CONCEPTUALIZING AND MEASURING DRIVERS OF POLICY CHANGE IN URBAN WATER GOVERNANCE

By

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As members of the Dissertation Committee, we certify that we have read the dissertation prepared by Emily Virginia Bell, titled "Conceptualizing and Measuring Drivers of Policy Change in Urban Water Governance" and recommend that it be accepted as fulfilling the dissertation requirement for the Degree of Doctor of Philosophy.

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DEDICATION

For Virginia ('Gram') Bridges, who always told me to "slooooow dooooown" and to keep things simple. The memory of you and your directions continue to guide me and bring me back to center.

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Abstract

This dissertation conceptualizes and measures key drivers of policy change articulated in the Advocacy Coalition Framework (ACF). The ACF is a widely-used framework that has guided researchers worldwide in their efforts to find answers to leading policy puzzles. Analysts have continued to improve the framework over the past three decades, but there is still room for theoretical and methodological development. With better clarification of concepts and measurement, scholars can gain better traction in offering theoretical contributions in the ACF's research program.

This work presents three studies that contribute to the objective of advancing the ACF. The first study investigates how narratives in gray literature highlight important actors in the policy network, and how well this aligns with centrality measures in the network structure. The second discusses ways to conceptualize environmental shocks, and examines how these affect change in the structure of a policy coordination network over time. Finally, the third study assesses the validity of gray literature data used for the first two studies by correlating coordination networks of policy actors detected through analysis of gray literature and survey methods. These efforts collectively offer novel ways to improve the clarity of concepts in the ACF, as well as the framework's utility for empirical studies across a variety of policy domains and geographic settings.

Chapter 1

Drivers of policy change can take many forms, presenting a wide variety of areas for theoretical investigation. As the body of empirical literature on the policy process grows, novel insights on drivers continue to emerge. These not only address important puzzles in the policy world, but improve our understanding about different aspects of factors motivating change, such as the behavior of policy stakeholders, or the conditions under which their actions induce change or maintain the status quo. Yet, with this development comes increased variety and complexity in ways to think about drivers of policy change. It also highlights ways researchers can advance areas that need refined theory and measurement.

To maintain traction in developing the theoretical core of interest (Lakatos 1976), it is important not only to take regular stock of theoretical and methodological developments of the field (e.g., Weible and Sabatier 2009), but to ensure clarity in the conceptualization and measurement of the concepts scholars present in these studies. A guiding maxim for many policy researchers (myself included) comes from Paul Sabatier, who said "clarity begets clarity, and mush begets mush" (Jenkins-Smith 2013). With this principle in mind, there are three questions that can foster precision in the generation of new knowledge: i) how are constructs of interest conceptualized?, ii) how are these concepts measured?, and iii) how does this illuminate areas that need reconsideration or refinement?

This dissertation examines different ways to conceptualize and measure principal policy actors, belief change, and coordination—each a driver of policy change (Mintrom and Norman 2009; Jenkins-Smith et al. 2014). I think of the policy process and the drivers of change therein through the lens of the Advocacy Coalition Framework. The ACF has guided empirical research on the policy process for more than three decades, and is a well-suited guide for organizing inquiry on policy change. At the broadest level, the ACF conceptualizes the policy process as taking place within a *subsystem*. This is defined as a policy domain (e.g., health, water, or housing) that affects a certain geographic scope (e.g., cities, watersheds, or states). Within the subsystem, there are relevant stakeholders with competing policy preferences and values. According to the ACF, these differences may stem from unique *policy-core* beliefs, which are viewed as ontological and normative perceptions about subsystem features such as problem severity, causes of these problems, and effective or appropriate policy solutions. These beliefs are hypothesized to drive behavior that motivates or prevents policy change. The framework also posits that individuals with similar policy-core beliefs form relationships to engage in non-trivial degrees of coordination to achieve shared policy goals that might have otherwise been unobtainable. Principal policy actors occupy distinct roles in the subsystem, and might act as leaders in advocacy coalitions, or navigate auxiliary roles that foster processes such as information exchange or conflict mitigation between rivaling groups.

Collectively, these actors and the relationships among them in the policy subsystem comprise a policy network. From this foundation, several ACF scholars have used social network analysis (SNA) to conceptualize and examine patterns of interaction. Current work shows that this is a well-suited approach to investigate not only relations between network members, but to explain their belief systems. Several studies, for example, investigate how stakeholders form relationships, or *ties* with others of similar beliefs through a process called *belief homophily* (Henry 2011; McPherson et al. 2001). This is a key process that explains how policy stakeholders choose those with whom they engage in non-trivial degrees of coordination, and form coalitions to achieve shared objectives (Sabatier and Weible 1999). Other studies have applied network measures to examine the role of important policy actors in the policy process. Entrepreneurs and brokers, namely, have received considerable attention because they assume unique relational positions among other stakeholders in the subsystem to advance policy change. Entrepreneurs seize opportunities by recognizing areas for improvement, draw attention to current policy issues, garner coalition support and resources, and frame problems and offer solutions to decision makers (Mintrom and Vergari 1996). Brokers intervene to resolve disagreements between coalitions in high-conflict situations (Sabatier and Jenkins-Smith 1999). The network literature identifies important actors such as these as occupying central roles, which also extends to those in policy settings (Laumann and Pappi 1976; Krackhardt 1990).

There are still concepts in the ACF that require further refinement. One area that demands more attention is how network measures guide detection of important actors. Network centrality concepts, borrowed from Freeman (1979) are becoming increasingly common for measuring actors of importance in the policy literature (e.g., Henry 2011b; Ingold and Leifeld 2014; Arnold et al. 2017). Recent efforts have improved sophistication in the measurement of entrepreneurs and brokers (Christopoulos and Quaglia 2009; Ingold and Varone 2012; Christopoulos and Ingold 2015). However, an ongoing challenge is understanding why reports of important actors are not always detected with network measures, or how to account for central network actors that are not identified in reports.

Another factor the ACF hypothesizes to drive change is shocks. ACF scholars have also called for new approaches to articulate processes that occur between shocks and policy change (Nohrstedt and Weible 2012). Shocks are defined in the ACF literature as perturbations to the policy subsystem that may include events such as crises, disasters, change in socioeconomic conditions, shifts in power, scandals, or policy failures (Jenkins-Smith et al. 2014). Although these types of events are hypothesized to drive major policy change, it is not clear how or when this occurs. Nohrstedt and Weible suggest that scholars need to direct attention to not only the characteristics of the shock in consideration, but the mediating mechanisms between shocks and policy outputs.

In the chapters that follow, I examine the validity of conceptualization and measurement for i) important actors, ii) belief change, as observed through homophily, and iii) coordination. In addition to assessing the explanatory power of new theoretical conceptualizations of key subsystem components, I seek to examine how well innovative applications of social network analysis can detect these concepts. Chapter 2 details my data collection strategies and measurement approaches for variables used in the next three chapters. Chapters 3 and 4 are based on data gathered through gray literature on policies and their participants in the Tucson, Arizona urban water policy domain. There is wide variation in ideas of what constitutes gray literature, but one broad way to describe this type of content is that it is not made for commercial publication, it is not distributed in a standard way, and it often does not have a bibliographic record (Mahood, Van Erd, and Irvin 2014; Tillett and Newbold 2006). Use of gray literature data is motivated by a growing body of research that illustrates the virtues of using data from content analysis of various media (e.g., Hayes and Scott 2017). Nevertheless, like any data-collection method, this approach may be subject to bias, such as reporting that focuses only on new policy actors or salient problems (Yi and Scholz 2016). Thus, Chapter 5 presents a study that correlates graphs comprised of the same policy participants with data derived from both gray literature and survey techniques. Survey methods and content analysis both present unique limitations in the way information about coordination can be gathered, so significant correlations suggest instances in which measures from gray literature offer a promising approach to operationalize coordination (and potentially other drivers of change, such as important actors and belief change). Finally, Chapter 6 offers a review of the theoretical and methodological contribution of these studies, the generalizability of their findings, key limitations, and next steps.

Chapter 2

Introduction

In this chapter, I detail the methods used for sampling survey contact data, development and distribution of the survey, and collection of gray literature content. These data were used in social network analysis, so the final section also discusses how relevant subsystem actors and their interactions were operationalized. Collectively, these activities were part of a larger group research effort for the project titled *Coupled Networks in Urbanized Landscapes: Linking Ecosystem Services and Governance for Water Sustainability*.[*]

Sampling Survey Contacts

In 2016, we used a purposive sampling approach to identify survey recipients. The preliminary search focused on Arizona government organizations that partake in activities associated with water governance and/or management. This was followed by a supplementary seed search in 2017 for positions in government that we identified as water-relevant, but that we had missed with the original search.

Identified contacts received the survey in January 2018; these participants then recommended other respondents whose knowledge they deemed useful for the survey. From this, we expanded our sample frame to include actors responsible for water governance and management outside the public sector, including non-profit organizations, interest groups, and private organizations. Survey respondents nominated additional contacts at both the individual and organizational levels, which guided our subsequent searches for contact information. In addition to these contacts were "informal" recipients and "reference" contacts. The former was based on current knowledge of the Arizona water governance system and relevant actors that had not already been included; the latter were informal references through email. In the next section, I discuss the seed-sampling, and snowball-sampling procedures for 2016, 2017, and 2018.

Local Water Governments

Defining a Local Water Government

To understand policy decisions on the ground relating to water policy, the CNH team focused on gathering 2016 seed data on local water governments. To identify relevant respondents, we first defined local water governments by referring to the US Bureau of the Census *Government Finance and Employment Classification Manual* (US Census Bureau 2006). The Census defines local governments as county, municipal, and township governments. These are considered general purpose local governments, while special district and school district governments serve as special purpose governments. Local water governments (LWGs) consist of entities at the municipal, county, or regional level, and carry the authority to regulate, supply, and manage a wide range of water-related functions. These functions consist of water supply, wastewater, water quality, flood, groundwater, water conservation, and stormwater.

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[*]This project was funded by the National Science Foundation's Dynamics of Coupled Natural and Human (CNH) Systems Program. From here on, I refer to this as the "CNH project" and its affiliates as the "CNH team".

We also included special districts, which are typically subdivisions of state-established government, and provide a single public service. These governments may act independently or may collaborate to govern water-related functions. That is, some special districts may function as a board of commissioners, while others may be embedded in *local governments* as departments or as *special districts*. In special cases, regional councils or agencies may be viewed as governments if they have substantial employment activity and financial activity.

Identifying Local Water Governments
The CNH team initially identified local water governments through organizational spending in water-related areas. Specifically, if a government incorporated in the Census had a *Function Code* that indicated spending in a water-related area, that government was included in the sample frame. Figure 2.1 shows a table of government organization function codes and water-related spending categories (highlighted in yellow).

Table 1.1 Government Organization Function and Activity Codes

Function Code	Activity Code	Title	Function Code	Activity Code	Title
01	01	Air Transportation	60	60	Parking Facilities
02	...	Cemeteries	61	61	Parks and Recreation
03	03	Miscellaneous Commercial Activities	62	62	Police Protection
04	04	Correctional Institutions	63	...	Flood Control
05	05	Other Corrections	64	...	Irrigation
09	...	Education (School Building Authorities)	77	77	Public Welfare Institutions
...	12	Elementary and Secondary Education	79	79	Public Welfare
...	18	Other Higher Education	80	80	Sewerage
...	21	Other Education	81	81	Solid Waste Management
...	22	Social Insurance Administration	86	...	Reclamation
...	23	Financial Administration	87	87	Sea and Inland Port Facilities
24	24	Local Fire Protection	88	...	Soil and Water Conservation
...	25	Judicial and Legal	89	...	Other Single Function Districts
...	26	Legislative	...	89	Other and Unallocable
...	29	Central Staff Services	...	90	Liquor Stores
...	31	General Public Buildings	91	91	Water Supply Utility
32	32	Health	92	92	Electric Power Utility
40	36	Hospitals	93	93	Gas Supply Utility
41	...	Industrial Development	94	94	Public Mass Transit Utility
42	...	Mortgage Credit	96	24/91	Fire Protection and Water Supply
44	44	Regular Highways	97	59/91	Natural Resources and Water Supply
45	45	Toll Highways	98	80/91	Sewerage and Water Supply
50	50	Housing and Community Development	99	Various	Other Multi-function Districts
51	...	Drainage	...	X1	Public Employee Retirement Systems
52	52	Libraries	...	Y1	Workers' Compensation Systems
59	59	Other Natural Resources			

Figure 2.1 Function Code from US Census of Government Manual

From this, we derived seven functional water domains directly related to management and governance relating the domains listed in Table 2.1.

Table 2.1 Functional Water Domains

Stormwater	Wastewater
Water supply	Water quality
Groundwater	Water conservation
Flood	

These are based on the highlighted expenditure areas from Figure 2.1 also listed in Table 2.2:

Table 2.2 Water-Related Expenditures

Toll Highways	Flood Control
Regular Highways	Irrigation
Drainage	Sewerage
Other Natural Resources	Soil and Water Conservation
Water Supply Utility	Fire Protection and Water Supply
Natural Resources and Water Supply	Sewerage and Water Supply

We designated organizations as LWGs if their expenditures included at least one of the water-related areas we identified in Census classification manual. If a government organization showed no spending in the highlighted expenditure areas, but its name included the words ‘water,’ ‘drainage,’ ‘flood,’ or ‘irrigation,’ we also coded this as an LWG. Finally, if a government did not have either of the first two features but showed a water-related functional code relating to water, we also designated this as an LWG.

Including LWGs in the Sample Frame

To create a sample frame for our first contact search, we referred to the US Census of Government Financials (2012) data set. We generated a list of identified LWGs, as well as their Federal Information Processing (FIPS) Standard geographic code, for their respective counties, state, and other places. We also included variables that specified their respective county and state, their unique identification number, and their type code, which specified whether they were municipalities, counties, or special districts. Additional features to the LWG name were useful for reference to the original US Census of Government Financials data set.

