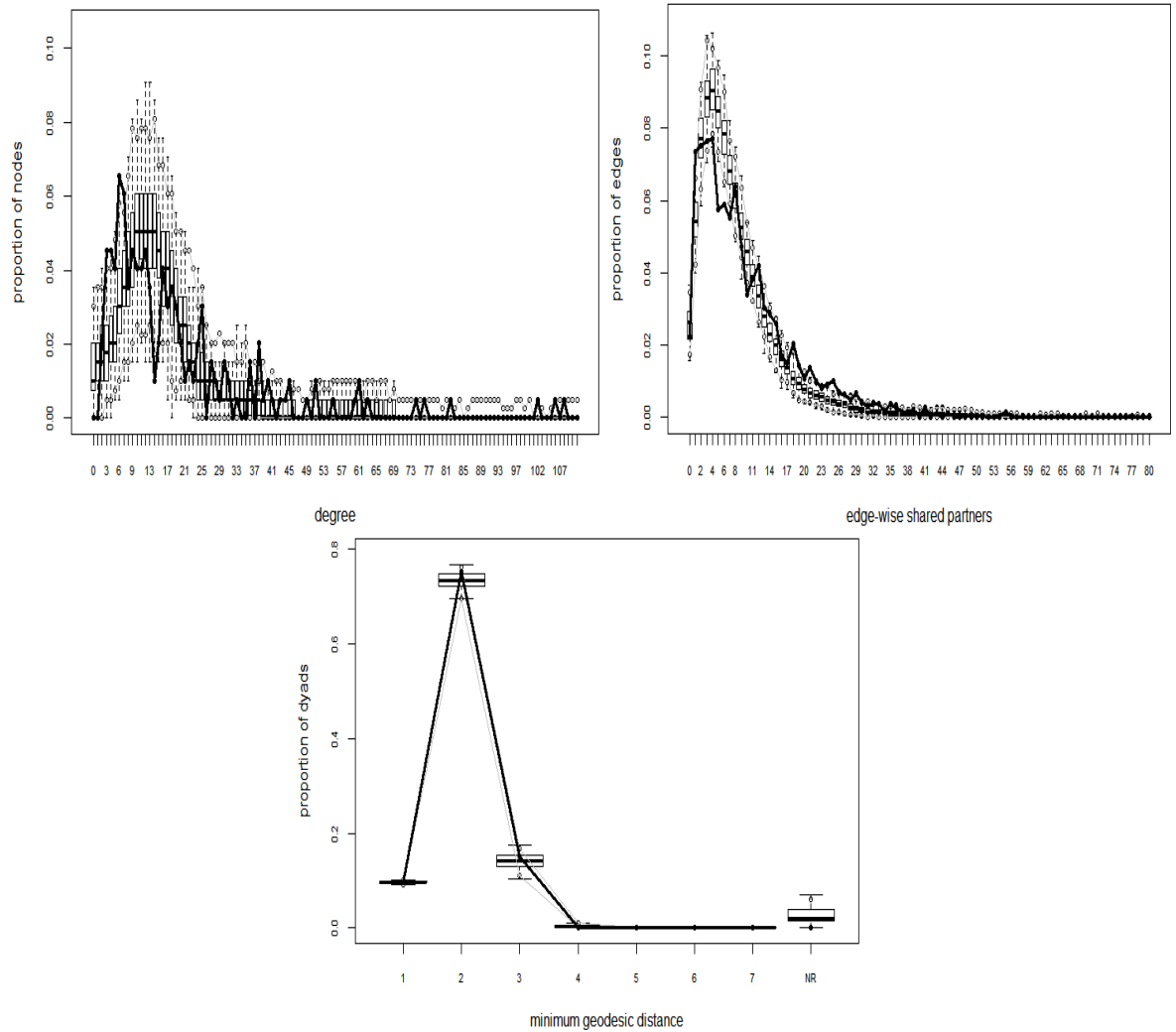


Figure 4.6: Goodness-of-Fit Diagnostics for the SPEDM

Consistent with the SPDM, the SPEDM shows positive and statistically significant #participation groups, negative and statistically significant square of #Participation Groups, and positive and statistically significant political homophily. Apart from it being a strong, positive and statistically significant predictor of collaboration ties, the inclusion of the functional polycentric index brings to the fore two results. Firstly, unlike the SDM and the SPDM, the GWD term is negative and statistically significant. This supports the first hypothesis that high centralization (bridging social capital) drives collaboration ties

between policy actors. Secondly, state government actors and SWCDs are the only policy actors with significantly higher level of activity than local government actors. Therefore, the SPEDM supports all the hypotheses except for the third hypothesis. It does not support wholly the hypothesis that collaboration ties in governing the MRG urban watershed is driven by federal and state government actors. These two and the other SPEDM results will be the focus in the paper's discussion section.

4.8 Discussion and Conclusion

There are two key findings which explain the dynamics of interorganizational collaboration within a polycentric ecology of water policy games in governing the MRG urban watershed. Firstly, the SPEDM results show that collaboration is driven by polycentric governance because it satisfies the dual conditions of segmentation and a statistically significant functional polycentric governance parameter. Recall that the segmentation condition (hypothesis 6a) means negative and statistically significant bridging social capital (centralization) as well as positive and statistically significant bonding social capital/transitive closure (decentralization)—the Lubell-Robins-Wang polycentric hypothesis (Lubell et al. 2014). Hypothesis 6a, in essence, is a breakdown and support of hypotheses 1 (centralization) and 2 (decentralization). Again, a positive and statistically significant polycentric index means that the probability of a collaboration tie between policy actors improves when policy actors make strategic decisions to connect with other policy actors operating within different sectors and at different governing scales within the system. In the SPEDM, the odds of observing a collaborating tie between two policy actors increases by 11% with a unit increase in a policy actor's polycentric index—that is, if a policy actor makes a strategic decision to connect with a policy actor operating

with a different sector and at a different governing scale. Policy actors make strategic collaboration decisions bounded by the constraints and opportunities presented within their politico-economic environment.

The segmentation hypothesis unpacks the coupling of hierarchical and non-hierarchical relationships as policy actors wrestle with coordination and cooperation dilemmas in governing social-ecological systems. The support of the segmentation hypothesis by the SPEDM and Lubell et al.'s (2014, p. 7) "strategic geography model" shows that the EG framework is about the synergy of, not tradeoff between (Berardo & Scholz, 2010), centralization and decentralization. The co-existence of hierarchical and non-hierarchical institutions promotes institutional diversity (Ostrom, 2005). This creates opportunities for policy learning and innovation (i.e. trial-and-error evolutionary process) as policy actors find the "institutional fit" to address coordination and cooperation dilemmas in governing complex social-ecological systems like the MRG's urban watershed (Lebel, Nikitina, Pahl-Wostl, & Knieper, 2013; Lubell et al., 2014; E. Ostrom, 2005).

The co-constitution of hierarchical and non-hierarchical relational structures within the MRG's ecology of water policy games also highlights the argument that polycentricity exists within monocentricity and vice versa (McGinnis, 1999; V. Ostrom, 1999[1972]). The SPEDM shows strong centralization (coefficient of -0.78) compared to decentralization (coefficient of 0.33). This conveys a core-periphery collaborative policy network structure segmented into a chain of smaller cohesive (decentralized) subgroup areas within the network (Robins, Pattison, et al., 2007). In other words, the policy network in governing the MRG urban watershed is polycentric within a largely monocentric system.

Hierarchical structures could facilitate policy actors' effort to solve coordination and cooperation dilemmas through means such as: providing the needed forum for policy actors to dialogue and resolve conflicts; assisting in monitoring the behavior of policy actors especially in large social-ecological systems; and creating the needed legal and democratic environment to legitimize coordination and cooperation practices among policy actors (Lubell, 2004a; E. Ostrom, 1990, 1999a; Sarker, 2013). For instance, the MRG is currently part of the 19 urban watersheds selected by the U.S. Environmental Protection Agency under the "Urban Waters Federal Partnership" to encourage collaboration among multiple organizations in revitalizing urban water resources.

Secondly, state government actors and SWCDs are the only policy actors with significantly higher level of activity than local government actors within the MRG. The fact that SWCDs have strong significance ($p\text{-value} < 0.001$) compared to state government actors supports the view that SWCDs are well-organized and represent the more powerful interests in the ecology of water policy games (Lubell & Lippert, 2011; Lubell et al., 2014). Again, the fact that the activities of SWCDs and state government actors become significant in the SPEDM points to two issues about the role of polycentrism in MRG's ecology of urban water policy games. Firstly, the activities of policy actors within an EG framework is best captured if we control for their strategic collaboration decisions across multiple scales and multiple sectors. That is, the actor hypothesis must account for the scale(s) and sector(s) within which policy actors operate. Federal government actors in the PCM and the SPDM were highly active compared to local government actors probably because their connections were mainly to themselves (connecting to actors within the same federal governing scale) and/or to other government actors (connecting to actors within the

same political sector). Secondly, a polycentric ecology of urban water policy games, shown in the case of the MRG collaborative policy network, implies that traditional hierarchical institutional structures (e.g. state government actors and SWCDs) help to solve coordination and cooperation dilemmas if they collaborate with policy actors across multiple governing scales and within multiple sectors.