<u>Local Water Organizations</u>

Identifying Local Water Organizations

Although LWG contacts had a role water in governance and/or management, these actors were not necessarily water professionals. We conducted an additional search to identify those we assumed would have a more intimate knowledge of water management-related activities. Figure 2.2 offers a flowchart of our decision-making process to delineate between LWG and LWO respondents.

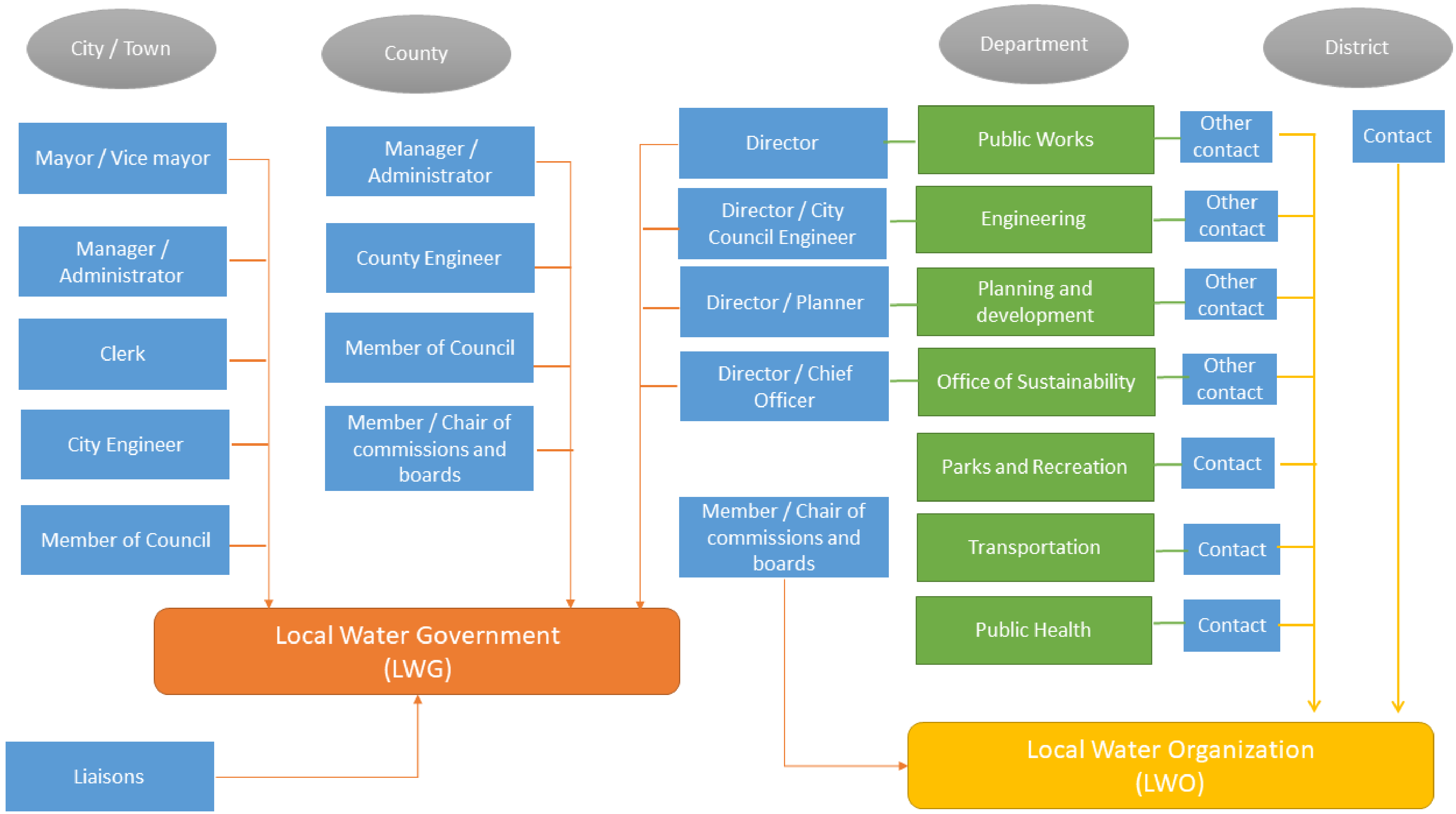


Figure 2.2 Flowchart Guide for Coding of Sample Frame Contacts for LWG and LWO Surveys

Systematic Web Search of Local Water Organizations
We conducted a manual Google search that combined our seven water function domains with the name of each LWG to identify LWOs. For each search, we would include first the functional domain, followed by the LWG's domain name (Figure 2.4).

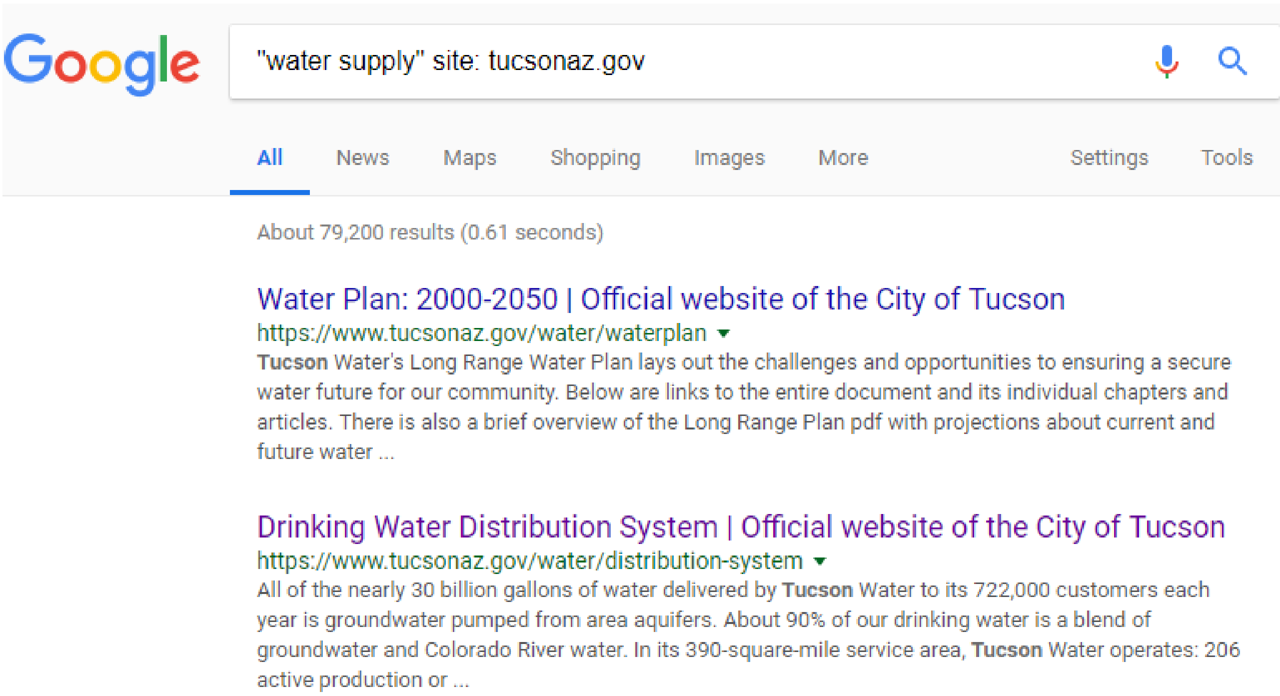


Figure 2.3 Systematic Web Search Example

From each search combination, we then sampled the first ten unique results (i.e., not previously identified through any other search). We added LWOs to the sample frame with their corresponding LWG name and associated information (e.g., FIPS and identification numbers). Although LWOs exist within LWGs, we treated LWO observations as distinct from the LWG observations that we sampled first. Some LWGs had multiple water LWOs (Figure 2.5).

<u>Identifying Contacts within LWGs and LWOs</u>
For each URL we sampled through our systematic searches, we sought three individuals and their contact information. This included job title, first and last names, email address, and phone number and mail address, if possible (Figure 2.6). Our first preference was to identify those in head positions, such as directors or supervisors; if necessary, second and third contacts from the LWG or LWO could include middle management, such as office managers, supervisors, head engineers, or deputy directors. If available, we sought most information on the sites' directories. If no websites were available, we gathered contact information from online documents, which was common for special districts. In these circumstances, contact information was relatively scarce, so we included what information we could find, regardless of the individuals'

professional titles. In some cases, smaller LWGs and LWOs had no contact information, or produced one contact, at most.

Subsequent Search for Local Water Government Contacts, 2017

Following the 2016 search, we recognized that the LWG sample frame was comparatively small to the number of LWO contacts. To increase the number of contacts, we conducted an additional search for specific positions within the LWG. These included the following positions listed in Table 2.3

Table 2.3 LWG Positions in 2017 Web Search

Public works directors	Directors of sustainability offices	Members/chairs of commissions or boards
Directors of city planning	City/county managers/administrators	Mayors
Directors of engineering or city/county engineers	Council members	Clerks

Arizona Master Data Set, Survey Distribution, and Snowball Sampling

From the 2016 and 2017 searches, we produced a sample frame of 692 contacts. For LWG and LWO contacts, the CNH team designed two separate surveys, each version which solicited additional contacts from survey respondents at the individual and/or organizational level. The nominated contacts and those identified in web searches of nominated organizations brought the sum to 1935 survey contacts. A breakdown of the sample frame development and snowball sampling is shown in Table 2.4.

Table 2.4 Number of LWG and LWO Contacts through Searches and Snowball Sampling

Search Type	*Date*	*Number of LWG contacts*	*Number of LWO contacts*
Seed search	05/03/16—07/17/16	368	134
Second seed search	08/30/17—11/23/17	142	38[2]
First snowball sample search	01/28/18—02/10/18	407	389
Second snowball sample search	02/04/18—02/10/18	159	106
Third snowball sample search	02/09/18—02/12/18	52	53
Informal sample search	02/05/18—02/12/18	53	12
Referred (by email)	01/23/18—02/06/18	3	0

We used Qualtrics, an online survey software platform to distribute our questions to LWG and LWO contacts. Before we distributed the main survey, we sent a pilot survey to 26 LWGs and 32 LWOs in Pinal County, and four reminders from September 13, 2017 through October 9, 2017

[22] Incidental LWOs discovered during the second seed search for LWGs were also included in the sample.

(Table 2.5) Four of the LWGs and three of the LWOs completed the survey. The remaining non-respondents received the main LWG and LWO survey in 2018.

Table 2.5 LWG and LWO Pilot Surveys Distribution and Reminder Schedule

Date 1	*Reminder 1*	*Reminder 2*	*Reminder 3*	*Reminder 4*	*Reminder 5*
09/13/17	09/19/17	09/25/17	10/09/17	10/26/17	11/27/17

	A	B	C	D	E	F	G	H	I	J	K
1	LWG Name	FIPS_COUNTY	FIPS_STATE	County_St	ID	SortCode	TypeCode	Website	Date Website Retrieved	Directory Link	LWO Name (Department)
3	TUCSON CITY	19	4	PIMA AZ	32010002	1464	Municipal	https://www.tucsonaz.gov/t	4/26/2016	https://www.tuc	Tucson Department of Transportation Engineering
4	TUCSON CITY	19	4	PIMA AZ	32010002	1464	Municipal	https://www.tucsonaz.gov/t	4/26/2016	https://www.tuc	Stormwater Management Section
5	TUCSON CITY	19	4	PIMA AZ	32010002	1464	Municipal	https://www.tucsonaz.gov/e	4/26/2016	https://www.tuc	Environmental Services Department
6	TUCSON CITY	19	4	PIMA AZ	32010002	1464	Municipal	https://www.tucsonaz.gov/p	4/26/2016	https://www.tuc	Tucson Parks and Recreation

Figure 2.4 Local Water Organization Sample Frame – Multiple LWOs in One LWG

website	reviewDat	reviewer	Directory	lwoDepartmentN	address1	address2	city	zip	orgPhone	title1	firstName	lastName	email1
https://www.tucson	8/30/17	ADH	NA	Office of the City I	City Mana	255 W. Ala	Tucson	85701	520-791-4	City Manager	John	Smith	jsmith@tucsonaz.gov
https://www.tucson	8/30/17	ELGF	NA	Planning and Deve	Public Wo	201 North	Tucson	85701	520-791-5	Director of Planning	Johnny	Smith	director@tucsonaz.gov
https://www.tucson	8/30/17	EVB	NA	Architecture and E	PO Box 27210		Tucson	85726-721	520-837-3	City Engineer	Jane	Smith	jsmith@pima.gov

Figure 2.5 Example of Contact Information for LWO Sample Frame

On January 23, 2018, we distributed the first wave of the main survey to all non-respondents from the pilot survey, as well as all other LWG and LWO contacts in Arizona. The first contacts to receive the survey were from LWGs and LWOs identified in the systematic searches. We sent three subsequent waves of LWG- and LWO-specific surveys in three additional waves to contacts we identified through snowball sampling (Table 2.6). All survey recipients received four reminders, with an option to take a truncated version of the survey with our final email.

We closed the LWG survey on March 30, 2018 with 211 of 889 respondents having competed the survey (a 24% response). The LWO survey is currently still open to respondents, but we anticipate at least a 25% response rate, given with 249 of 998 respondents have completed the survey.‡

Table 2.6 LWG and LWO Survey Distribution and Reminder Schedule

Date	*Wave 1*	*Wave 2*	*Wave 3*	*Wave 4*	*Close all surveys*
01/23/18	Send survey				
01/30/18	Reminder 1	Send survey			
02/06/18	Reminder 2	Reminder 1	Send survey		
02/13/18	Reminder 3 (offer phone call)	Reminder 2	Reminder 1	Send survey	
02/20/18	Skip	Reminder 3 (offer phone call)	Reminder 2	Reminder 1	
02/27/18	Reminder 4 (offer truncated version)	Skip	Reminder 3 (offer phone call)	Reminder 2	
03/06/18		Reminder 4 (offer truncated version)	Skip	Reminder 3 (offer phone call)	
03/13/18			Reminder 4 (offer truncated version)	Skip	
03/20/18				Reminder 4 (offer truncated version)	
03/30/18					Close all LWG surveys
TBD					Close all LWO surveys

<u>Survey Questions Used in Chapter 4</u>

To measure coordination activities for the study in Chapter 4, I used data from respondents who answered the LWO survey. Respondents could nominate up to ten organizations with whom their respective organizations interact. In the survey, we specified that we were interested in learning

‡ In Qualtrics, we only have record of fully completed surveys before we close access to the survey. However, partial completions will also be tallied into the total count after the survey is closed.

about respondents' ties to those with whom they interacted as a part of their job in water management, either on a voluntary or mandatory basis (Figure 2.7).

INTERACTIONS WITH ORGANIZATIONS IN YOUR REGION

In this section we are interested in learning about how your organization interacts with other organizations in your region. We are interested in interactions with specific organizations, such as federal/state agencies or municipal departments, as well as private and nonprofit organizations.

Please list up to ten organizations that you interact with as part of your job in water management, including both voluntary and required interactions. Please also include organizations that do not necessarily share your goals.

Organization 1	Tucson Water
Organization 2	Watershed Management Group
Organization 3	Pima County Regional Flood Control District
Organization 4	The Nature Conservancy
Organization 5	

Figure 2.6 Survey Example 1

The survey then asked respondents to offer additional information on the organizations they nominated (Figure 2.8). Although respondents had the option to specify additional activities to the ones provided, there were too few reports to generate a sizeable adjacency matrix.

In general, what types of interactions do you have with these organizations? Please check all that apply, and feel free to add activities below.

	attend same meetings	jointly implement programs or policies	seek/ provide consulting services	share information or data	seek/ provide advice	seek/ provide funding or physical resources	jointly advocate for policy	other (please specify below)
Tucson Water	☐	☐	☐	☐	☐	☐	☐	☐
Watershed Management Group	☐	☐	☐	☐	☐	☐	☐	☐
Pima County Regional Flood Control District	☐	☐	☐	☐	☐	☐	☐	☐
The Nature Conservancy	☐	☐	☐	☐	☐	☐	☐	☐

Figure 2.7 Survey Example 2

<u>Gray Literature</u>

This section covers the sampling process to collect data on gray literature (i.e., non-peer-reviewed media). Here, I define gray literature and list examples identified for this dissertation. Next, I discuss the parameters I used to systematically search and sample content pertaining to water management and governance in Tucson, Arizona. Finally, I review how I operationalized key concepts used in Chapter 3.

Defining Gray Literature

Gray literature takes many forms (Table 2.7) but can be thought of, broadly, as documents not produced for commercial publication, without standard distribution, and not included in common bibliographic retrieval systems (Mahood, Van Eerd, and Irvin 2014; Tillett and Newbold 2006).

Table 2.7 Examples of Media Found in the Gray Literature Search

Ordinances	White papers
News articles	Technical reports
Informational pamphlets	Archives
Presentations	Meeting minutes
User guides or manuals	

Sampling Gray Literature

The gray literature data collection process was adapted from the LWG detection method that uses expenditure information from the US Bureau of the Census (discussed in Sections 2.2 and 2.3 of this appendix). With a geographic focus limited to Tucson, Arizona, I conducted a systematic, manual web search with Google on water supply, wastewater, water quality, flood, groundwater, water conservation, and stormwater. I searched each of these functional domains in Tucson for the years 2007 to 2017. Google has a feature to set the range of time for which to search documents (Figure 2.9). For each year, I sampled the first ten unique documents that did not appear in previous searches. In the rare event a result produced a document with no information on events—water or not—I excluded these from the sample. In addition to the systematic search, I used a snowball sampling approach, in which I included any relevant documents that were displayed as hyperlinks in the original media produced through the systematic search. Sampled websites were often hubs for information on programs and events in the area (Figure 2.10).

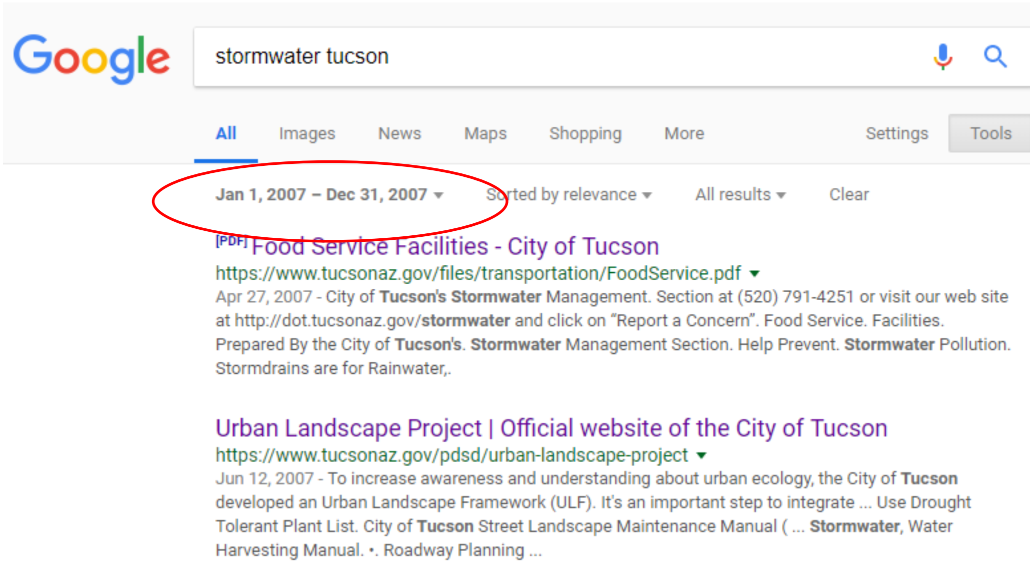
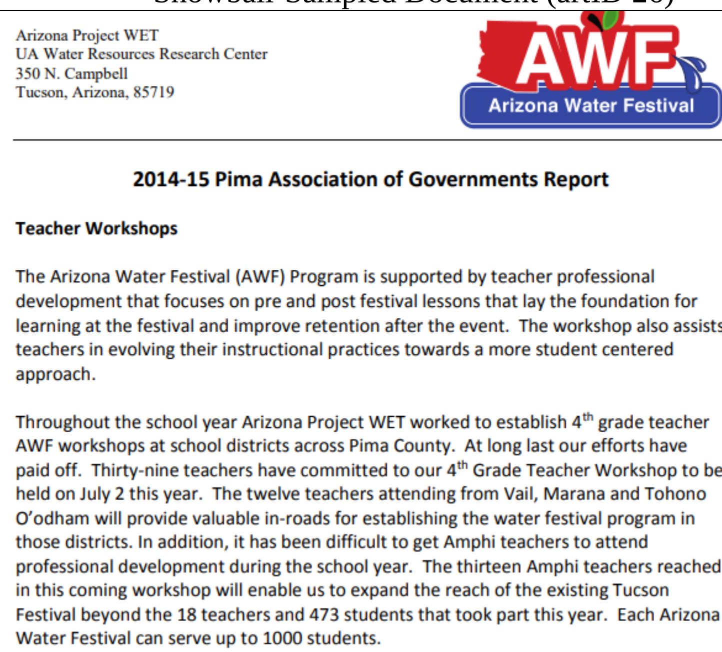


Figure 2.8 Example of Google Search

Systematically-Sampled Website (artID 25) Snowball-Sampled Document (artID 26)



Arizona Project WET
UA Water Resources Research Center
350 N. Campbell
Tucson, Arizona, 85719

AWF Arizona Water Festival

2014-15 Pima Association of Governments Report

Teacher Workshops

The Arizona Water Festival (AWF) Program is supported by teacher professional development that focuses on pre and post festival lessons that lay the foundation for learning at the festival and improve retention after the event. The workshop also assists teachers in evolving their instructional practices towards a more student centered approach.

Throughout the school year Arizona Project WET worked to establish 4th grade teacher AWF workshops at school districts across Pima County. At long last our efforts have paid off. Thirty-nine teachers have committed to our 4th Grade Teacher Workshop to be held on July 2 this year. The twelve teachers attending from Vail, Marana and Tohono O'odham will provide valuable in-roads for establishing the water festival program in those districts. In addition, it has been difficult to get Amphi teachers to attend professional development during the school year. The thirteen Amphi teachers reached in this coming workshop will enable us to expand the reach of the existing Tucson Festival beyond the 18 teachers and 473 students that took part this year. Each Arizona Water Festival can serve up to 1000 students.

Figure 2.9 Systematic and Snowball Sampling

Before coding data from the gray literature, I generated a reference document (Figure 2.11). This offers a unique identification code for each document (*artID*), the year in which it was searched (*date*), the functional domain (*domain*), the website address (*site*), the title of the media (*title*), and whether the document was produced through a systematic search or a snowball sampling procedure (*snowball*). Additionally, I printed each sampled piece of gray literature to a .pdf document and saved this in Box, an online cloud content management and file sharing platform; each of these files has a unique name, listed under *fileName* in the reference document.

Coding Gray Literature

I collected the gray literature to generate a network of organizations that coordinate in the implementation or promotion of a water-related event, program, or strategy. The limitation of content analysis, however, is that there is often an absence of reports on the nature of relationships between actors of interest. One way in which networks scholars have addressed this challenge is by using an event-based approach, which identifies relevant actors by their participation in the same activities (Laumann, Marsden, and Prensky 1989). Following this approach, I coded events, programs, and strategies (which I collectively refer to as *events* from here on for simplicity) mentioned in the gray literature. I then recorded organizations that played a key role in the implementation or promotion of an event, program, or strategy. This could include activities such as sponsoring an event, or hosting a demonstration, or developing and leading a program. The event data and organization data comprised two separate data sets. However, each was linked to the other through a shared reference identification number, discussed in the next sections.

Events, Programs, and Strategies

I developed a gray literature data set that has information on events, programs, and strategies, information on organizations (and in four cases, individuals that had no organizational affiliation), and information on shocks. For each event, I generated a unique identification number (*eventID*), the name of the event (*eventName*), and a normalized code of the event name (*eventCode*). From the sampled gray literature, I also sought information on the dates in which the events started (*eventStart*) and ended (*eventEnd*), if applicable. Sometimes the gray literature did not have timeline information, so I informally searched additional dates online. In these cases, I included the sites in which the dates were found (*extDateSite1*). I also included notes on how I searched the sites in the case there was any necessary additional information (*dateSiteNotes*). I then created a dummy variable to indicate whether the event should be kept in timelines or longitudinal studies (*keepTimeline_q*). I excluded events with dates if there was any uncertainty about the validity of the information.

Next, I coded policy-design features of the events (Figure 2.12). I included all documents that discussed events, whether these were related to water or not. For this reason, I included a dummy variable, *isWater_q* to indicate whether the event of interest should be included in the water event coordination network. Following this, I specified the types of implementation strategies each event used (there could be more than one). These included regulation (*reg*), such as ordinances, mandates, statutes, standards, or laws at the state and federal levels; education (*edu*), such as workshops, demonstrations, classes, and material such as information pamphlets or manuals; non-green-infrastructure-based technology (*techOth*), such as centralized-piped water supply systems, water reclamation facilities, or graywater reuse approaches; green infrastructure technology (*techGI*), such as active and passive stormwater harvesting approaches or low-impact development that mimics natural landscapes to improve pre-development water flows; price-based mechanisms (*price*), such as taxes, block-price or peak demand pricing strategies, rebates, or fines; and non-price based incentives (*nonPrice*), such as competitions or awards for water technologies. Finally, I included whether there was mention that the event required (*isMandated_q*).

Although these events are presented in a data set separate from the reference document, they are linked to their respective articles in the reference document with a dummy variable indicating whether they are mentioned in that article (*art1…art843*). Listing events under article IDs in this manner would allow quick access to identify what events are listed in each article.