4.9 Conclusion

This paper brings together several hypotheses derived from the ecology of games literature to examine the governance of an urban watershed. However, there are still many unknowns. For instance, it is important to explore how these hypotheses might still hold in different urban watersheds both within the U.S. and international contexts. Doing so could assist with the development of a meta-theory of governance dynamics within the EG framework. Again, engaging polycentric governance methodologically is often hijacked by the fuzziness in defining the concept. This paper contributes by integrating multiple conceptual and epistemological traditions to frame and provide a robust test of polycentric governance (see also Author, forthcoming). Future research is aimed at exploring this area especially within the EG framework. Finally, future research could test interesting hypotheses on polycentric governance within the urban ecology of water policy games (emergence and dissolution of ties within a polycentric system) using longitudinal data. A dynamic network model or an agent-based network model holds promise to test whether polycentric governance is a cause or effect of interorganizational collaboration.

CHAPTER V CONCLUSION

5.1 Introduction

More than four decades after Hardin's (1968) seminal piece, the (under)supply of institutions to govern social-ecological systems has been an enduring discourse among (neo)institutional economics, political science, environmental and allied scholars. E. Ostrom's (1990) challenge of the prevailing orthodoxy—the state-market institutional prescriptions—marked a critical juncture in the literature on how to govern social-ecological systems. Based on the famous IAD framework and design principles, Ostrom and other scholars argued that there are certain conditions animating actors to collaborate and cooperate to self-govern their commons (Cox, Sadiraj, & Sadiraj, 2008; E. Ostrom, 1999b, 2005, 2007; Edella Schlager, 1994). Other frameworks such as the Advocacy Coalition Framework (Jenkins-Smith & Sabatier, 1994; Sabatier, 1988, 1998) and Institutional Collaborative Action (ICA) framework (Feiock & Scholz, 2009; Feiock et al., 2009), often seen as complementary to the IAD Framework (Edella Schlager, 2007), also proffer conditions under which actors collaborate and cooperate in governing social-ecological systems. In other words, the 'basket of institutions' that could be supplied to govern social-ecological systems contain more than the bifurcated state-market institutional prescriptions.

The ecology of games framework, an update of Norton Long's "ecology of games", builds on the IAD and other frameworks to explain the conditions under which collaboration and cooperation emerge among actors. It presents itself as framework that supports and synthesizes multiple theories and methods—meta theory and method framework of governance dynamics. Presented as "a theory of polycentric governance", Lubell (2013, p. 538) centralizes an important cornerstone, a defining feature of the Bloomington School of Political Economy, of the IAD framework: there is no panacea in governing social-ecological systems; in reality, an effective governing systems is constituted by polycentric public economies involving a diversity of institutional arrangements (E. Ostrom, 2000; 2010b, p. 552). The essays in this dissertation 1) offered both theoretical and methodological means to enact polycentric public economies within the ecology of games framework, and 2) explicated the conditions under which interorganizational collaboration is fostered within a polycentric ecology of policy games in governing the Middle Rio Grande urban watershed. The next sections of the chapter delineates the specific theoretical, methodological and policy contributions of the essays. The discussions here are interlaced with suggestions for future research.

5.2 Theoretical Contributions

Chapter two explicated the conceptual tenets of a polycentric urban water governance system by synthesizing three theoretical efforts on polycentric governance, polycentric urban regions, and SENA framework. First, the chapter contributes to the literature by offering conceptual bridges among hitherto disparate theoretical efforts in political science, (neo)institutional economics, spatial planning, environmental management and conservation biology. In social-ecological research, scholars such as

Collins et al. (2011) have long called for scholarships that cross disciplinary lines to “bridge the biophysical and social domains” (see also E. Ostrom, 2007; Edella Schlager, 2007). The relevance and implications of polycentric governance in social-ecological research relies on such interdisciplinary efforts to minimize conceptual and definitional ambiguity and fuzziness which also cripples methodological and empirical engagements of polycentric governance.

Second, the delineated five tenets of polycentric water governance offers theoretical refinement to the ecology of games framework. Specifically, polycentricity in the ecology of games should, among others, be specific as to the 1) existence of multiple actors, 2) presence of functional linkages between these actors, 3) embeddness of actors within geopolitical jurisdictions (i.e. ecolocial units) which represents multiple governing scales, 4) relative autonomy of actors within the governing system even as they form scale bridging ties with other actors, and 5) operation of actors within multiple sectors—*islands of polycentric order*. In its current form, the ecology of games framework addresses the first two but not the remaining three conditions (see Lubell, 2013; Lubell et al., 2010; Lubell et al., 2014).

Third, by incorporating these five tenets into the ecology of games framework, we begin to properly contextualize the centrality of power and resource distribution within this framework, at least in the case of the MRG. As shown in the third chapter, despite the presence of more nonprofit actors than political and market actors within the MRG, more connections (SMBEs) are formed with political actors. We also see that the density of SMBEs is relatively higher between local-regional (political) actors than between local-local actors. Again, an actor’s FPGI is positively and significantly related to its political

influence (closeness centrality) and ability to control information flow (technical/information capacity) within the network (betweenness centrality). Describing the ecology of games framework as a theory of polycentric governance, especially in governing social-ecological systems, should centralize the politics of power and resource distribution (see Bulkeley, 2005; Huitema et al., 2009; McGinnis, 2011). In fact, the fourth chapter makes this point more explicitly when the SPEDM results showed that, compared to local government actors, the probability of collaborative ties forming between actors within the MRG increases with the presence and activities of state government actors and SWCDs. The role of these traditional, hierarchical and political authorities in solving collaboration and cooperation dilemmas in governing social-ecological systems needs further exploration by scholars working at the nexus of social-ecological systems and polycentric governance (see examples of such needed works in DeCaro et al., forthcoming; Sarker, 2013).

Finally, describing the ecology of games as a theory of polycentric governance requires incorporating both form (structure) and agentic (decisions/actions of actors) aspects of human-ecological processes. A governing structure *appears* polycentric when it is composed of centralized and decentralized institutional arrangements—discussed in the fourth chapter as the segmentation or the Lubell-Wang-Robins hypothesis (Lubell et al., 2014). The current version of ecology of games, therefore, privileges the structure formed over the continuous strategic decisions and actions of actors in creating the overall polycentric governing structure. The result, then, is to fall into a teleological explanation of why the ecology of games could be described as a theory of polycentric theory. As the SPEDM results shows, the following speaks little or nothing about the role of polycentric

governance in the MRG's collaborative policy network: the segmented nature of collaborative policy network; and the existence of multiple federal, state, local, business, nonprofit, and market actors within the MRG governing system. However, the role of polycentric governance in interorganizational collaboration becomes clear when we account for their FPGI—the strategic decisions of actors as they with other actors operating within different sectors and at different governing scales within the governing system. More of such micro-analytic lens is needed to understand how a polycentric governing system is continuously shaped as a result of the 'unintended' and boundedly rational decisions and actions of actors as they collaborate and cooperate in governing the commons.

5.3 Methodological Contributions

The third and fourth chapters provide methodological tools, grounded in social network theory and analysis, and SENA, to contextualize defining concepts and debates in the literature on polycentrism. For instance, Aligica and Tarko (2012) and V. Ostrom (1999[1972]) notes that the argument that polycentric governance shapes and is also shaped by polycentric order within multiple pulsating polycentric domains needs to be made explicit through empirical testing. However, they aver that “Not only that a proper language and concepts needed to map, describe, and analyze polycentric systems were lacking, but even worse, the existent language in political science was deeply contaminated by the monocentric vision...That meant that the existent conceptual frameworks and their associated vocabulary needed to be tested, refocused, and reconfigured in way that would make their limits and preconceptions explicit” (Aligica & Tarko, 2012, p. 248). In other

words, we are faced with questions like how do we provide the empirics of 1) these multiple pulsating domains, and 2) the interactions between these domains?

Chapter 3 uses social network and SENA methods to provide three pulsating domains in governing the MRG urban water commons—political, nonprofit, and market polycentric orders. The chapter also uses bivariate regression to test the relationships among these pulsating domains. However, as noted in the chapter, there is more to the dynamic relationship among these polycentric domains, as discussed by V. Ostrom (1999[1972]) and Aligica and Tarko (2012). This chapter begins the process of dealing with the dynamics. Dynamic network models and agent-based simulations could be used in this regard to explore 1) how polycentrism (both actor- and system-level FPGI) evolves, and 2) how islands of polycentric orders are constituted as a result of actors' strategic decisions and (re)alignments of interests over time.

Again, the fourth chapter also provides a methodological approach to contextualize the debate about the normative goal of polycentrism. Some scholars have challenged the normative focus of polycentrism (e.g. Davoudi, 2003; Huitema et al., 2009) and others, such as social-ecological scholars (e.g. Chaffin et al., 2014; Cosens & Williams, 2012; Folke, 2007; Folke et al., 2005) also prescribe it as a key institutional arrangement for adaptive and resilient social-ecological systems. Somewhere in-between these bifurcated arguments are other scholars who believe that polycentrism needs to be made analytically relevant through 1) moving beyond the normative and descriptive and 2) engaging it with more empirical tests (e.g. Green, 2007; Lieberman, 2011; Lubell, 2013). This also means moving beyond system level analysis of polycentrism by examining the actions and decisions of the actors who shape and are shaped by the system. This gets us closer to the

Polanyi (1951) logic of polycentrism—a governing system centered on individuals and the exercise of their autonomy and liberty in opinions as they make strategic decisions.