Organizations and Individuals

These data were collected with the organization as the intended unit of analysis. However, there were a few cases in which relevant individuals also played key roles in the implementation or promotion of water events in Tucson, who were included as well. Like the event data, I generated a data set for organizations (Figure 2.13), with an identification number for all identified organizations and individuals (*orgID*), the organizations' and individuals' names (*orgName*), and their normalized code names (*orgCode*). To distinguish organizations and individuals, I included a *sector* variable. This provided a way to distinguish organizations from different sectors, and individuals from organizations. More detail on sectoral categorizations is provided in Table 2.8

artID	date	domain	site	title	fileName	snowball
1	2017	storm	https://tucsoncleanandbeautiful.(	Neighborhood Scale Stormwater Harvesting Program	neighborhoodScale	0
2	2017	storm	https://www.tucsonaz.gov/water,	One Water	oneWater	0
3	2017	storm	https://www.tucsonaz.gov/water,	Neighborhood Scale Green Infrastructure	neighborhoodScaleGI	0
4	2017	storm	https://www.tucsonaz.gov/gis/ma	Map Resources	mapResources	0
5	2017	storm	https://www.tucsonaz.gov/tdot/n	Tucson Department of Transportation Operation Splash San	tdotOperationSplash	0
6	NA	NA	https://www.pagnet.org/Default.	Green Infrastructure	workConferences	1
7	NA	NA	https://www.pagnet.org/docume	GI Workshop Bios	giWork	1
8	NA	NA	https://www.pagnet.org/docume	2016 AZ Stormwater Summit	stormSummit2016	1
9	2017	storm	https://www.pagregion.com/docu	Regional Green Stormwater Infrastructure Survey (Progress	regGreen	1
10	NA	NA	http://webcms.pima.gov/cms/one	Low Impact Development	lidPima	1
11	2017	storm	http://nrcsolutions.org/green-stre	Green Streets Active Practice, Tucson, Arizona	greenStreetActivePractice	0

Figure 2.10 Gray Literature Article Reference Document

eventID	eventName	eventCode	eventStart	eventEnd	extDateSite1	dateSiteNotes	keepTimeline_q	isWater_q	reg	edu	techOth	techGI	price	nonPrice	isMandated_q	isMandateNotes	art1	art2
1	Tucson Clean and Beautiful Ne	STORM	2016	ongoing	https://tucso	NA	1	1	0	0	0	1	1	0	0	0	1	0
2	One Water Summit of 2016	ONEWATER	2016	2016	NA	NA	1	1	0	1	0	0	0	0	0	0	0	1
3	Pima County Regional Flood C	GIWORK	2011	ongoing	http://webcm	NA	1	1	0	1	0	1	0	0	0	0	0	0
4	Tucson Water Commercial and	CMFISRA	1990	ongoing	NA	NA	1	1	0	1	1	1	0	1	0	0	0	0
5	Operation Splash Distribution	SPLASH	2017	ongoing	NA	NA	1	1	0	0	1	0	0	0	0	0	0	0
6	Operation Splash Distribution	SPLASHPILOT	2016	2017	NA	NA	1	1	0	0	1	0	0	0	0	0	0	0
7	Pima County Regional Flood C	ALERT	2012	ongoing	NA	Google search	0	1	0	0	1	0	0	0	0	0	0	0
8	Green Infrastructure for Regio	GIRES	2015	2015	NA	NA	1	1	0	1	0	1	0	0	0	0	0	0
9	Tucson International Airport A	TIAAF	2011	2011	NA	NA	1	1	0	0	1	0	0	0	0	0	0	0
10	Pima Association of Governme	GIRETURN	2014	ongoing	NA	NA	1	1	0	0	0	1	0	0	0	0	0	0
11	Tucson Water Annual Water Q	TWAQR	2014	ongoing	https://www.	NA	1	1	0	0	1	0	0	0	1	required by Safe I	0	0

Figure 2.11 Gray Literature Event Data

orgID	orgName	orgCode	sector	isBroker_q	isEntrep_q	isLeader_q	isCentral_q	centWeight	centralNotes	event1	event2	event3
30	Watershed Management Group	WMG	1	1	1	1	1	3	NA	0	0	0
31	Tohono Chul Park	TOHONO	1	0	0	0	0	0	NA	0	0	0
32	Sonoran Permaculture Guild	SONORAN	1	0	0	0	0	0	NA	0	0	0
33	Tucson Audubon Society	TAS	1	0	0	1	1	1	NA	0	0	0
34	Sonoran Institute	SINST	1	0	0	1	1	1	NA	0	0	0
35	The Nature Conservancy	TNC	1	0	0	0	0	0	NA	0	0	0
36	Tucson Botanical Garden	TBG	1	0	1	0	1	1	NA	0	0	0
37	Ashton Company Incorporated Contractors and Engineers	ASHTON	3	0	0	0	0	0	NA	0	0	0
38	Community Food Bank of Southern Arizona	FBANK	1	0	0	0	0	0	NA	0	0	0
39	Montgomery and Associates	MASSOC	3	0	0	0	0	0	NA	0	0	0
40	Civano Neighborhood Association	CIVANO	6	0	0	0	0	0	NA	0	0	0

Figure 2.12 Gray Literature Organization Data

Table 2.8 Categorizations for the Sector Variable

1	Non-profit	5	Media (e.g., news, radio etc.)
2	Public	6	Interest group
3	Private	7	Individual
4	Research-related/academia		

I also coded organizations and individuals based on reports of their role as 'leaders' (*isLeader_q*), 'entrepreneurs' (*isEntrep_*q) and/or 'brokers' (*isBroker_q*). These could be self-reports if, for example, if an organization published a website to talk about its latest accomplishments, or it could be reports by others, such as news media. To code actors as satisfying these roles, I identified explicit mention of these roles (e.g., reports that called an actor a 'leader'), as well as descriptions of activities that matched the criteria I used to operationalize each role. I operationalized the behavior of 'leaders' as those who are responsible for heading or championing a current event or program. These parameters were broad, and allowed several types of activities, such as running current programs, or conducting educational events. To identify 'entrepreneurs,' I looked for behaviors that could be interpreted as seeking change or fostering the introduction of an event or program, reflect in behavior as having advocated for or having promoted the adoption or implementation of programs or events, or innovative technologies therein. In Figure 2.14 I highlight examples of this behavior. The Watershed Management Group (WMG), for example, demonstrates actions that could be interpreted as leadership, such as how it ran 16 public water harvesting workshops in 2007, or how it hosted a workshop series at one of the local city council wards that same year. I also identified WMG as demonstrating what I conceptualized as entrepreneurial behavior, as it engaged in activities like securing funding for its rainwater harvesting demonstration sites in 2006, or by how it started the Tucson Green Living Co-op in 2008. To identify 'brokers,' I very broadly conceptualized these actors those explicitly mentioned in the gray literature as occupying some role between two other organizations or events also involved in Tucson water management. Figure 2.15 shows, for example, how WMG worked on behalf of the City of Tucson's Ward 1 Office with the Pima County Regional Flood Control District to address localized challenges relating to flooding and water quality. For additional analyses, I also included a dummy variable *isCentral_q* to indicate whether the organization satisfied at least a 'leader,' 'entrepreneur,' or 'broker' role. I also included a weighted score, *centWeight*, that was the sum of these positions, and an option to include any additional notes *centralNotes.*

Finally, I linked the observations in the organization and individual data set to the event data set. I developed a variable for every event (*event1…event806*) and indicated with a dummy variable the program(s) or event(s) in which an organization or individual participated. In several instances, an actor was involved in more than one program or event, and several programs and events had more than one participating organization or individual identified in as involved in Tucson water management.

Shocks in the Gray Literature

In the gray literature documents, I recorded mention of any event that was out of the ordinary, unexpected, and could have positive or detrimental effects on actors in the subsystem. Shocks did not need to be described as explicitly linked to an event in consideration (although I also have record of instances where this did occur). I then coded shocks as environmental (*shockEnviro*), political (*shockPol*), or socioeconomic (*shockEcon*). Environmental shocks included any instance relating to flood, drought, or water quality issues; political shocks were thought of as any events that related to change in power, political scandals, or any noteworthy behavior that affects who gets what, when, and how (Laswell 1936). Socioeconomic shocks were interpreted as positive or negative forces that could impact resources available to stakeholders in the policy subsystem. Each type of shock was additionally distinguished as exogenous or endogenous to the policy subsystem (*enviroExo, enviroEndo, polExo, polEndo, econExo, econEndo*). For each shock, I also included a brief description (*shockDesc*), and the date on which this occurred (*specificDate*). If an event spanned a time period longer than a year, I specified this with *shockStart* and *shockEnd*. Finally, I listed the article(s) in which the shocks were mentioned (*art1…artN*). Although documents were sampled for a ten-year period, shocks, in many cases were detected dating back to 1945. A sample of the shocks data is shown in (Figure 2.13).

shockEnviro	enviroEx	enviroEnd	shockDesc	specificDates	isFlood_q	isQuant_q	isQual_q	shockStart	shockEnd	art1	art2
1	0	1	flooding, $20,000 damages	08-04-2005	1	0	0	2005	2005	0	0
1	0	1	flooding, $10,000 damages	07-13-1999	1	0	0	1999	1999	0	0
1	0	1	flooding, $20,000 damages	07-07-2006	1	0	0	2006	2006	0	0
1	0	1	flood broke out of wash and flooded neighborhood	08-20-2010	1	0	0	2010	2010	0	0
1	0	1	UA Study finds over half of the 50 public vending ma	2010	0	0	1	2010	2010	0	0
1	0	1	flooding, $10,000,000 damages	07-15-1999	1	0	0	1999	1999	0	0
0	0	0	Pima County Regional Wastewater Reclamation Dep	2010	0	0	0	2010	2010	0	0
0	0	0	Wolslager foundation provided matching funds to P	NA	0	0	0	2010	2011	0	0
0	0	0	local water consumers were going bankrupt (see pg	NA	0	0	0	1990	1995	0	0
1	0	1	Tucson's water tested positive for low levels of the	NA	0	0	1	2011	2016	0	0
1	0	1	major waterline break	1999	0	1	0	1999	1999	0	0
0	0	0	Mike Letcher fired from position as City Manager, re	2011	0	0	0	2011	2011	0	0
1	0	1	major flooding at Rillito Creek in Tucson	12-18-1978	1	0	0	1978	1978	0	0
0	0	0	Tucson Water fires several employees and hires Dav	1994	0	0	0	1994	1994	0	0
1	0	1	heavy runoff from the Santa Catalina Mountains tha	07-31-2006	1	0	0	2006	2006	0	0
1	0	1	Tucson has 4-day cold snap, has major damage to its	2011	0	1	0	2011	2011	0	0
1	0	1	flooding, $20,000 damages	08-23-2003	1	0	0	2003	2003	0	0
1	0	1	Tucson coasted along, growing with little regard to t	1974	0	1	0	1974	1974	0	0
0	0	0	Brad Lancaster started cutting curbs for improved st	1998	0	0	0	1998	1998	0	0

Figure 2.13 Example of Shocks Data

2006

- Lisa Shipek becomes volunteer Executive Director, WMG's first staff member
- WMG receives first grant to develop 6 water harvesting demonstration sites in Tucson

2007

- Run 16 public water harvesting workshops in Tucson including first Earth Day event with 50 volunteers
- Schoolyard Water Education program launched in Tucson
- Workshop series at Tucson's Ward 3 Council Office: idea for Co-op sparked through conversations with volunteers

2008

- Start Tucson Green Living Co-op; 1st year has 70 members and 12 workshops
- Green Streets program emerges through two-year stormwater harvesting project with Rincon Heights neighborhood and federal water quality funding
- First job training program – 10-month Water Harvesting Apprenticeship, a bilingual program with southern Tucson partner Tierra y Libertad

Figure 2.14 Example of Entrepreneur and Leader Behavior

Executive Summary

Neighborhoods throughout Tucson are challenged by aging stormwater infrastructure or a lack thereof. Even in small rain events streets, homes, and community centers become flooded with polluted stormwater. Residents in the area south of Airport Wash are significantly impacted by impassable or dangerously flooded roads, damage to roads and buildings, and pollution in their washes and rivers as well as the pollution remaining when the water recedes.

On behalf of the City of Tucson's Ward 1 Office, Watershed Management Group (WMG) worked with the Pima County Regional Flood Control District (PCRFCD) to understand the potential for Green Stormwater Infrastructure (GSI) to cost effectively address flooding and water quality challenges. A holistic Cost Benefit Analysis (CBA) was utilized to assess the full range of benefits that would be experienced if GSI were implemented throughout the area south of the Airport Wash. Flooding and GSI retention were assessed using a 2-dimensional hydrologic and hydraulic model in three watersheds that drain directly into the Santa Cruz River: Valencia, El Vado, and the Santa Clara. Conditions resulting from frequent small events as well as an infrequent extreme storm event were modeled for existing conditions and two GSI scenarios. WMG utilized ESRI ArcGIS to map potential GSI infrastructure for homes, rights-of-way (ROW), and streets, as well as commercial properties, schools, churches, other community nodes, and their associated parking lots.

Figure 2.15 Example of Broker Behavior

<u>Construction of the Network Boundary</u>

From the survey and content data, I constructed networks for the studies in Chapters 3, 4, and 5. The data from each approach required unique approaches in operationalization of network actors and their relation. Here, I briefly detail how I operationalized network features from both types of data.

Rendering Networks from Gray Literature Data

Network actors in the gray literature data were conceptualized primarily as organizations, with the exception of four actors who played prominent roles, but could not be clearly identified as a member of any one organization. The three studies in this dissertation focus on processes relating to actor-actor relations, so I construct a *unpartite* network of actors, or *nodes*, that share relationships, or *ties* with one another.

I was interested in coordination ties, since the ACF assumes that subsystem actors engage in this type of interaction to achieve shared policy goals. The gray literature generally did not offer detailed information on the relationships between water-policy actors, so I operationalized coordination as joint participation in a water-related program or event. That is, if actor *A* and actor *B* both had some role in the adoption, implementation, or promotion of a program or event, they would receive a coordination tie.

Networks from Survey Data

Network actors from the survey data were also conceptualized as the organizational level. Information was provided by individual respondents, but I aggregated their responses. This information was used for the study in Chapter 5, which examines types of coordination between network actors. Since individuals within the organization can have different experiences, we received some unique reports of those with whom the respondent had interacted, but this was included as representative of the organization. In no instances were there conflicting reports.

As shown earlier in Figure 2.7 the survey asked respondents to list up to ten organizations with whom they interacted in a professional capacity. Unlike the content data, the survey approach captured relationships with greater precision to the extent that there was no assumption of coordination, and actors could offer more information about the nature of the tie. This free-recall method was useful in that we did not have a clear definition of the network boundary in Arizona. While responses may have been limited by the ten-nomination limit, there were very few cases in which respondents nominated the maximum number of organizations.

Ties between organizations in the network were undirected. This meant that if respondent *A* listed organizations *1*, *2*, and *3* as those with whom they interact, there would be a tie, regardless of whether there were any survey respondents from organizations *1, 2,* or *3*. Like the content data, this presents an area that may introduce error, because ties are generated on the assumption that reports are correct.

Chapter 3

Introduction

This chapter is concerned with identifying how well gray literature narratives of important actors reflect network measures of central actors in the policy process. Important actors have been a topic of interest in the policy literature for a long time (Kingdon 1995; Sabatier 1986), and can play a critical role in processes of sustainable development (Henry and Vollan 2014). These actors occupy a variety of roles to influence policy change in different ways, including mediating conflict and promoting compromise between opposed advocacy coalitions (Sabatier 1988), fostering dissemination of new information between competing stakeholders (Sabatier and Jenkins-Smith 1993), and as coordinating policy actors and assembling resources to promote policy innovation (Mintrom and Vergari 1996).

The Advocacy Coalition Framework is a theoretical starting point from which to examine important actors. Policy scholars often use the ACF to guide studies on change in the policy process. This framework conceptualizes policy change as occurring within a *subsystem*, which is defined as a policy area that affects a certain geographic scope, and the actors therein that seek to affect policy change. In this study, actors of interest are those occupying central roles, including policy brokers and policy entrepreneurs. The behavior of these types of actors is contingent on their relationships to others in the subsystem, and more broadly, their position in the policy network. For example, attenuating conflict may depend on ability to bridge ties and foster communication between two groups that would otherwise not interact (Sabatier and Jenkins-Smith 1993); an actor seeking to advance a proposal to the policy agenda may rely many connections with different groups in the subsystem to access timely knowledge or receive support needed to facilitate this process (Kingdon 1995; Mintrom and Vergari 1998).

However, recent studies have demonstrated a need to improve clarity in measurement of important actors. It has also been suggested that a key step forward in the research agenda of the ACF is to refine ways to operationalize those acting as policy entrepreneurs and brokers (Jenkins-Smith et al. 2014). I extend these areas of investigation to examine how well network measures of central actors align with reports of importance.

In this chapter, I study measurement of important actors in the context of urban water governance. Clarifying how we conceptualize and measure important actors in this context is critical for addressing challenges relating to sustainable development. Environmental systems are complex, and decision makers often have different understandings of what sustainability means, as well as conflicting beliefs and values that require cross-coalition learning to reach a consensus on shared problems (Henry 2009). Evidence of this need for policy consensus and linking new knowledge with action is particularly salient for water management in cities globally today, as increased pressure on urban water resources is demanding new policy strategies and investment in infrastructural development (Grimm et al. 2008; Ezcurra 2006; UN Water 2013).

The next section discusses how policy brokers and entrepreneurs (sometimes identified as 'leaders') are conceptualized broadly in the policy literature, as well as more narrowly in studies on urban water management. I review how social network analysis (SNA) is becoming an increasingly popular tool, but how there remains some challenges in measuring important actors in the policy network. Recent work has found that reports of importance through surveys of policy stakeholders do not always align with network measures. I try an innovative approach, then, by rendering a policy coordination network from gray literature on urban water management in Tucson, Arizona and estimating the Pearson correlation between network measures of centrality and reported importance, which I conceptualize as policy leadership, entrepreneurship, and brokerage.

<u>Conceptualization and Network Measurement of Important Actors</u>

As discussed in Chapter 1, the Advocacy Coalition Framework is designed to explain how stakeholders behave to affect subsystem affairs, and ultimately, policy outcomes. In some cases, subsystems are characterized by high levels of conflict, which can be explained most fundamentally by competing policy goals. At the individual level, policy actors are assumed to be boundedly rational, meaning that they have imperfect information due to limited time or cognitive ability to identify optimal paths to achieve their goals (Simon 1947). Thus, policy goals are largely shaped by actors' belief systems, and particularly, *policy-core* beliefs. These beliefs are limited by scope and topic and can include empirically-based orientations such as perceptions about problem severity, cause-and-effect relationships, and policy effectiveness.

When policy actors have similar policy-core beliefs, they often coordinate to achieve a common goal. Collectively, groups of actors coordinate to achieve a shared policy objective. Yet, coalitions can have different and often competing goals. Borrowing from a key finding in prospect theory (Quattrone and Tversky 1988), the ACF suggests that competing, boundedly-rational coalitions[4] often engage in a process called the *devil shift*, where each side exaggerates the negative intentions and overestimates the power of their opponents (Sabatier, Hunter, and McLaughlin 1987). This can lead to polarization and little communication. Over time, divided coalitions may reach a *hurting stalemate* where they each deem the status quo unacceptable, but refuse to compromise their respective positions, even though negotiation is necessary to achieve their goals (Weible and Sabatier 2007).

Policy Brokers

The ACF suggests, however, that policy brokers can mediate conflict between competing advocacy coalitions in order to promote policy change (Sabatier and Jenkins-Smith 1999). Through achieving reasonable compromise, stakeholders can arrive at a policy outcome that has shared support. Empirical examples have shown that brokerage can foster resolution in a variety of policy settings relating to coupled natural-human systems, such as navigating new flood risk management plans that incorporate integrated water resource management approaches (Rouillard et al. 2013), or retrofitting urban settings to restore balance between natural and human systems (Karvonen 2010). New information from this process and novel policy outcomes can also lead coalitions to update their policy-core beliefs in a process commonly referred to as *policy-oriented learning* (Sabatier and Jenkins-Smith 1993). Learning is hypothesized to have a

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[4] The coalitions themselves do not have belief systems or cognition – this is reference to the actors therein.

connection to policy change, although empirical evidence of this linkage has been varied (Weible, Sabatier, and McQueen 2009).

Entrepreneurs and Leaders

The ACF proposes that policy entrepreneurs also play a significant part in driving policy change. Mintrom and Vergari (1996) first recommended that entrepreneurs be included in the ACF to explain why dynamic periods of policy change occur when the subsystem is otherwise generally stable. The idea of the policy entrepreneur is borrowed from the agenda setting literature, which suggests that these actors frame issues and draw attention of stakeholders to promote policy change and innovation (Kingdon 1995).

Kingdon hypothesizes that policy entrepreneurs seize ‘windows of opportunity’ to promote policy change (1995). These actors rely on novel information in the policy network to stay alert to opportunities and to mobilize others in the subsystem to achieve these objectives (Mintrom and Norman 2009; Christopoulos and Ingold 2015). In urban water governance systems, policy entrepreneurs have promoted change in a variety of ways, such as adoption of new, adaptive water management techniques to deal with increasing change and uncertainty (Brouwer and Biermann 2011), and promoting integrated urban water management to improve integrated processes between water supply, wastewater, sewerage, stormwater services, and environmental flows (Keremane 2015).

In the urban water governance literature, however, discussion of ‘leaders’ may be referring to what policy scholars conceptualize as policy entrepreneurs. In the policy literature, entrepreneurs have been described as having leadership-type qualities (e.g., Christopoulos 2006; Weible 2007). Also, there are several examples in the empirical urban water governance literature in which leaders are described as engaging in policy entrepreneur-type behavior. Bettini et al. (2015), for instance, suggest that leadership is essential for framing issues, building relationships, exploiting opportunities, garnering resources, and maintaining momentum for water governance systems to have the adaptive capacity to maintain resilient socio-ecological systems. Farrelly and Brown (2011), similarly, recognize leadership as necessary for transition to sustainable urban water practices because it promotes organizational experimentation and learning. One of the key components that facilitates this action is the strategic positions of leaders, in which they develop partnerships that allow them to build their reputation and co-implement innovations (Brown 2008).

Measuring Important Actors through Social Network Analysis

In the ACF literature, there is a growing number of studies that use social network analysis (SNA) to examine how important actors rely on their positions in the network to achieve policy goals. Social networks can be thought of with regard to how their boundaries are defined. Boundaries refer to the criteria that guide what actors or *nodes* are included in the network, and the nature of the relationships, or *ties* they share (Laumann, Marsden, and Prensky 2017). As such, the policy network represents relevant stakeholders in the policy subsystem, and how they interact. Networks also offer insight about nodal-level attributes and the behavior associated with these features.

In social networks, some actors may occupy relational positions that afford them greater benefits and power as compared to those around them. These important actors, in particular, are seen as generally having central roles in the policy network (Laumann and Pappi 1976; Krackhardt 1990). *Betweenness centrality* and *degree centrality*, developed by Freeman (1979), are two common types of measures in social network analysis that show how well connected one is in relation to others in the network. Betweenness centrality refers to the position of an actor, *ego* and how many other, nonadjacent or otherwise disconnected actors that ego connects through a shortest tie. Policy brokers can be measured in social networks by their betweenness centrality, following the assumption that they are linking sparsely or completely disconnected subgroups. In policy networks where organizations coordinate in implementation of water-related programs and events, for example, we may see limited connectedness across the network because some policy actors limit their engagement to only some programs and events, and have limited or no interaction with stakeholders that are responsible for other programs and events. One reason this might occur is because policy stakeholders have divergent policy preferences. A broker, on the other hand, could have an active role in programs and events that are implemented by *both* groups of actors. This would situate the broker in an ideal position to attenuate any conflict that may exist, or disseminate information between once marginally- or unconnected parties.

Degree centrality refers to the number of ties one shares with adjacent others in the network. Entrepreneurs or other actors in leadership positions may be identified through their degree centrality. Returning once more to the policy-coordination network example, an entrepreneur may be well-connected and have a high degree centrality because of their involvement in many programs and events, or programs and events that involve many other participating stakeholders. This degree of connectedness to others may be representative of a strategy to mobilize many other actors, their resources, and to access diverse information needed to promote policy change. Assuming 'leaders' described in the urban water governance literature are also policy entrepreneurs and are dependent on those around them to achieve their policy objectives, we should see a similar structural position with high degree centrality.

The ACF literature has applied degree centrality in unique ways to flesh out concepts about important actors and how they influence the policy process. Ingold (2011), for example, combines SNA with multicriteria analysis and finds that actors with high betweenness centrality have moderate to centrist beliefs between pro-economy and pro-ecology positions, and are well-suited to enable compromise in a hurting stalemate between competing advocacy coalitions. Another study finds that policy actors with high degree centrality have comparatively higher success in securing passage of anti-fracking policies when compared to those that are less central in the network (Arnold, Nguyen Long, and Gottlieb 2017).

Yet, despite the utility of SNA, a trend in recent empirical findings suggests a need to address incongruence between relational network measures of centrality and qualitative reports of importance. A study by Ingold and Varone (2012), for example, measures brokerage through reports of reputational power, or 'importance' in the Swiss climate policy subsystem. Yet, not all respondents share the same opinion about the importance of policy actors that have the highest betweenness centrality in the network. Another study by Christopoulos and Quaglia (2009) uses surveys, interviews and graph theoretic approaches to identify most influential actors and their means of influence in the EU banking policy domain. Many of those reported as important—which is operationalized as prominence in lobbying activities relating to banking legislation—tend to not have *honest* brokerage roles in the network. [5] Christopoulos and Ingold (2015) conduct a study that draws further insights from these prior two cases. Using the Swiss climate data and the EU banking data, they compare qualitatively-identified actors of importance with additional types of network measures, including Bonacich power,[6] Burt's effective size and constraint,[7] and again honest brokerage to compare centrality with qualitatively-identified important actors. Nevertheless, they still find that several actors in the network display high centrality without having a notable impact on the policy process.

One way to explain this observed disparity between centrality and reports of importance is that measurement is never precise in the social sciences (King, Keohane, and Verba 1994). Conceptualization of central roles, then may be too broadly or narrowly specified. For example, asking respondents to nominate those of 'importance' in the policy process can elicit a sample of actors that occupy wide variety of prominent roles. Yet, this may not include those participating as brokers, leaders, or entrepreneurs. Despite underreporting important actors, they might nevertheless be detected in the network through high centrality scores. Alternately narrowly defining what activity signals behavior of a broker, leader, or entrepreneur can make multiplexity of actions inherent to each role go undetected (Christopoulos and Ingold 2011). Again, this could lead to underreporting of important actors when the network structure suggests that they are present.

Another important aspect of measurement to consider is respondent error. Some individuals may tend to only nominate only those in the network they deem important, or those with whom they interact frequently, which could also be limited if they are unable to remember the entire list (Bernard et al. 1984). A similar aspect that may bias reports is unique areas of unknown relationships that make up different *cognitive social structures.* These can be thought of as perceptions of what ties exist, where some respondents have a better knowledge of extant relationships than others (Krackhardt 1987).

Together, these findings suggest that it is important to develop a holistic view of the policy network by examining more than one type of important actor in each case. Also, brokerage, leadership, and entrepreneurship, when operationalized as positions that could be carried out by multiple types of activities, creates moderately narrow parameters for conceptualization of 'importance,' but allows sufficient flexibility so as not to exclude policy actors that do not

[5] Honest brokerage is defined as a relational position in the network structure, where the actor of interest serves as the only intermediary between other actors (Borgatti, Everett, and Freeman 2002).

[6] The concept of Bonacich Power proposes that the amount of power one has is a function of the power of those to whom she is connected (Bonacich 1987).

[7] Burt's (1992) effective size refers to the network size minus redundancy in the network, and constraint refers an index that measures the redundancy of one's contacts.

participate in a single activity, like lobbying. I anticipate, then, that the parameters for reported activities of important actors will be reflected in the network structure. Specifically, I posit that:

> H_1: Reported entrepreneurs will exhibit high degree centrality.
>
> H_{1a}: Reported leaders will exhibit high degree centrality.
>
> H_2: Reported policy brokers will exhibit high degrees of betweenness centrality.

Study Area: Tucson Water Governance

This study focuses on policy stakeholders participating in the urban water governance domain in Tucson, Arizona. Traditionally, the city has relied largely on the use of groundwater, which is delivered through a centralized, piped system (Water 2000). Yet, after the state legislature passed the Groundwater Management Act in 1980 (ADWR 2002), the city began to adopt additional measures to reduce risk of groundwater overdraft. Over the past three decades, Tucson has expanded its portfolio to include innovative approaches, such as rainwater harvesting, graywater applications, and the use of water-efficient appliances (Tucson Water 2013; Davis 2014; Hester et al. 2015; City of Tucson and Pima County 2009). While city and county government have played key roles in the adoption and implementation of Tucson's water policies, recent diversification in approaches has brought new stakeholders to the policy domain. Systematic methods to identify additional key actors and the nature of their involvement can be useful in providing greater insight on how policy change has occurred.