The FPGI, a scalable index measuring both individual- and system-level polycentrism and as used in the SPEDM in the fourth chapter shows that the probability of interorganizational collaboration increases when we control for actor level FPGI—actors’ strategic decision to connect with others within different sectors and at different governing scales. Thus, by engaging polycentrism as an analytical concept, this dissertation can make a normative claim, in the case of the MRG, that the probability of interorganizational collaboration in governing the urban water commons increases as a result of polycentrism. But more empirical evidence is needed across multiple contexts and temporalities before such normative claims can be concretized and generalized.

5.4 Conclusion: No Panacea!

It goes without saying that this dissertation resists the temptation to offer panacea in governing the urban water commons. In terms of policy contribution, the results from the dissertation (specifically the SPEDM in chapter 4) shows that both centralized and decentralized institutional arrangements support inter-organizational collaboration in urban water resource governance. This generally supports the Ostrom logic that there is no one-size-fit-all solution (e.g. institutions and/or policies) to govern social-ecological resources. Again, the activities of traditional hierarchical organizations, state and SWCDs in the case of the MRG, also support interorganizational collaboration. The supports provided by these traditional hierarchical organizations, such as support in the form of technical, information, and financial resources as well as serving as an avenue to resolve conflicts from these organizations, are potentially vital policy interventions in dealing with

collaboration and cooperative dilemmas in restoring, managing, and sustaining social-ecological systems (see also Lubell, 2004b; Robins, Bates, & Pattison, 2011). Again, actors' participation in collaborative organizations also increases the probability of interorganizational collaboration among actors within the MRG. Sponsoring collaborative groups, such as the Federal Urban Watershed Partnership by the U.S. EPA, should still be viable policy options in dealing with ecological planning and restoration efforts (see also Lubell et al., 2002; Weible, Sabatier, & Lubell, 2004). The policy path to governing the urban water commons are many and the onus till lies with researchers and policy makers to explore these paths if we are to avoid proffering panacea in governing social-ecological systems.

REFERENCES

- Agrawal, A. (2002). Common resources and institutional sustainability. In C. H. D. G. Change, E. Ostrom, T. Dietz, N. Dolsak, P. C. Stern, S. Stonich, E. U. Weber, B. E. C. Society, D. B. S. S. Education, & N. R. Council (Eds.), *The Drama of the Commons* (pp. 41-85). D.C., Washington: National Academies Press.
- Aligica, P. D. (2014). *Institutional Diversity and Political Economy: The Ostroms and Beyond*. Oxford, UK.: Oxford University Press.
- Aligica, P. D., & Boettke, P. J. (2009). *Challenging institutional analysis and development: the Bloomington school*. New York: Routledge.
- Aligica, P. D., & Tarko, V. (2012). Polycentricity: from Polanyi to Ostrom, and beyond. *Governance*, 25(2), 237-262.
- Angst, M., & Hirschi, C. (2016). Network Dynamics in Natural Resource Governance: A Case Study of Swiss Landscape Management. *Policy Studies Journal*.
- Ansell, C., & Gash, A. (2008). Collaborative governance in theory and practice. *Journal of public administration research and theory*, 18(4), 543-571.
- Anthonisse, J. M. (1971). The rush in a directed graph. *Stichting Mathematisch Centrum. Mathematische Besliskunde*(BN 9/71), 1-10.
- Bailey, N., & Turok, I. (2001). Central Scotland as a polycentric urban region: useful planning concept or chimera? *Urban Studies*, 38(4), 697-715.
- Bates, R. H. (1988). Contra contractarianism: some reflections on the new institutionalism. *Politics & Society*, 16(2-3), 387-401.

- Batty, M. (2001a). Cities as small worlds. *Environment and Planning B: Planning and Design*, 28(5), 637-638.
- Batty, M. (2001b). Polynucleated urban landscapes. *Urban Studies*, 38(4), 635-655.
- Baumgartner, T., & Pahl-Wostl, C. (2013). UN–Water and its role in global water governance. *Ecology and Society*, 18(3), 3.
- Bednar, J., & Page, S. (2007). Can game (s) theory explain culture? The emergence of cultural behavior within multiple games. *Rationality and Society*, 19(1), 65-97.
- Benson, M. H., Llewellyn, D., Morrison, R., & Stone, M. (2014). Water Governance Challenges in New Mexico's Middle Rio Grande Valley: A Resilience Assessment. *Idaho L. Rev.*, 51, 195.
- Bentley, A. (1949). *The Process of Government*. Evanston, IL: Principia Press.
- Berardo, R. (2009). Processing complexity in networks: A study of informal collaboration and its effect on organizational success. *Policy Studies Journal*, 37(3), 521-539.
- Berardo, R., & Lubell, M. (2016). Understanding What Shapes a Polycentric Governance System. *Public Administration Review*.
- Berardo, R., & Scholz, J. T. (2010). Self-Organizing Policy Networks: Risk, Partner Selection, and Cooperation in Estuaries. *American Journal of Political Science*, 54(3), 632-649.
- Bergsten, A., Galafassi, D., & Bodin, Ö. (2014). The problem of spatial fit in social-ecological systems: detecting mismatches between ecological connectivity and land management in an urban region. *Ecology and Society*, 19(4), 6.
- Blomley, N. (2008). Enclosure, common right and the property of the poor. *Social & Legal Studies*, 17(3), 311-331.

- Blomquist, W., & Schlager, E. (2005). Political pitfalls of integrated watershed management. *Society and Natural Resources*, 18(2), 101-117.
- Bodin, Ö., Crona, B., Thyresson, M., Golz, A.-L., & Tengö, M. (2014). Conservation success as a function of good alignment of social and ecological structures and processes. *Conservation Biology*, 28(5), 1371-1379.
- Bodin, Ö., & Crona, B. I. (2009). The role of social networks in natural resource governance: What relational patterns make a difference? *Global Environmental Change*, 19(3), 366-374.
- Bodin, Ö., & Tengö, M. (2012). Disentangling intangible social–ecological systems. *Global Environmental Change*, 22(2), 430-439.
- Boland, J. J., & Baumann, D. D. (2009). Water resources planning: past, present and future. In C. S. Russell & D. D. Baumann (Eds.), *The Evolution of Water Resource Planning and Decision Making*. Northampton, MA: Edward Elgar.
- Borg, R., Toikka, A., & Primmer, E. (2015). Social capital and governance: a social network analysis of forest biodiversity collaboration in Central Finland. *Forest Policy and Economics*, 50, 90-97.
- Bourdieu, P. (1985). The forms of capital. In J. G. Richardson (Ed.), *Handbook of Theory and Research for the Sociology of Education* (pp. 241-258). New York: Greenwood.
- Brandes, U. (2008). On variants of shortest-path betweenness centrality and their generic computation. *Social Networks*, 30(2), 136-145.
- Brennan, G., & Buchanan, J. (1984). Voter Choice: "Evaluating Political Alternatives". *The American Behavioral Scientist*, 28(2), 185.

- Buchanan, J. (1965). An economic theory of clubs. *Economica*, 32(125), 1-14.
- Buchanan, J. (1979). Politics without romance : a sketch of positive public choice theory and its normative implications. Inaugural lecture, Institute for Advanced Studies, Vienna, Austria. *IHS Journal, Zeitschrift des Instituts für Höhere Studien*, 3(B1–B11).
- Bulkeley, H. (2005). Reconfiguring environmental governance: Towards a politics of scales and networks. *Political Geography*, 24(8), 875-902.
- Burger, M., & Meijers, E. (2012). Form follows function? Linking morphological and functional polycentricity. *Urban Studies*, 49(5), 1127-1149.
- Burt, R. S. (1975). Corporate society: A time series analysis of network structure. *Social Science Research*, 4(4), 271-328.
- Burt, R. S. (1983). *Corporate profits and cooptation: Networks of market constraints and directorate ties in the American economy*. New York: Academic Press.
- Burt, R. S. (2005). *Brokerage and closure: An introduction to social capital*. Oxford, UK: Oxford University Press.
- Butts, C. T. (2008). network: a Package for Managing Relational Data in R. *Journal of statistical software*, 24(2), 1-36.
- Buynak, B., & Oglesby, A. B. (2014). Water for New Mexico Rivers. In S. D. Bushnell (Ed.), *Water Matters!* New Mexico: The Utton Transboundary Resources Center, The University of New Mexico School of Law.
- Cairney, P. (2013). Standing on the shoulders of giants: how do we combine the insights of multiple theories in public policy studies? *Policy Studies Journal*, 41(1), 1-21.

- Camerer, C. (2003). *Behavioral game theory: Experiments in strategic interaction*. NJ: Princeton University Press.
- Campbell, J. L., Quincy, C., Osserman, J., & Pedersen, O. K. (2013). Coding in-depth semistructured interviews problems of unitization and intercoder reliability and agreement. *Sociological Methods & Research*, 0049124113500475.
- Carley, K., & Hummon, N. (1993). Scientific influence among social networkers. *Social Networks*, 15, 71-108.
- Carlsson, L. G., & Sandström, A. C. (2008). Network governance of the commons. *International Journal of the Commons*, 2(1), 33-54.
- Carpenter, S. R., & Brock, W. A. (2008). Adaptive capacity and traps. *Ecology and Society*, 13(2), 40.
- Chaffin, B. C., Gosnell, H., & Cosens, B. A. (2014). A decade of adaptive governance scholarship: Synthesis and future directions. *Ecology and Society*, 19(3).
- Christenson, J. A., & Sachs, C. E. (1980). The Impact of Government Size and Number of Administrative Units on the Quality of Public Services. *Administrative science quarterly*, 25(1), 89-101. doi:10.2307/2392228
- Cohen, A., & Davidson, S. (2011). The watershed approach: Challenges, antecedents, and the transition from technical tool to governance unit. *Water alternatives*, 4(1), 1.
- Coleman, J. S. (1988). Social capital in the creation of human capital. *American Journal of Sociology*, S95-S120.
- Collingridge, D. (1992). *The management of scale: big organizations, big decisions, big mistakes*. London, UK.: Routledge.

- Collins, S. L., Carpenter, S. R., Swinton, S. M., Orenstein, D. E., Childers, D. L., Gragson, T. L., . . . Whitmer, A. C. (2011). An integrated conceptual framework for long-term social–ecological research. *Frontiers in Ecology and the Environment*, 9(6), 351-357. doi:10.1890/100068
- Coombes, M. G., Green, A. E., & Openshaw, S. (1986). An efficient algorithm to generate official statistical reporting areas: the case of the 1984 travel-to-work areas revision in Britain. *Journal of the operational research society*, 37(10), 943-953.
- Copus, A. K. (2001). From core-periphery to polycentric development: concepts of spatial and aspatial peripherality. *European Planning Studies*, 9(4), 539-552.
- Cosens, B. A., & Williams, M. (2012). Resilience and water governance: adaptive governance in the Columbia River basin. *Ecology and Society*, 17(4), 3.
- Cox, J. C., Friedman, D., & Gjerstad, S. (2007). A tractable model of reciprocity and fairness. *Games and Economic Behavior*, 59(1), 17-45.
- Cox, J. C., Sadiraj, K., & Sadiraj, V. (2008). Implications of trust, fear, and reciprocity for modeling economic behavior. *Experimental Economics*, 11(1), 1-24.
- Cresswell, T. (2013). *Geographic Thought: A Critical Introduction*. UK: Wiley-Blackwell.
- Crowder, L. B., Osherenko, G., Young, O. R., Airamé, S., Norse, E. A., Baron, N., . . . Halpern, B. S. (2006). Resolving mismatches in US ocean governance. *Science*, 313(5787), 617.
- Cumming, G. S., Bodin, Ö., Ernstson, H., & Elmqvist, T. (2010). Network analysis in conservation biogeography: challenges and opportunities. *Diversity and Distributions*, 16(3), 414-425.

- Cumming, G. S., Cumming, D. H., & Redman, C. L. (2006). Scale mismatches in social-ecological systems: causes, consequences, and solutions. *Ecology and Society*, 11(1), 14.
- Dagan, H., & Heller, M. A. (2001). The liberal commons. *Yale Law Journal*, 549-623.
- Dahl, R. A., & Lindblom, C. E. (1953). *Politics, economics, and welfare*. New York: Harper and Bros.
- Davoudi, S. (2003). EUROPEAN BRIEFING: Polycentricity in European spatial planning: from an analytical tool to a normative agenda. *European Planning Studies*, 11(8), 979-999.
- Davoudi, S. (2007). *Polycentric development and metropolitan governance*. Paper presented at the Social Policy and Regional Development.
- Davoudi, S. (2008). Conceptions of the city-region: a critical review. *Urban Design and Planning*, 161(2), 51-60.
- DeCaro, A. D., Chaffin, B., Schlager, E., Garmestani, A. S., & Ruhl, J. B. (forthcoming). Legal and Institutional Foundations of Adaptive Environmental Governance. *Ecology and Society*.
- DeCaro, A. D., & Stokes, K. M. (2013). Public participation and institutional fit: a social-psychological perspective. *Ecology and Society*, 18(4). doi:10.5751/ES-05837-180440
- Demsetz, H. (1983). The structure of ownership and the theory of the firm. *The Journal of law & economics*, 26(2), 375-390.
- Dietz, T., Ostrom, E., & Stern, P. C. (2008). The struggle to govern the Commons *Urban Ecology* (pp. 611-622): Springer.

- Dinar, A., Kemper, K., Blomquist, W., Diez, G., Sine, M., & Fru, W. (2005). *Decentralization of river basin management. A global analysis*. Washington, D.C., USA.: World Bank.
- Downs, A. (1957). An Economic Theory of Political Action in a Democracy. *Journal of Political Economy*, 65(2), 135-150.
- Edelman, M. (1985). *The symbolic uses of politics*. Chicago: University of Illinois Press.
- Eizenberg, E. (2012). Actually existing commons: three moments of space of community gardens in New York City. *Antipode*, 44(3), 764-782.
- Emerson, K., Nabatchi, T., & Balogh, S. (2012). An integrative framework for collaborative governance. *Journal of public administration research and theory*, 22(1), 1-29.
- Ernstson, H., Barthel, S., Andersson, E., & Borgström, S. T. (2010). Scale-crossing brokers and network governance of urban ecosystem services: the case of Stockholm. *Ecology and Society*, 15(4), 28.
- Evans, M. (2001). Understanding dialectics in policy network analysis. *Political Studies*, 49(3), 542-550.
- Farias, I., & Bender, T. (2009). *Urban Assemblages: How Actor-Network Theory Changes Urban Studies*. London: Routledge.
- Fehr, E., & Leibbrandt, A. (2011). A field study on cooperativeness and impatience in the tragedy of the commons. *Journal of Public Economics*, 95(9), 1144-1155.
- Feiock, R. C., & Scholz, J. T. (2009). *Self-organizing federalism: Collaborative mechanisms to mitigate institutional collective action dilemmas*. New York: Cambridge University Press.

- Feiock, R. C., Steinacker, A., & Park, H. J. (2009). Institutional collective action and economic development joint ventures. *Public Administration Review*, 69(2), 256-270.
- Folke, C. (2007). Social–ecological systems and adaptive governance of the commons. *Ecological research*, 22(1), 14-15.
- Folke, C., Hahn, T., Olsson, P., & Norberg, J. (2005). Adaptive governance of social-ecological systems. *Annu. Rev. Environ. Resour.*, 30, 441-473.
- Folke, C., Pritchard, L., Berkes, F., Colding, J., & Svedin, U. (2007). The problem of fit between ecosystems and institutions: ten years later. *Ecology and Society*, 12(1), 30.
- Frank, O., & Strauss, D. (1986). Markov graphs. *Journal of the American Statistical Association*, 81(395), 832-842.
- Friesema, H. P. (1966). The metropolis and the maze of local government. *Urban Affairs Review*, 2(2), 68-90.
- Garnett, N. S. (2011). *Managing the urban commons*. Paper presented at the Essay for the November 2011 University of Pennsylvania Law Review Symposium on “New Dimensions in Property Theory.”
- Geddes, P. (1968[1915]). *Cities in Evolution*. London: Ernest Benn Ltd.
- Gillespie, T. (2016). Accumulation by urban dispossession: struggles over urban space in Accra, Ghana. *Transactions of the Institute of British Geographers*, 41(1), 66-77.
- Global Water Partnership. (2002). *Towards Water Security: A Framework for Action*. Stockholm: Global Water Partnership.

- Goodreau, S. M., Handcock, M. S., Hunter, D. R., Butts, C. T., & Morris, M. (2008). A statnet Tutorial. *Journal of statistical software*, 24(9), 1-27.
- Governa, F., & Salone, C. (2005). Italy and European spatial policies: polycentrism, urban networks and local innovation practices 1. *European Planning Studies*, 13(2), 265-283.
- Granovetter, M. (1973). The strength of weak ties. *American Journal of Sociology*, 1360-1380.
- Granovetter, M. (1985). Economic action and social structure: the problem of embeddedness. *American Journal of Sociology*, 481-510.
- Green, N. (2007). Functional polycentricity: a formal definition in terms of social network analysis. *Urban Studies*, 44(11), 2077-2103.
- Griffin, C. B. (1999). Watershed councils: An emerging form of public participation in natural resource management. *Journal of the American Water Resources Association*, 35(3), 505-518.
- Grimm, N. B., Grove, J. G., Pickett, S. T., & Redman, C. L. (2000). Integrated Approaches to Long-Term Studies of Urban Ecological Systems Urban ecological systems present multiple challenges to ecologists—pervasive human impact and extreme heterogeneity of cities, and the need to integrate social and ecological approaches, concepts, and theory. *BioScience*, 50(7), 571-584.
- Guerrero, A. M., McAllister, R., Corcoran, J., & Wilson, K. A. (2013). Scale Mismatches, Conservation Planning, and the Value of Social-Network Analyses. *Conservation Biology*, 27(1), 35-44.