Research Design

Data Collection and Methods

To construct an urban water policy coordination network, I collected data through analysis of gray literature (i.e., non-peer-reviewed sources, such as news articles, websites, and reports) relating to urban water policy (discussed in Chapter 2). Policy in this regard was operationalized as strategies to achieve policy objectives, such as programs, events, or means by which to disseminate information. To identify relevant policies, I reviewed the U.S Bureau of the Census (2006) and identified water-related activities in which government organizations spend money. I then organized these activities into seven general domains with the guidance of water experts in hydrology, planning, and natural resources. Next, I conducted a systematic, manual web search of policies for each domain within Tucson, Arizona. For each search, I sampled the first ten unique results for 2007 to 2017; this produced 844 documents total (which included those collected through snowball sampling).

Through an event-based analysis, I identified 784 water-related policies and 440 actors. Actors in this study were interpreted as water organizations,[8] with the exception of four individuals without organizational affiliations. To define the network boundary, I selected actors based on those involved in adoption, implementation, or promotion any of the mentioned water policies. If more than two actors participated in the same policy, I assigned them a tie that represented coordination. From these data, I rendered a unipartite (actor-actor) network of 268 actors that coordinated on at least one of 526 events in 2017 (Figure 3.1). Although the gray literature provided insight on participating stakeholders, it did not offer much information on the ties themselves. Ties in the network, then, are undirected but valued, reflecting the number of events in which two actors participate (Scott 2017).

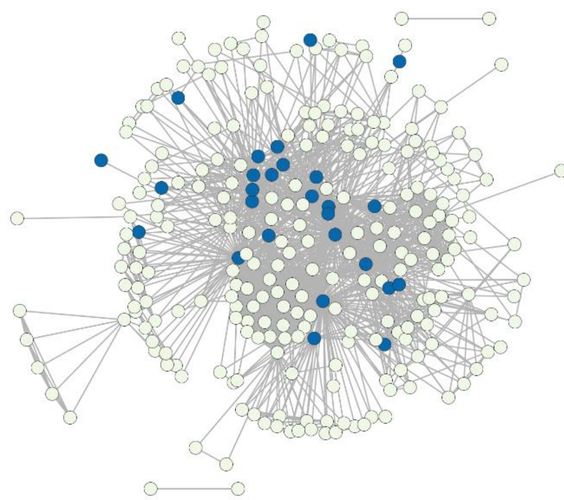

Figure 3.1 2017 Tucson Water Policy Network

Measuring Important Actors

I used social network approaches and media reports to identify important actors. One of the major theoretical foundations for social network measures is graph theory, which can help illuminate 'most important' actors in the network (Wasserman and Faust 1994). I recorded the degree centrality and betweenness centrality of organizations and individuals participating in the water policies. I also operationalized centrality of actors by recording media accounts of importance. Actors filling an important role in the policy network engaged in at least one of the following activities: i) having led or championed a current program or event, ii) having advocated for, or having promoted the adoption or implementation of programs, events, or innovative technologies, or iii) for acting as a broker between other network members. For more

[8] Organizations included spanned a broad range of sectors. These included the public, non-profit, private sectors, as well as research organizations, media, and interest groups.

detailed discussion on this operationalization, please see *Organizations and Individuals* in Chapter 2.

Point-Biserial Correlation

A Pearson product-moment correlation is a common way to estimate the correlation coefficient between relational importance in the network and reports of importance, but this requires both variables to be continuous. A point-biserial correlation, however, or a variation of the Pearson's *r,* calculates the correlation between a continuous and dichotomous variable. This is well-suited for the data because degree and betweenness centrality are continuous, while nominations of leaders, entrepreneurs, and brokers are dichotomous. The point-biserial *r*, like the Pearson's *r*, estimates the correlation coefficient between two variables *X* and *Y*, where 1 indicates a completely positive, linear correlation, 0 indicates no correlation, and -1 signifies a totally negative linear correlation (Rodgers and Nicewander 1988; Pearson 1895; Kurtz and Mayo 1979). Assumptions of the point-biserial correlation require that i) the continuous variable *X* is normally distributed, and has a normal distribution for each level of the dichotomous variable, and ii) that the continuous variable *X* has equal variances for each level of the dichotomous variable (Pett 2016).

Q-Q plots allow us to visually check the distribution of the degree centrality observations. Following the natural log transformation, the data appear to satisfy the assumption of a normal distribution, except for a few outlier observations at the lower end of the sample and theoretical quartiles (Figure 3.2). This may be explained by how nearly 8% of the actors in the network have a degree centrality score of 1. Q-Q plots of the log-transformed data for the non-leader and leader levels show a similar trend (Figure 3.3). In the non-linear condition, we see several outliers with a sample quantile of 0. Again, this likely reflects how many of the peripheral actors that had a degree centrality measure of 1, which became 0 following the natural log transformation. In the leader condition, degree centrality appears normally distributed, except for one outlier, which is the Coalition for Sonoran Desert Protection. This organization had a degree centrality of 1, but received a report as a leader. The distribution of the log-transformed, degree centrality observations appear to have a similar, normal distribution for the entrepreneur and non-entrepreneur conditions (Figure 3.4).

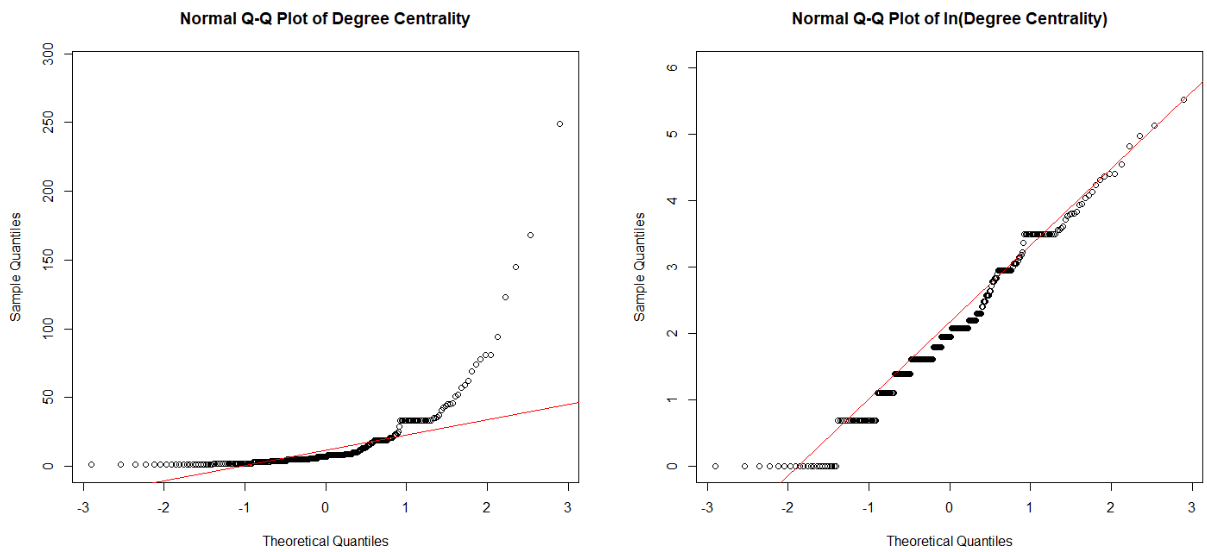

Figure 3.2 Q-Q Plot of degree centrality (left) and natural log-transformed degree centrality (right)

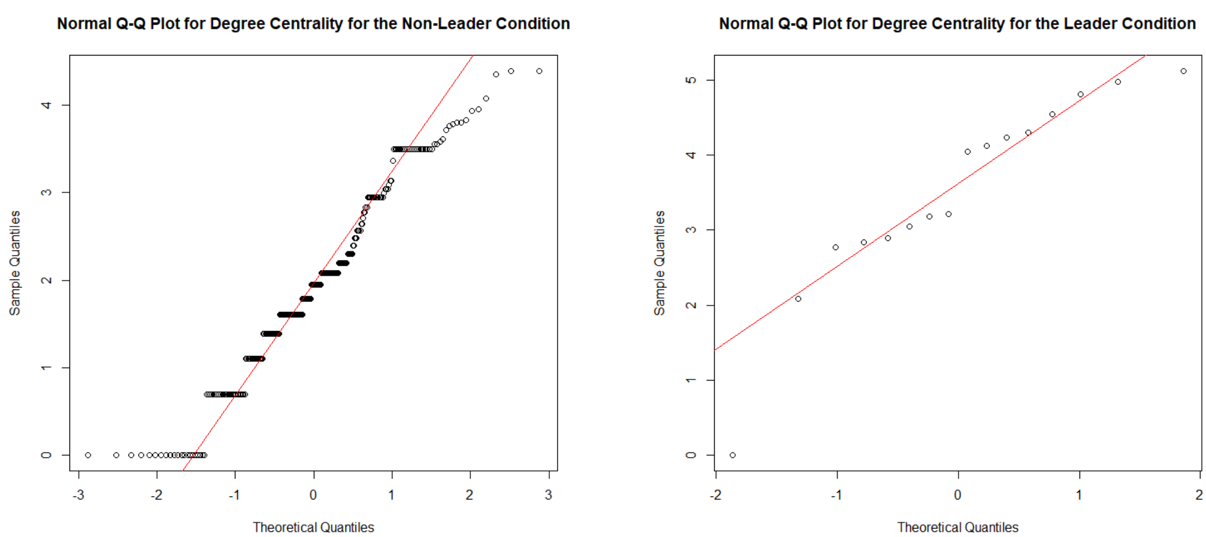

Figure 3.3 Q-Q Plot of transformed degree centrality for non-leader condition (left) and leader condition (right)

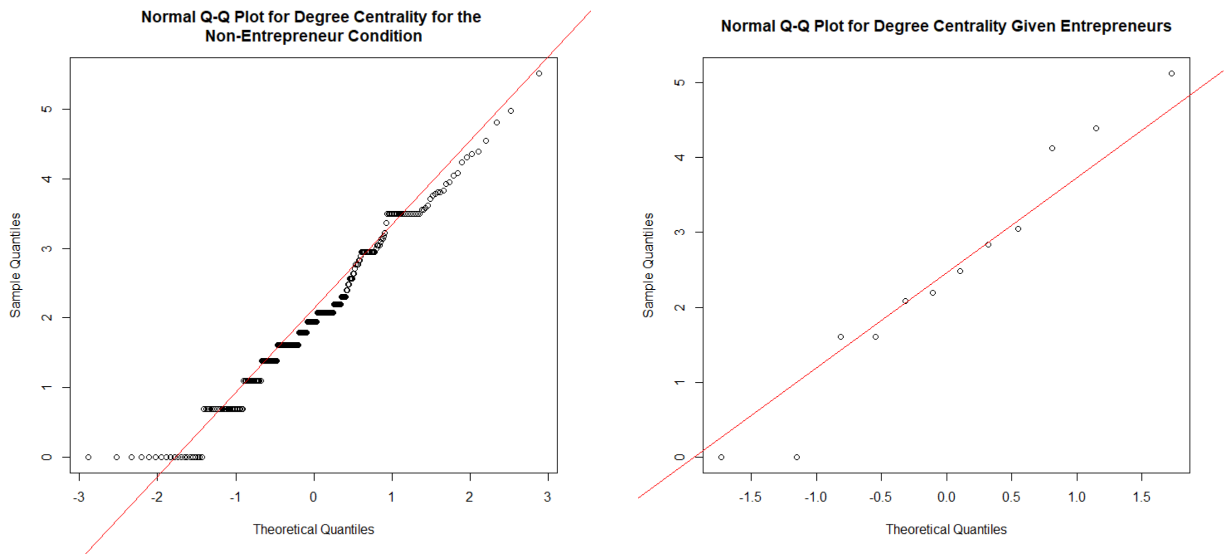

Figure 3.4 Q-Q Plot of transformed degree centrality for non-entrepreneur (left) and entrpereneur condition (right)

To assess whether there was equality of variance for the different conditions leader and entrepreneur conditions, I used a Levene's test, which indicates the homogeneity of variance. The *p* value is greater than $\alpha = .05$ and is insignificant, so I fail to reject the null. This means that the data satisfy the second assumption of the point-biserial correlation, that *X* has equal variances for both the non-leader and leader conditions.

Unlike the degree centrality, betweenness centrality measures fail to satisfy the assumption of normal distribution. This may be explained by how there are many organizations in the sample with no betweenness centrality, generally occupying a position in the periphery of the network (Figure 3.5). These skew the distribution to the point that transforming the data does little to improve the distribution. However, the observations with betweenness centrality greater than or equal to one appear to be normally distributed (Figure 3.6). A Breusch-Pagan test also shows that these observations are homoskedastic. I decide to subsample these observations and examine their relationship with gray literature reports of behavior that satisfies a brokerage role.