- Gulick, L. (1957). Metropolitan organization. *Annals of the American Academy of Political and Social Science*, 314(1), 57-65.
- Gunderson, L. H., & Holling, C. S. (2002). *Panarchy : understanding transformations in human and natural systems*. Washington, DC: Island Press.
- Hall, P. (1984). *The World Cities*. London: Weidenfeld and Nicolson.
- Hall, P., & Pain, K. (2006a). From strategy to delivery: policy responses. In P. Hall & K. Pain (Eds.), *The Polycentric Metropolis: Learning from Mega-city Regions in Europe*. London: Earthscan.
- Hall, P., & Pain, K. (2006b). *The Polycentric Metropolis: Learning from Mega-city Regions in Europe*. London: Earthscan.
- Handcock, M. S. (2003). *Assessing degeneracy in statistical models of social networks*. Retrieved from <http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.81.5086&rep=rep1&type=pdf>
- Handcock, M. S., Hunter, R. D., Butts, T. C., Goodreau, M. S., & Morris, M. (2003). statnet: Software tools for the Statistical Modeling of Network Data.
- Hardin, G. (1968). The Tragedy of the Commons. *Science*, 162(3859), 1243-1248. doi:10.1126/science.162.3859.1243
- Hardin, G. (1978). Political requirements for preserving our common heritage. In H. P. Bokaw (Ed.), *Wildlife and America* (pp. 310-317). Washington, D.C.: Council on Environmental Quality.
- Harvey, D. (2011). The future of the commons. *Radical History Review*, Winter 2011(109), 101-107.

- Hayek, F. A. (1945). The use of knowledge in society. *American Economic Review*, 519-530.
- Heckathorn, D. D., & Maser, S. M. (1987). Bargaining and the sources of transaction costs: The case of government regulation. *Journal of Law, Economics, & Organization*, 69-98.
- Heclo, H. (1978). Issue networks and the executive establishment. In A. King (Ed.), *The new American political system* (Vol. 501). Washington, DC: American Enterprise Institute.
- Hobbes, T. (1960[1651]). *Leviathan or the Matter, Forme and Power of a Commonwealth Ecclesiasticall and Civil*. In M. Oakeshott (Ed.). Oxford: Basil Blackwell.
- Hooghe, L., & Marks, G. (2001). *Multi-Level Governance and European Integration*. Lanham, Maryland: Rowman & Littlefield.
- Hooghe, L., & Marks, G. (2003). Unraveling the central state, but how? Types of multi-level governance. *American Political Science Review*, 97(02), 233-243.
- Horan, J., & Taylor, T. (1977). *Experiments in Metropolitan Government*. New York: Praeger.
- Howard, E. (1898). *To-morrow: A Path to Real Reform*. London: Swan Sonnenschein.
- Huitema, D., Mostert, E., Egas, W., Moellenkamp, S., Pahl-Wostl, C., & Yalcin, R. (2009). Adaptive water governance: assessing the institutional prescriptions of adaptive (co-) management from a governance perspective and defining a research agenda. *Ecology and Society*, 14(1), 26.
- Hunter, D. R. (2007). Curved exponential family models for social networks. *Social Networks*, 29(2), 216-230.

- Islam, S., Gao, Y., & Akanda, A. S. (2010). Water 2100: A synthesis of natural and societal domains to create actionable knowledge through AquaPedia and water diplomacy? In S. Khan, H. H. G. Savenije, S. Demuth, & P. Hubert (Eds.), *Hydrocomplexity: New Tools for Solving Wicked Water Problems* (pp. 193–197). Paris: IAHS.
- Islam, S., & Repella, A. C. (2015). Water Diplomacy: A Negotiated Approach to Manage Complex Water Problems. *Journal of Contemporary Water Research & Education*, 155(1), 1-10.
- Islam, S., & Susskind, L. (2012). *Water diplomacy: A negotiated approach to managing complex water networks*. New York: Routledge.
- Jenkins-Smith, H. C., & Sabatier, P. A. (1994). Evaluating the advocacy coalition framework. *Journal of Public Policy*, 14(02), 175-203.
- John, D. (1994). *Civic environmentalism*. Washington, DC: Congressional Quarterly Press.
- Jones, V. (1942). *Metropolitan Government*. Chicago: University of Chicago Press.
- Kaushal, S. S., & Belt, K. T. (2012). The urban watershed continuum: evolving spatial and temporal dimensions. *Urban Ecosystems*, 15(2), 409-435.
- Keating, M. (1995). Size, efficiency and democracy: consolidation, fragmentation and public choice. In D. Judge, G. Stoker, & H. Wolman (Eds.), *Theories of urban politics*. London; Thousand Oaks, Calif.: Sage Publications.
- Kolaczyk, E. D. (2009). *Statistical analysis of network data : methods and models*
- Krippendorff, K. (2004). *Content Analysis: An Introduction to Its Methodology*. Thousand Oaks, CA: Sage.

- Lebel, L., Nikitina, E., Pahl-Wostl, C., & Knieper, C. (2013). Institutional fit and river basin governance: a new approach using multiple composite measures. *Ecology and Society*, 18(1), 1.
- Lieberman, E. S. (2011). The perils of polycentric governance of infectious disease in South Africa. *Social science & medicine*, 73(5), 676-684.
- Lin, N. (2001). *Social capital : a theory of social structure and action*. Cambridge, UK: Cambridge University Press.
- Lind, M. (1997). A Horde of Lilliputian Governments. *The New Leader*, 6-7.
- Lindblom, C. E. (1959). The science of" muddling through". *Public Administration Review*, 79-88.
- Long, N. E. (1958). The local community as an ecology of games. *American Journal of Sociology*, 251-261.
- Lubell, M. (2004a). Collaborative environmental institutions: All talk and no action? *Journal of Policy Analysis and Management*, 23(3), 549-573.
- Lubell, M. (2004b). Resolving conflict and building cooperation in the National Estuary Program. *Environ Manage*, 33(5), 677-691.
- Lubell, M. (2013). Governing institutional complexity: The ecology of games framework. *Policy Studies Journal*, 41(3), 537-559.
- Lubell, M., Henry, A. D., & McCoy, M. (2010). Collaborative institutions in an ecology of games. *American Journal of Political Science*, 54(2), 287-300.
- Lubell, M., & Lippert, L. (2011). Integrated regional water management: a study of collaboration or water politics-as-usual in California, USA. *International Review of Administrative Sciences*, 77(1), 76-100.

- Lubell, M., Robins, G., & Wang, P. (2014). Network structure and institutional complexity in an ecology of water management games. *Ecology and Society*, 19(4), 23.
- Lubell, M., Schneider, M., Scholz, T. J., & Mete, M. (2002). Watershed Partnerships and the Emergence of Collective Action Institutions. *American Journal of Political Science*, 46(1), 148.
- Lubell, M., Scholz, J., Berardo, R., & Robins, G. (2012). Testing policy theory with statistical models of networks. *Policy Studies Journal*, 40(3), 351-374.
- Lundqvist, L. (2004). Integrating Swedish water resource management: a multi-level governance trilemma. *Local Environment*, 9(5), 413-424.
- Maass, A. (1951). *Nuddy Waters: The Army Engineers and the Nation's Rivers*. Cambridge, MA.: Havard University Press.
- Mann, J. (2007). Reservoir Runs through It: A Legislative and Administrative History of the Six Pueblos' Right to Store Prior and Paramount Water at El Vado. *Nat. Resources J.*, 47, 733.
- Margerum, R. D. (2007). Overcoming locally based collaboration constraints. *Society & Natural Resources*, 20(2), 135-152.
- Margerum, R. D. (2011). *Beyond consensus: Improving collaborative planning and management*. Cambridge: MIT Press.
- McFarlane, C. (2011). Assemblage and Critical Urbanism. *City: analysis of urban trends, culture, theory, policy, action*, 15(2), 204-224.
doi:10.1080/13604813.2011.568715

- McGinnis, M. (1999). *Polycentricity and Local Public Economies: Readings from the Workshop in Political Theory and Policy Analysis*. Ann Arbor, MI: University of Michigan Press.
- McGinnis, M. (2005). *Costs and challenges of polycentric governance*. Paper presented at the Workshop on analyzing problems of polycentric governance in the growing EU, Humboldt University, Berlin.
- McGinnis, M. (2011). Networks of adjacent action situations in polycentric governance. *Policy Studies Journal*, 39(1), 51-78.
- McGinnis, M. (2015). *Polycentric Governance in Theory and Practice: Dimensions of Aspiration and Practical Limitations*. Paper presented at the Polycentricity Workshop, Ostrom Workshop, Indiana University, Bloomington.
- McGinnis, M., & Ostrom, E. (2012). Reflections on Vincent Ostrom, public administration, and polycentricity. *Public Administration Review*, 72(1), 15-25.
- McPherson, M., Smith-Lovin, L., & Cook, J. M. (2001). Birds of a feather: Homophily in social networks. *Annual Review of Sociology*, 415-444.
- Meijers, E. (2005). Polycentric urban regions and the quest for synergy: is a network of cities more than the sum of the parts? *Urban Studies*, 42(4), 765-781.
- Mitchell, B. (1990). *Integrated water management; international experiences and perspectives*. London, UK.: Belhaven Press.
- Morris, M., Handcock, M. S., & Hunter, D. R. (2008). Specification of exponential-family random graph models: terms and computational aspects. *Journal of statistical software*, 24(4), 1548.
- Mostert, E. (2003). The challenge of public participation. *Water policy*, 5(2), 179-197.

- Mostert, E. (2012). Water management on the island of IJsselmonde 1000 to 1953: polycentric governance, adaptation, and petrification. *Ecology and Society*, 17(3).
- Mumford, L. (1938). *The Culture of Cities*. New York: Secker & Warburg.
- Murdoch, J. (2006). *Post-Structuralist Geography: A Guide to Relational Space*. London: Sage.
- Nagendra, H., & Ostrom, E. (2012). Polycentric governance of multifunctional forested landscapes. *International Journal of the Commons*, 6(2).
- Newman, M. E. (2005). A measure of betweenness centrality based on random walks. *Social Networks*, 27(1), 39-54.
- Newman, M. E., & Girvan, M. (2004). Finding and evaluating community structure in networks. *Physical review E*, 69(2), 026113.
- Nickerson, C., Ebel, R., Borchers, A., & Carriazo, F. (2011). *Major Uses of Land in the United States, 2007*. Retrieved from
- North, D. C. (1990). *Institutions, institutional change and economic performance*. New York: Cambridge University Press.
- North, D. C. (2005). *Understanding the Process of Institutional Change*. Princeton, NJ: Princeton University Press.
- Olson, M. (1965). *The Logic of Collective Action: Public Goods and the Theory of Group*. Cambridge, MA: Harvard University Press.
- Ophuls, W. (1973). Leviathan or oblivion. In H. Daly (Ed.), *Toward a Steady-state Economy* (pp. 214-219).
- Ostrom, E. (1972). Metropolitan reform: Propositions derived from two traditions. *Social Science Quarterly*, 474-493.

- Ostrom, E. (1990). *Governing the commons : the evolution of institutions for collective action*. Cambridge, UK: Cambridge University Press.
- Ostrom, E. (1991). Rational Choice Theory and Institutional Analysis: Toward Complementarity. *American Political Science Review*, 85(01), 237-243.
- Ostrom, E. (1998). A Behavioral Approach to the Rational Choice Theory of Collective Action: Presidential Address, American Political Science Association, 1997. *American Political Science Review*, 92(1).
- Ostrom, E. (1999a). Coping with tragedies of the commons. *Annual review of political science*, 2(1), 493-535.
- Ostrom, E. (1999b). Institutional rational choice: An assessment of the institutional analysis and development framework. In P. A. Sabatier (Ed.), *Theories of the policy process* (pp. 35–72). Boulder, CO: Westview Press.
- Ostrom, E. (2000). The Danger of Self-Evident Truths. *Political Science & Politics*, 33(01), 33-46.
- Ostrom, E. (2005). *Understanding institutional diversity*. Princeton: Princeton University Press.
- Ostrom, E. (2007). Institutional Rational Choice: An Assessment of the Institutional Analysis and Development Framework. In P. A. Sabatier (Ed.), *Theories of the Policy Process*. Boulder, CO: Westview Press.
- Ostrom, E. (2010a). Beyond markets and states: polycentric governance of complex economic systems. *Transnational Corporations Review*, 2(2), 1-12.
- Ostrom, E. (2010b). Polycentric systems for coping with collective action and global environmental change. *Global Environmental Change*, 20(4), 550-557.

- Ostrom, E., Gardner, R., & Walker, J. (1994). *Rules, games, and common-pool resources*.
Ann Arbor: University of Michigan Press.
- Ostrom, E., Parks, R., & Whitaker, G. (1978). *Patterns of Metropolitan Policing*.
Cambridge, MA: Ballinger.
- Ostrom, V. (1994a). *The Meaning of American Federalism: Constituting a Self-Governing Society*. San Francisco: Institute for Contemporary Studies.
- Ostrom, V. (1994b). *The meaning of American federalism: constituting a self-governing society*. San Francisco, California.: Institute for Contemporary Studies.
- Ostrom, V. (1999[1972]). Polycentricity. In M. McGinnis (Ed.), *Polycentricity and Local Public Economies: Readings from the Workshop in Political Theory and Policy Analysis* (pp. 52-74). Ann Arbor, MI: University of Michigan Press.
- Ostrom, V. (2002). What is Federalism? A Search for Meaning. In A. Venzor, C. Castillo, & Z. Memorias (Eds.), *Gobernabilidad: Nuevos Actores, Neuvos Desafíos, edición, coordinación y compilación* (Vol. II, pp. 439-449). Mexico: Editorial Porrúa.
- Ostrom, V. (2008a). *The Intellectual Crisis in American Public Administration* (3 ed.).
Tuscaloosa: University of Alabama Press.
- Ostrom, V. (2008b). *The Political Theory of a Compound Republic: Designing the American Experiment*
Lanham, MD: Lexington Books.
- Ostrom, V., & Ostrom, E. (1965). A behavioral approach to the study of intergovernmental relations. *The Annals of the American Academy of Political and social science*, 359(1), 137-146.

- Ostrom, V., Tiebout, C., & Warren, R. (1961). The organization of government in metropolitan areas: A theoretical inquiry. *American Political Science Review*, 55(4), 831-842.
- Pahl-Wostl, C. (2009). A conceptual framework for analysing adaptive capacity and multi-level learning processes in resource governance regimes. *Global Environmental Change*, 19(3), 354-365.
- Pahl-Wostl, C., Holtz, G., Kastens, B., & Knieper, C. (2010). Analyzing complex water governance regimes: the management and transition framework. *Environmental Science & Policy*, 13(7), 571-581.
- Pahl-Wostl, C., & Knieper, C. (2014). The capacity of water governance to deal with the climate change adaptation challenge: Using fuzzy set qualitative comparative analysis to distinguish between polycentric, fragmented and centralized regimes. *Global Environmental Change*, 29, 139-154.
- Parr, J. (2004). The polycentric urban region: a closer inspection. *Regional Studies*, 38(3), 231-240.
- Platt, R. H. (2006). Urban Watershed Management: Sustainability, One Stream at A Time. *Environment*, 48(4).
- Polanyi, M. (1951). *The Logic of Liberty*. Chicago, IL: University of Chicago Press.
- Popper, K. (1985[1944]). Piecemeal Social Engineering. In D. Miller (Ed.), *Popper selections* (pp. 304-318). Princeton, New Jersey.: Princeton University Press.
- Popping, R. (2010). Some views on agreement to be used in content analysis studies. *Quality & Quantity*, 44(6), 1067-1078.

- Poteete, A. R., Janssen, M. A., & Ostrom, E. (2010). *Working together: collective action, the commons, and multiple methods in practice*. NJ: Princeton University Press.
- Prell, C. (2012). *Social network analysis : history, theory & methodology*. Los Angeles: SAGE.
- Prell, C., Hubacek, K., & Reed, M. (2009). Stakeholder analysis and social network analysis in natural resource management. *Society and Natural Resources*, 22(6), 501-518.
- Rathwell, K. J., & Peterson, G. D. (2012). Connecting social networks with ecosystem services for watershed governance: a social ecological network perspective highlights the critical role of bridging organizations. *Ecology & Society*, 17(2), 24.
- Reed, S. M. (2008). Stakeholder participation for environmental management: A literature review. *Biological Conservation*, 141(10), 2417–2431.
- Rhodes, R. W. A. (1997). *Understanding Governance. Policy Networks, Reflexivity and Accountability*. Buckingham, UK: Open University Press.
- Rittel, H. W., & Webber, M. M. (1973). Dilemmas in a general theory of planning. *Policy Sciences*, 4(2), 155-169.
- Robins, G., Bates, L., & Pattison, P. (2011). Network governance and environmental management: conflict and cooperation. *Public Administration*, 89(4), 1293-1313.
- Robins, G., Elliott, P., & Pattison, P. (2001). Network models for social selection processes. *Social Networks*, 23(1), 1-30.
- Robins, G., Lewis, J. M., & Wang, P. (2012). Statistical network analysis for analyzing policy networks. *Policy Studies Journal*, 40(3), 375-401.