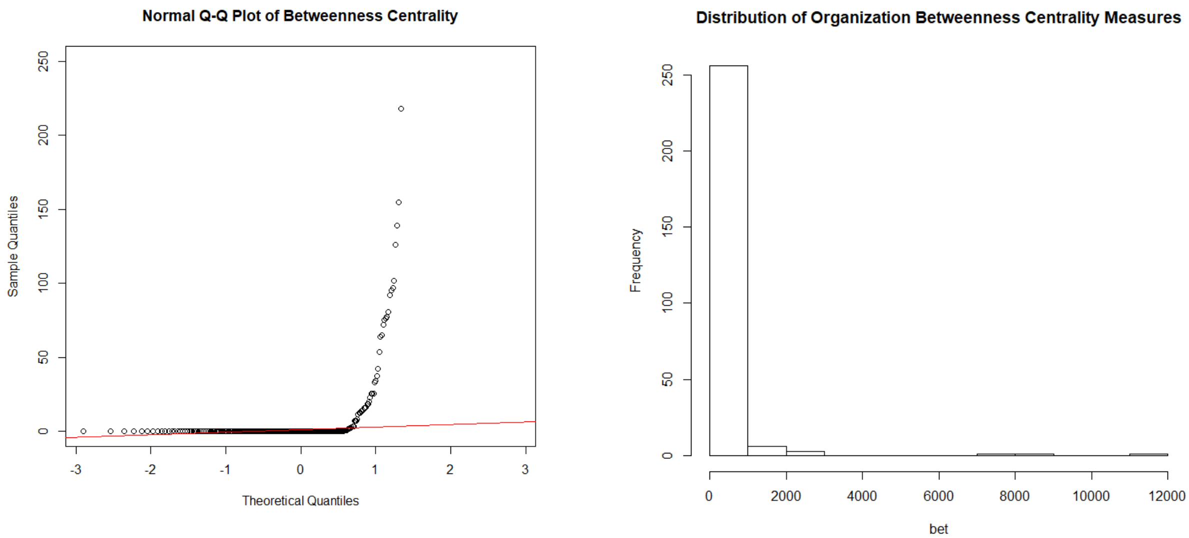

Figure 3.5 Q-Q plot of betweenness centrality (left) and histogram of betweenness centrality distribution (right)

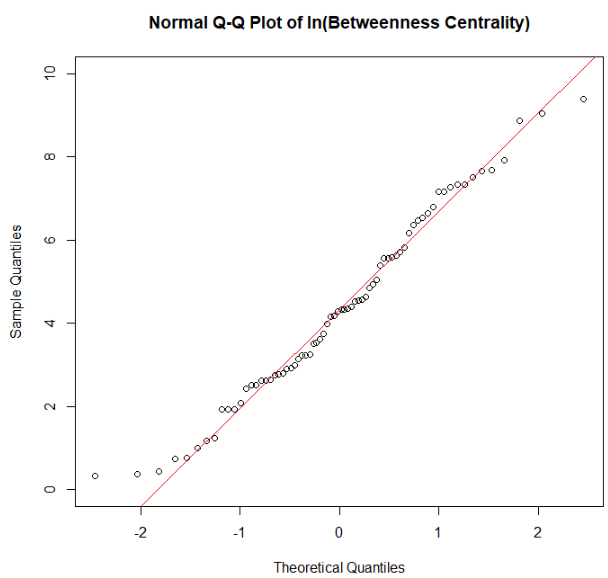

Figure 3.6 Distribution of log-transformed observations with betweenness centrality greater than or equal to 1.

Results

Reports and Centrality Scores

Correlation results show no support for Hypothesis 1, that reported entrepreneurs have high degree centrality. There is, however, support for Hypotheses 1_a and 2, that nominated leaders have high degree centrality and brokers have betweenness centrality. Another interesting finding is that there appears to be a stronger relationship between nominated brokers and degree centrality than nominated brokers and betweenness centrality.

Table 3.1 Correlation Between Network Centrality and Reports of Important Actors

	Reported Importance		
Network Measures of Importance	Broker (Subsample)	Leader	Entrepreneur
Degree centrality	.157***	.350***	.075
Betweenness centrality	.256*	.442***	.036

* $p \leq .05$ ** $p \leq .01$ *** $p \leq .001$

<u>Contextual Understanding of Important Actors</u>

The Effect of Network Construction on Centrality Measures

These findings potentially reveal two interesting features that offer more insight about the validity of gray literature data. First, although degree centrality and betweenness centrality generally measure different aspects of connectedness to others in the network, this may not be as clear when data are coded based on shared participation in programs and events. That is, given the assumption that all actors in a program or event share ties, those participants may have a higher degree centrality than if they had nominated those with whom they interact. To that end, if actor *A* participated in Event 1 and Event 2, but no other participants from Event 1 also participated in Event 2, actor *A* would have not only high degree centrality through its connection to others in each event, it would have high betweenness centrality (see Figure 3.7).

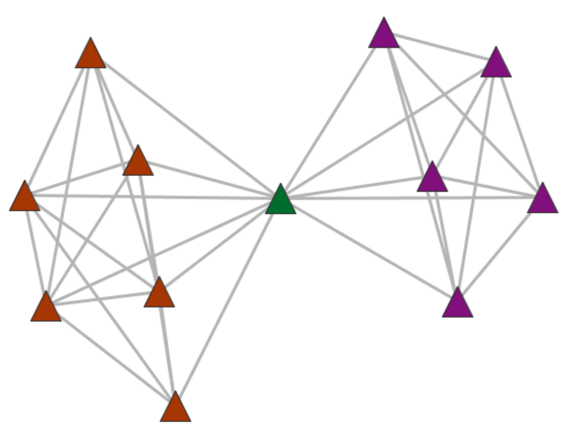

Figure 3.7 Network Graph of Brokerage: A schematic of actors that participate in two different events. The actor with high betweenness centrality and degree centrality is in green.

Bias in Reporting
A second interesting feature in the findings that may be unique to gray literature content is the strength of the relationship between leadership and centrality, as well as the lack of significance between nominated entrepreneurs and centrality. This may be interpreted as bias in reporting in the gray literature. It has been suggested that media often direct extra attention to those who have a role in new policies or problems or that have a well-established reputation in the policy domain (Yi and Scholz 2016).

In Figure 3.8, a scatterplot shows that actors that fit descriptions of leaders, entrepreneurs, and/or brokers also tended to have higher degree centrality. Most mentions focused on leaders, however, totaling 50% of all roles detected; entrepreneurs comprised 35%, and brokers 15%. Emphasis on leadership may be explained by the nature of the content: most documents were annual reports or news with the latest policy innovations, and actors responsible for implementation of current programs and events. A much smaller portion of the literature detailed processes in which policy actors advocated for the promotion or adoption of a policy, and processes leading up to a policy innovation.

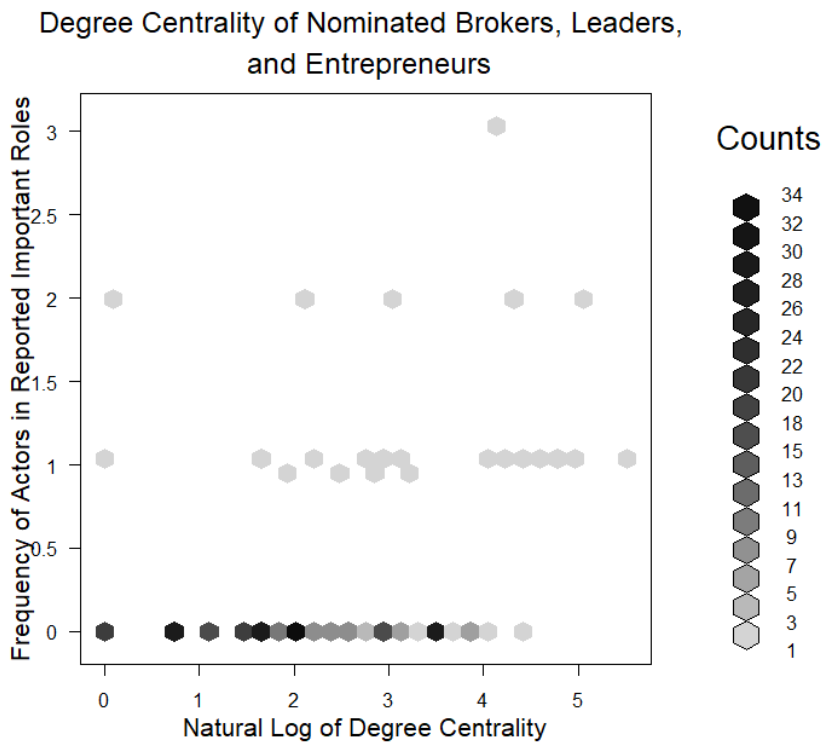

Figure 3.8 The x axis shows log degree centrality, which is a count of the number of ties an actor shares with others. The y axis shows reported importance. Important roles include brokerage, leadership, and entrepreneurship. Actors received a tally of 1 for each position they occupied; those with a score of 0 did not have any important role, whereas the actor with a

score of three was reported as a broker, leader, and entrepreneur. Most actors with a score of 1 were leaders.

Another trend in the gray literature showed that most policy actors coded as entrepreneurs, leaders, and/or brokers were from the government sector. Upon closer inspection, the most important government actors exhibited additional traits that indicate their prominence in the network. First, all had participated in Tucson's water policy domain for at least three decades. Tucson Water, for example, introduced its well-known "Beat-the-Peak" educational program in 1987 to encourage the city's water consumers to reduce summer peak demand (City of Tucson and Pima County 2009); the Pima County Regional Wastewater Reclamation District began its Biosolid Land Application Program in 1980, which continues to provide biosolids recycled from wastewater as a source of fertilizer and soil conditioner in the agricultural industry (Pima County Wastewater Reclamantion 2016); the Pima Association of Governments adopted its Area Water Quality Management Plan in 1978 to fulfill requirements of the Clean Water Act (PAG Environmental Planning Advisory Committee 2012), identify problems areas for point and nonpoint pollution, and recommend solutions and alternatives to address these challenges; and the Tucson Department of Transportation introduced its 1988 Interim Watercourse Improvement Policy to preserve vegetation adjacent to urban waterways (Cleveland 2013).

The University of Arizona and a non-profit organization called the Watershed Management Group also showed top centrality scores and were reported as satisfying criteria to be coded as important actors. Like the important government stakeholders, the university was reported as having been active over the past three decades. One of its earlier water management strategies was its 1985 development of Casa del Agua and the Arizona Desert House, which served as demonstration sites to educate the public about water conservation techniques, such as use of graywater, efficient appliances, rainwater harvesting, and drought-tolerant plants (Sheikh 2009). Although the Watershed Management Group was not founded until 2003, it has since played a key leadership role in the adoption and implementation of green infrastructure policies. Through 2017, the gray literature identified the organization as responsible for 13 different water conservation programs, events, and other approaches. Some of these included its rainwater harvesting demonstration site, workshops and certification program (City of Tucson 2017b; Tucson Water 2016; Watershed Management Group 2014)**.**

These public, non-profit, and academic actors that had the highest centrality scores among those nominated as important were also very well connected in the network. In 2017, each organization participated in a relatively high percentage of the extant programs and events (5%) as compared to the average stakeholder in the Tucson water policy network (.7%). As shown in Figure 3.9, Tucson Water and Pima County Regional Wastewater Reclamation District were comparatively much more active than the other important actors, but are also responsible for water supply and wastewater management in the Tucson metro area.

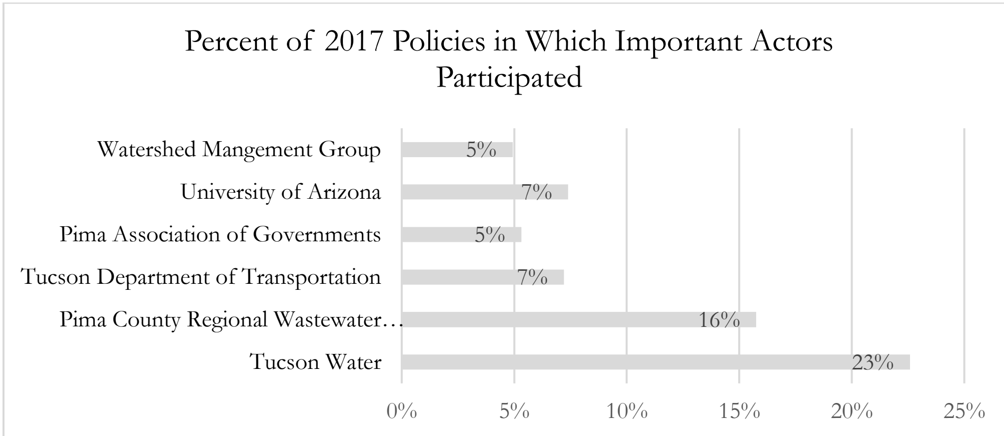

Figure 3.9

Other stakeholders nominated as important but that did not show high centrality were often connected to innovative policies. Much like the Watershed Management Group, several non-profit organizations nominated as leaders were responsible for introducing green infrastructure approaches, such as the Neighborhood Scale Stormwater Harvesting Program, introduced by Tucson Clean and Beautiful (Tucson Water, n.d.), the Sonoran Environmental Research Institute's loan program for low-income residents to install passive or active rainwater harvesting systems (Davis 2016b), the Tucson Botanical Garden's green stormwater infrastructure workshops and installment (Phillips 2005; Cleveland 2013), and the Santa Cruz River Initiative, an effort spearheaded by the Sonoran Institute to improve watershed conditions (WRRC 2008). The gray literature also directed much attention to Brad Lancaster, who has piloted several water conservation approaches and has been active in organizing stakeholders and advocating for policy innovation. Earlier efforts included his 1996 development of the Annual Dunbar Spring Neighborhood Rain, Tree, and Carbon Planting event, which continues to bring residents together to install and maintain street-side, passive rainwater harvesting features (Permaculture Research Institute 2016). Lancaster is also well known historically for making illegal curb cuts to facilitate better infiltration of street-side stormwater; the City of Tucson later institutionalized this approach in its Curb Cut Standards (Riley 2013).

Nominated Brokers and Betweenness Centrality

There is support for Hypothesis 2, in which reported brokers tend to have higher betweenness centrality. The coefficient for this is fairly low (.256), but stronger than the brokerage relationship with degree centrality (.157), which suggests that the operational definition of brokerage in this study can –at least marginally—illuminate those occupying unique roles that may leverage power between poorly-connected or disconnected actors in the network. As briefly mentioned earlier, this might occur in the observed Tucson water network when an organization participates in two or more events and there is little overlap of others involved in at least one of these events. Actors in positions of high betweenness centrality, then, may foster exchange of new information to participants in each respective program, or resolve differences in policy implementation. Tucson, for example, has seen incompatible perspectives emerge among actors in transportation, and other stakeholders seeking to promote practices relating to passive, roadside green infrastructure (Tucson Stormwater Summit 2017; Davis 2017 – Developer's Planned). However, organization participating in the Tucson Department of Transportation's seminars on stormwater regulations for the construction industry could be a good candidate to provide new information to a group of actors responsible for a neighborhood-level green infrastructure development initiative that were apprehensive about going to the city to discuss plans after previous experiences with the city that had inhibited action.