- Robins, G., Pattison, P., Kalish, Y., & Lusher, D. (2007). An introduction to exponential random graph (p^*) models for social networks. *Social Networks*, 29(2), 173-191.
- Robins, G., Snijders, T., Wang, P., Handcock, M., & Pattison, P. (2007). Recent developments in exponential random graph (p^*) models for social networks. *Social Networks*, 29(2), 192-215.
- Rogers, P., & Hall, A. W. (2003). *Effective water governance*. (7). Stockholm, Sweden.
- Rogers, P., MacDonnell, L., & Lydon, P. (2009). Political decision making: real decisions in real political contexts. In C. S. Russell & D. D. Baumann (Eds.), *The Evolution of Water Resource Planning and Decision Making*. Northampton, MA.: Edward Elgar.
- Rothstein, B. (2005). *Social traps and the problem of trust*. Cambridge, UK: Cambridge University Press.
- Sabatier, P. A. (1988). An advocacy coalition framework of policy change and the role of policy-oriented learning therein. *Policy Sciences*, 21(2), 129-168.
doi:10.1007/bf00136406
- Sabatier, P. A. (1998). The advocacy coalition framework: revisions and relevance for Europe. *Journal of European public policy*, 5(1), 98-130.
- Sabatier, P. A. (2007). *Theories of the policy process*. Cambridge, MA: Westview Press.
- Sabatier, P. A., Foucht, W., Lubell, M., Trachtenberg, A., & M. Matlock, M. (2005). *Swimming upstream: Collaborative approaches to watershed management*. Cambridge: MIT Press.

- Sandström, A., & Carlsson, L. (2008). The performance of policy networks: the relation between network structure and network performance. *Policy Studies Journal*, 36(4), 497-524.
- Sarker, A. (2013). The role of state-reinforced self-governance in averting the tragedy of the irrigation commons in Japan. *Public Administration*, 91(3), 727-743.
- Sayles, J. S. (2015). *Flowing Together: Addressing Social-Ecological Scale Mismatches for Estuary Watershed Restoration in the Whidbey Basin, Puget Sound, WA*. Arizona State University, Tempe, AZ.
- Scharpf, F. W. (1997a). *Games real actors play: actor-centered institutionalism in policy research*. Berkeley, CA: Westview Press.
- Scharpf, F. W. (1997b). *Games real actors play: Actor-centered institutionalism in policy research* (Vol. 1997): Westview Press Boulder, CO.
- Schlager, E. (1994). Fishers' Institutional Responses to Common-Pool Resource Dilemmas. In E. Ostrom, R. Gardner, J. Walker, & A. Hamlin (Eds.), *Rules, Games, and Common-Pool Resources* (pp. 247-265). Ann Arbor, MI: University of Michigan Press.
- Schlager, E. (2007). A Comparison of Frameworks, Theories, and Models of Policy Processes. In P. A. Sabatier (Ed.), *Theories of the Policy Process*. Boulder, CO: Westview Press.
- Schlager, E., & Blomquist, W. (1996). A comparison of three emerging theories of the policy process. *Political Research Quarterly*, 49(3), 651-672.
- Schlager, E., & Blomquist, W. (2000). *Local communities, policy prescriptions, and watershed management in Arizona, California, and Colorado*. Paper presented at

the Eighth Conference of the International Association for the Study of Common Property, Bloomington, Indiana, USA.

Schlager, E., Blomquist, W., & Tang, S. Y. (1994). Mobile flows, storage, and self-organized institutions for governing common-pool resources. *Land Economics*, 294-317.

Schneider, M., Scholz, J., Lubell, M., Mindruta, D., & Edwardsen, M. (2003). Building Consensual Institutions: Networks and the National Estuary Program. *American Journal of Political Science*, 47(1), 143-158.

Scholz, J. T., & Stiftel, B. (2005). Introduction: The Challenges of Adaptive Governance. In J. T. Scholz & B. Stiftel (Eds.), *Adaptive Governance of Water Conflict*. Washington: Resources for the Future Press.

Schoon, M., Baggio, J. A., Salau, K. R., & Janssen, M. (2014). Insights for managers from modeling species interactions across multiple scales in an idealized landscape. *Environmental Modelling & Software*, 54, 53-59.

Scott, T. (2015). Analyzing Policy Networks Using Valued Exponential Random Graph Models: Do Government-Sponsored Collaborative Groups Enhance Organizational Networks? *Policy Studies Journal*.

Scott, T., & Thomas, C. (2015). Do Collaborative Groups Enhance Interorganizational Networks? *Public Performance & Management Review*, 38(4), 654-683.

Shannon, P., Markiel, A., Ozier, O., Baliga, N. S., Wang, J. T., Ramage, D., . . . Ideker, T. (2003). Cytoscape: a software environment for integrated models of biomolecular interaction networks. *Genome research*, 13(11), 2498-2504.

- Simon, H. A. (1955). A behavioral model of rational choice. *the Quarterly journal of Economics*, 99-118.
- Skutsch, M., Vickers, B., Georgiadou, Y., & McCall, M. (2011). Alternative models for carbon payments to communities under REDD+: A comparison using the Polis model of actor inducements. *Environmental Science & Policy*, 14(2), 140-151.
- Snijders, T. A., Pattison, P. E., Robins, G. L., & Handcock, M. S. (2006). New specifications for exponential random graph models. *Sociological Methodology*, 36(1), 99-153.
- Stone, D. A. (2002). *Polivy Paradox: The Art of Political Decision Making* (revised ed.). Cambridge, New York: Norton.
- Szreter, S. (2000). Social capital, the economy and education in historical perspective. In S. Baron, J. Field, & T. Schuller (Eds.), *ocial Capital: Critical Perspectives* (pp. 56-77). Oxford: Oxford University Press.
- Szreter, S., & Woolcock, M. (2004). Health by association? Social capital, social theory, and the political economy of public health. *International Journal of Epidemiology*, 33(4), 650-667.
- Truman, D. B. (1958). *The Governmental Process*. New York: Knopf.
- Turok, I. (2005). Polycentric development: the key to regional competitiveness and cohesion. *Town and Country Planning*, 74(3), 102-104.
- van Gunsteren, H. R. (1976). *The quest for control: a critique of the rational-central-rule approach in public affairs*. London, UK.: Wiley.
- Vasanen, A. (2012). Functional polycentricity: examining metropolitan spatial structure through the connectivity of urban sub-centres. *Urban Studies*, 49(16), 3627-3644.

- Wasserman, S., & Faust, K. (1994). *Social network analysis: Methods and applications*. Cambridge, UK: Cambridge University Press.
- Weber, E. P. (1998). *Pluralism by the rules: Conflict and cooperation in environmental regulation*. Washington, DC:: Georgetown University Press.
- Weible, C., Sabatier, P. A., & Lubell, M. (2004). A Comparison of a Collaborative and Top-Down Approach to the Use of Science in Policy: Establishing Marine Protected Areas in California. *Policy Studies Journal*, 32(2), 187-207.
- Welch, W. (1983). The political feasibility of full ownership property rights: The cases of pollution and fisheries. *Policy Sciences*, 16(2), 165-180.
- Williamson, O. E. (1975). *Markets and hierarchies: antitrust analysis and implications*: The Free Press.
- Williamson, O. E. (1986). The Economics of Governance: Framework and Implications. In R. Langlois (Ed.), *Economics as a Process*. New York: Cambridge University Press.
- Wilson, W. (1885). *Congressional Government: A Study in American Politics*. Boston: Houghton Mifflin.
- Woolcock, M. (2001). The place of social capital in understanding social and economic outcomes. *Canadian journal of policy research*, 2(1), 11-17.
- Zafonte, M., & Sabatier, P. (1998). Shared beliefs and imposed interdependencies as determinants of ally networks in overlapping subsystems. *Journal of theoretical politics*, 10(4), 473-505.

APPENDICES

Appendix 1: Ranking of Actors Based on their index in the Islands of Polycentric Order

Category	Political Polycentric Order	Nonprofit Polycentric Order	Market Polycentric Order
Index > 50%	USEPA	Friends of Valle de Oro	Friends of Valle de Oro
	Pueblo of Isleta	USFWS	City of Albuquerque
	USNPS		
	Pueblo of Santa Ana		
	USGS		
	USFWS		
	Pueblo of Sandia		
	USHUD		
	City of Albuquerque		
	USBR		
Index 50% - 20%	USDoT		
	USACE		
	USEDA		
	Pueblo of San Felipe	USEPA	City of Rio Rancho
	MRGCD	City of Albuquerque	City of Santa Fe
	County of Bernalillo	NMDGF	USEDA
	Pueblo of Cochiti	U. New Mexico	USACE
	NMISC	County of Bernalillo	USBR
	Pueblo of Santo Domingo	Albuquerque Public Schools	USFWS
	NMDGF	Bosque Ecosystem Monitoring Program	NMED
ABCWUA	USGS	NMDGF	
USBLM	EEANM	NM Water Collaborative	
Nature Conservancy	USEPA		

AMAFCA
NMAD
USHS
USNWS
NMED
NM Office of the State Engineer
City of Rio Rancho
U. New Mexico
PNM Resources
Bosque Initiative Group
Sierra Club
Friends of Valle de Oro
City of Bernalillo
NMDoT
NMAGO
Save Our Bosque Task Force
NMSLO
Adubon New Mexico
Ducks Unlimited
Village of Corrales
Santafe County
SSCAFCA
USBIA
Laguna Pueblo
City of Socorro

Note: Actors are listed in descending order. Those with index below 20% were left out.

Appendix 2: Ranking of Actors According to their FPGI

Category	Functional Polycentric Governance Index
Index > 50%	Friends of Valle de Oro
	USEPA
	USFWS
Index 50% - 20%	City of Albuquerque
	USGS
	Pueblo of Isleta
	Pueblo of Santa Ana
	County of Bernalillo
	USNPS
	USBR
	NMDGF
	Pueblo of Sandia
	USACE
	U. New Mexico
	USHUD
	USEDA
	USDOT
	Pueblo of Cochiti
NMED	

Note: Actors are listed in descending order. Those with index below 20% were left out.

CURRICULUM VITA

Emmanuel Frimpong Boamah

Urban and Regional Studies Institute, 106 Morris Hall, Mankato, MN 56001

☎ 507. 351. 6689

emmanuel.frimpong-boamah@mnsu.edu OR emmanuel.frimpongboamah@louisville.edu

EDUCATION

Doctor of Philosophy, Urban and Public Affairs (Public Policy, Urban Planning and Sustainable Development)—2017

University of Louisville, Kentucky

Dissertation: Governing the Urban Water Commons: Essays on Collaborative Policy Networks in a Polycentric Ecology of Urban Water Policy Games

Master of Urban and Regional Studies—2013

Graduate Certificate in Local Government Management—2013

Minnesota State University, Minnesota

Thesis: Modeling Parking Demand: A Systems Approach to Parking Policy Analysis on Campus

Bachelor of Science (First Class Honors) in Development Policy Planning—2011

Kwame Nkrumah University of Science and Technology (KNUST), Ghana

FIELDS OF SPECIALIZATION

Public Policy, Urban Planning & Sustainability, Urban Economics & Finance, Environmental Governance & Policy Networks, Social Network Analysis, Critical Urban Studies, Research Methods

RESEARCH EXPERIENCE

Peer-Reviewed Articles

1. Grooms, Wes and ***Frimpong Boamah, E.*** (*forthcoming*). ‘Plannitizing’ Urban Politics: Learning from Growth Machine Theory to Reinvigorate Advocacy Planning. *Planning Theory*, DOI: 10.1177/1473095217690934
2. ***Frimpong Boamah, E.***, Osei, D., & Yeboah, T (*forthcoming*). Beyond Patriotic Discourse in Achieving the SDGs: An “Investment-linked” Diaspora Revenue Bonds Model (ILDRBM) for Sub-Saharan Africa. *Development in Practice*.

3. (*Special Issue*) DeCaro, D., Arnold, T., **Frimpong Boamah, E.**, and Garmestani, A (*forthcoming*). Understanding and Applying Principles of Social Decision Making in Adaptive Environmental Governance and Environmental Law. *Ecology and Society*.(*Special Issue*) **Frimpong Boamah, E.** & Walker, M. (2017). Legal Pluralism, Land Tenure and the Production of “Nomotropic Urban Spaces” in Post-colonial Accra, Ghana. *Geography Research Forum*. 36, 86-109.
4. Filipovitch, A., & **Frimpong Boamah, E.** (2016). A systems model for achieving optimum parking efficiency on campus: The case of Minnesota State University. *Transport Policy*, 45(1), 86-98.
5. Clifford, A., & **Frimpong Boamah, E.** (2016). Build as You Earn and Learn: Informal Urbanism and Incremental Housing Financing in Kumasi, Ghana. *Journal of Housing and the Built Environment*. Doi: 10.1007/s10901-016-9519-0.
6. Clifford, A., & **Frimpong Boamah, E.** (2015). The three-dimensional causes of flooding in Accra, Ghana. *International Journal of Urban Sustainable Development*, 7(1), 109-129.

Peer-Reviewed Articles in Progress

1. (*Revise and resubmit*). Walker, M & **Frimpong Boamah, E.** Map the gap: alternative visualizations of geographic knowledge production. *Geo: Geography and Environment*.
2. (*Revise and resubmit*). **Frimpong Boamah, E.** (Re) Mapping Polycentricity: The Political Economy, Spatiality, and Network of Polycentric Water Governance. *Environmental Policy and Governance*.
3. (*Under Review*). **Frimpong Boamah, E.** The Polycentricity of Urban Watershed Governance: A Methodological Approach. *Urban Studies*.

Ongoing Research

1. Institutions, Politics and Informality: Self-Help Assemblages as State Rescaling in the Global South
2. How far is Bloomington from College Park? : A Dialogue between the IAD Framework and the Pluralist Commonwealth Model in Urban Policies and Politics

TEACHING EXPERIENCE

1. **Lab Instructor—Market Analysis (Economic Development & Spatial Statistics)**
Department of Urban and Public Affairs, University of Louisville, Kentucky
2. **Teaching Assistant—Foundations of Public Administration**
Guest Lecture: Herbert Simon vs. Dwight Waldo
Department of Urban and Public Affairs, University of Louisville, Kentucky

3. ***Teaching Assistant—Introduction to the City***
Urban and Regional Studies Institute, Minnesota State University, Minnesota
4. ***Teaching Assistant—Development Planning and Policy Studio***
Department of Planning, Kwame Nkrumah University of Science and Technology (KNUST),
Ghana

PRESENTATIONS

1. “Revolutionary Methodologies,” session co-organizer for the upcoming **American Association of Geographers (AAG) Meeting**, Boston, MA, 2017.
2. “Governing the Urban Water Commons: Inter-organizational Collaborations in a Polycentric Ecology of Urban Water Policy Games,” presented at the **Annual Applied Geography Conference**, Louisville, KY, 2016
3. “Understanding and Applying Principles of Social Decision Making in Adaptive Environmental Governance and Environmental Law,” paper presented at the **Adaptive Water Governance Project Meeting**, National Socio-Environmental Synthesis Center (SESYNC), University of Maryland, Maryland, MD, 2016 (Co-authors: Daniel DeCaro, Tony Arnold, and Ahjond Garmestani)
4. “Encouraging Sustainable Transportation—Insights from the Earn-A-Bike Program at the University of Louisville,” paper presented at the **Southern Regional Science Association Conference**, Arlington, DC, 2016 (Co-authors: Sumei Zhang, and Justin Mog)
5. “Adaptive Governance for Resilient Urban Watersheds: The Case of the Anacostia Watershed,” poster presented at the **WaterSmart Innovations Conference and Exposition**, Las Vegas, 2015
6. “Rethinking Informal Institutional Spaces: Self-Help Assemblages as an Instance of State Rescaling in the Global South,” Roundtable Speaker, **Annual Critical Geography Conference**, Lexington, KY, 2015
7. “Modeling Campus Parking Policy,” paper presented at the **Minnesota Modeling & Simulation Center Brown Bag Series**, Mankato, MN, 2012

OTHER RELEVANT WORK EXPERIENCE

Regional Development Planner—2014 to 2015

Region 9 Development Commission, Minnesota.

Hazard Mitigation Research and Planning; Regional Climate Change Adaptation Research, Comprehensive Land Use Planning; Regional/Sub-regional Solid Waste Planning; Transportation Planning; and Grant Research and Writing.

Transportation, Community & Economic Development Consultant—2013 to 2014

Region 9 Development Commission, Minnesota

Transportation Planning; Hazard Mitigation Planning; Comprehensive Planning; Regional/Sub-regional Solid Waste Planning; Data Analysis and Database Management; and Comprehensive Economic Development Strategies.

Consultancy Team Member—2011

Project: *Capacity Building Workshop on Decentralisation, Community Participation, Gender-based Development, and Local Level Planning.*

Facilitation Team Member—2011

Project: *Institutional Strengthening and Capacity Building Workshop of Sub-district Structures organized by the Ohio State University, KNUST and the Offinso North District Assembly in Ghana*

SOFTWARES

STATA, SPSS, R, Statnet, ArcGIS, Vensim, Netanomics, Gephi, Cytoscape, and Netlogo.

PROFESSIONAL MEMBERSHIP

- ICMA — International City/County Management Association
- APA — American Planning Association
- AAG — American Association of Geographers

EXCELLENCE AND AWARDS

1. Ideas for Action Finalist (2015)—The World Bank Group, Zicklin Center, and Wharton School
2. University of Louisville Qualifying Exams for Doctoral Candidacy— Pass with Distinction on Urban Theory, Public Policy, and Urban Planning and Sustainable Development.
3. Graduate Conference Scholarship—2015 WaterSmart Innovation Conference and Exposition
4. Ph.D. Fellowship (2014-2016)—School of Interdisciplinary and Graduate Studies, University of Louisville
5. Gunnar Isberg Scholarship (2012)—American Planning Association (Minnesota State Chapter)
6. Patrick J. Kelly Scholarship in Urban Finance (2012-2013)—Urban & Regional Studies Institute, Minnesota State University
7. Minnesota County(2012)—City Managers Association Conference Fellowship
8. Robert A. Barrett Distinguished Graduate Fellowship (2011-2012)—Urban & Regional Studies Institute, Minnesota State University
9. Grant Award for Regional Climate Change Adaptation Plan for Region Nine, Minnesota(2014)— Minnesota Pollution Control Agency

SERVICE

1. Referee, Jambá: Journal of Disaster Risk Studies

2. Governing Committee Member (2014-2015)—Ph.D. Students' Association, Urban and Public Affairs, University of Louisville.
3. Judicial Commission Chair, College of Architecture and Planning Students Society, KNUST, Ghana (2008-2009)
4. Member, Students Representative Council, KNUST, Ghana (2008-2009)