Another feature of the network that may explain the low coefficient is that the gray literature did not indicate any major points of conflict to be resolved. Of the 440 actors identified, only 3% were reported having any kind of adversarial relationship with others in the network. This is also exhibited in the network structure, where there are low levels of modularity (.455), meaning there were some densely-connected groups of actors that were either isolated, or that shared few ties with other groups (Newman 2006).There was even lower segregation (.398), indicating that coordination ties among actors in the network were not very restricted to others only participating in the same programs or events. Even if these policy actors *had* held divergent policy beliefs, the presence of coordination ties among them means there would be less opportunity to aggravate conflict (Henry 2011a).

A second feature that may explain the low coefficient is the core-periphery structure,[9] which can be thought of as a central group of densely-connected actors in comparison to those situated around the periphery of the network (McPherson, Smith-Lovin, and Cook 2001). Nevertheless, actors in the literature that engaged in broker-type behavior could still foster policy-oriented learning. Occupying a position in the core has been identified not only as a centrality measure (Borgatti and Everett 1999), but as an advantageous relational position (Christopoulos and Quaglia 2009). In a review of empirical research on the role of social networks in sustainable development, Henry and Vollan (2014) report that central actors can wield disproportionate control over information flows, can act as opinion leaders, and are well-positioned to diffuse new technologies. Thus, brokers may be instrumental (even in times of low conflict) to affect policy change. An empirical study of policy change in urban water, for instance, illustrates this point when a research center improves the linkage between scientific knowledge and policy decisions among multiple policy stakeholders to achieve a common goal (Chong et al. 2017). In Tucson, for example, the Watershed Management Group has been reported not only as a broker between the Pima County Regional Flood Control District and Tucson's Mayor and City Council in the "core" (discussed in Chapter 2, page 23), it has been shown in the network to link core actors to those in the periphery, such as the Rincon Heights Neighborhood Association or the Tierra y Libertad Organization.

To that end, when the network exhibits a core-periphery structure, we may learn more about the role of important actors and policy change not by examining whether nominated actors have high individual centrality measures, but whether they are situated in the core. An interesting finding that highlights this point is that Tucson Water, the Pima County Regional Wastewater

[9] In a core-periphery configuration, those more central appear to be more densely connected to each other than those occupying positions in the periphery. I opted, however, not to delineate the core and periphery to measure density because I acknowledge that there is continued disagreement among network scholars about the best way to do this.

Reclamation District, and the University of Arizona –again, all which had top measures of degree centrality and nominations of leadership—were also the actors with the highest betweenness centrality (Figure 3.10).

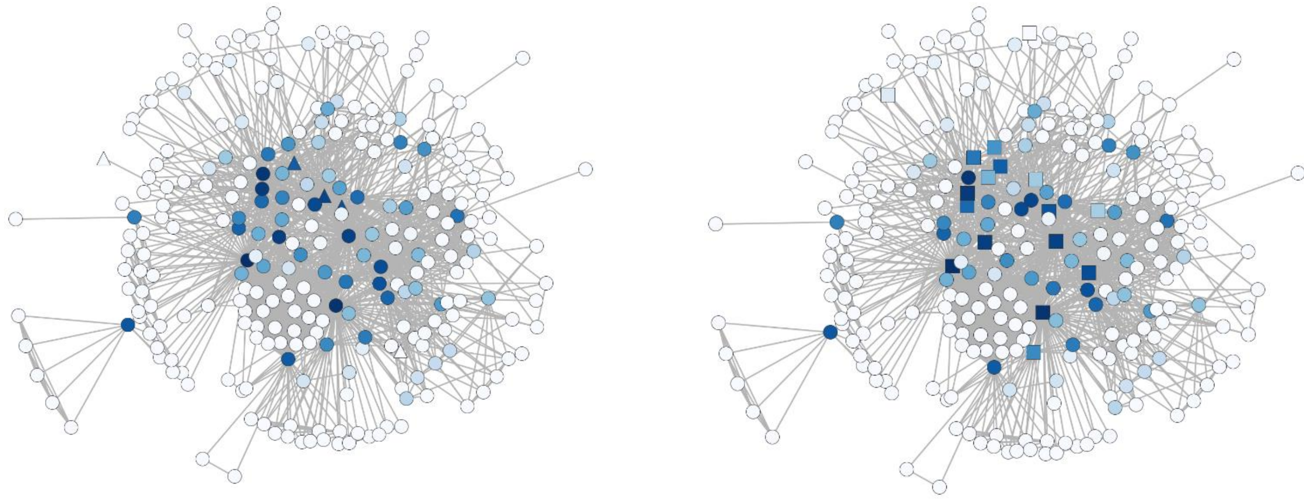

Figure 3.10 In both networks, darker shades of blue resemble higher measures of betweenness centrality. The triangles in the left network represent actors that engaged in activities to be identified as 'brokers' and the squares in the right network represent actors that engaged in activity associated with 'leaders'.[10]

Measurement Error and Identifying Brokers, Leaders, and Entrepreneurs in the Gray Literature

The network structure, the bias in gray literature reports, and the low correlation coefficients all illustrate that ways to conceptualize brokers, leaders, and entrepreneurs will need further consideration. Measurement error may have led to inaccurate detection of these actors, or it may have missed several others that occupy these roles in the policy network. This is particularly salient in the case of entrepreneurs in the gray literature, which had no significant relationship with network measures. Mention of actors engaging in entrepreneurial-type behavior may have been too narrowly-defined, or may require more thought about what constitutes policy entrepreneurship under different subsystem conditions. Also, the potential bias in reporting of leaders may warrant further consideration. A more conservative definition of leadership may be necessary to accurately detect this role. Next steps will be to revisit how the variables are theorized and operationalized.

Conclusion

Content analysis and social network analysis both offer valuable insights on the policy process, and are becoming increasingly popular methods to identify important actors. Recent studies have used reports of importance to validate network measures, and findings show promise for the

[10] Two pairs of isolates have been removed from the graph to save space.

utility of each method. Yet a recurring trend shows that reports of importance may not detect all policy actors that have central positions in the network.

This chapter addresses incongruence between reports and network measures by assessing how well reports of importance in gray literature can detect centrality in an urban water policy network. Drawing conceptualizations of importance from the Advocacy Coalition Framework, I search gray literature for actors exhibiting policy leader, entrepreneur, or broker behavior. Results from a point biserial correlation show i) no significant relationship between entrepreneurs and degree centrality, ii) a significant, positive relationship between leaders and degree centrality, and iii) a significant, positive relationship for betweenness centrality and brokers. Findings indicate that the operational definition of leadership and brokerage roles may suffice to detect positions that are also reflected through social network measures. However, low coefficients, and lack of significance between entrepreneur reports and degree centrality suggest that there is further attention needed to refine these measures. Other areas that need more consideration are how network construction influence correlations with reports, and how to reconcile differences in correlation between reports and networks with very different structural configurations.

Findings from this study offer a theoretical contribution to the ACF literature by taking steps to consider other types of ways to operationalize important actors in the policy network. It supports the notion that those engaging in leadership activities—an aspect identified in the literature as a feature of entrepreneurs—tend to occupy central positions among other policy stakeholders, which is posited to one's ability to perform different behaviors, such as accessing timely information, or mobilizing others to achieve a common policy objective. Methodologically, it highlights potential limitations of gray literature data and one's ability to distinguish brokers from leaders. Finally, it suggests that there needs to be further consideration of how to operationalize entrepreneurs in the policy network.

Chapter 4

<u>Introduction: The Puzzle of Shocks, Beliefs, and Policy Change</u>

The previous study examined use of gray literature and social network measurements to operationalize important actors responsible for policy change. In this study, I turn my focus to two other drivers of policy change: shocks and beliefs. Specifically, I examine how well shocks—when conceptualized by their relevance to the policy domain—explain updates in beliefs. Using a social network analysis (SNA) approach, I operationalize belief change as the observed percentage of annual change in the structure of a policy coordination network. This is based on the ACF assumption that policy behavior is a manifestation of beliefs. I review empirical literature on urban water governance to identify relevant shocks that drive policy change; this services as a foundation on which I organize shocks mentioned in gray literature on urban water management in Tucson, Arizona. Key events that have impacted Tucson over the past ten years have included and ongoing state-level drought that is potentially threatening one of the city's key water supplies (Pima County Wastewater Reclamation 2016), periodic water-quality challenges, such as intermittent infiltration of contaminants, such as pharmaceuticals (Associated Press 2008), and annual, recurring flooding events (Kornman 2008). From the gray literature, I identify environmental shocks and crises, including flood, drought, and pollution to be salient events for urban water governance. I then use an ordinary least squares (OLS) model to examine how these shocks affect change in the whole policy coordination network from 2008 to 2017. I find that environmental shocks drive change in the coordination network structure that may reflect updates in beliefs, or *policy-oriented learning.*

The Advocacy Coalition Framework guides this analysis. As mentioned in the last chapter, the ACF is a theoretical lens that offers direction for examining policy change processes. Key features encompassed in this framework include coalitions, learning, and policy change (Jenkins-Smith et al. 2014). These exist within a policy subsystem, or policy domain that affects a certain geographic area. Here, the ACF explains that stakeholders seek to either affect policy change, or to maintain the status quo. However, they are considered *boundedly rational*, with limited time, cognitive capacity, or ability to know all relevant information for the 'best' decision (Simon 1947). The ACF posits that similar beliefs relating to policy are the basis for coordination among policy stakeholders, and that these ties are generally stable over time. However, a change in the way policy problems and solutions are understood can drive policy change (Baumgartner and Jones 1995 and 2007). The ACF posits that shocks, such as socioeconomic change, crises, disaster, or shifts in power, can drive policy actors to question and update their current beliefs. A key puzzle remains however: how do we link shocks with policy-oriented learning?

The theoretical motivation of this chapter is to examine a different way to conceptualize shocks in the Advocacy Coalition literature. Shocks have been identified in the ACF literature as major pathways to policy change. Yet, an important challenge has been to identify what mechanisms link different shocks with different outcomes (Jenkins-Smith et al. 2014). Without this clarification, scholars risk ascribing change wholesale to disparate events, which can lead to confirmation bias (Nohrstedt and Weible 2010; Capano 2009).

I address the gap between shocks and policy change by examining how shocks influence policy-oriented learning. I am interested, particularly, in whether conceptualizing environmental shocks without regard to their geographic point of origin can help illuminate when they drive policy-oriented learning. Typically, the ACF considers endogenous shocks as influencing stakeholder beliefs (among other aspects), whereas exogenous shocks are assumed to largely influence other mediating factors. Yet, when examination of shocks (or crises) are not confined by their exogenous/endogenous divide, how does this change what we know about policy-oriented learning? In this study, I conceptualize shocks together, regardless of whether they occur external to, or within the geographic boundaries of the policy subsystem. Borrowing a concept from Nohrstedt and Weible (2010), I then think of shocks on the dimension of *policy proximity*, which refers to the extent with which these are relevant to a policy domain. Shocks high in policy proximity are hypothesized to illuminate problems with current policy mechanisms, or need to update current strategies.

The question of how to conceptualize shocks motivates the methodological contribution of this chapter. To examine the relationship between policy proximal shocks and policy-oriented learning, I rely on content analysis and social network analysis techniques. Surveys could offer an easy way to measure policy-oriented learning following shocks, with direct respondent input from respondents, but observations necessary for this approach are not always available (Jenkins-Smith and Sabatier 1993). Another technique commonly used in the policy literature is content analysis. It is more cost effective, offers greater flexibility, and allows researchers to collect longitudinal data without challenges relating to respondent attrition (Macnamara 2006). While it is impossible to ask policy actors about their beliefs, behavioral patterns in the policy network can exhibit policy-oriented learning.

In the next section, I discuss how the ACF conceptualizes shocks to the policy subsystem. In the context of urban water governance, I argue that traditional exogenous and endogenous distinctions may not be well-suited to theoretical understanding of the relationship between environmental shocks and policy-oriented learning. I then shift focus to review the ACF's model of belief systems, how these can be detected through social network analysis, and how change in the policy network structure may help us identify when policy-relevant shocks influence policy-oriented learning.

Conceptualizing Shocks to the Policy Subsystem

The ACF conceptualizes shocks as major pathways to policy change. Shocks stemming from both within and outside of the policy subsystem are hypothesized to focus attention on key problems, redistribute resources, shift power in coalitions that espouse competing policy goals, open venues, and drive agenda change (Sabatier and Weible 2007; Jenkins-Smith et al. 2014). Exogenous shocks are outside the control of actors in the policy subsystem, and include events such as crises, disasters, change the systemic governing coalition, in socioeconomic conditions, or in other policy subsystems (Sabatier and Jenkins-Smith 1999). The ACF also assumes that shocks within the subsystem can cause majority coalitions to question their policy-related perceptions, and confirm the beliefs of the minority coalition (Jenkins-Smith et al. 2014). These are events such as policy fiascoes, scandals, and some crises that occur within the geographic boundaries of the subsystem (Sabatier and Weible 2007).

In urban water governance, water-related, environmental shocks (including crises) have been identified as salient problems that afflict city centers worldwide. These include pollution, such as chemical contamination, outbreaks of water-borne disease, or improperly managed industrial wastewater; water shortages from growing demand and increased drought, especially for urban areas in arid and semi-arid regions; and increasing spatial and temporal variability in rainfall, which can impose flooding (UNESCO-IHP 2009; Yuan et al. 2013; Kenney, Klein, and Clark 2004). Empirical evidence has shown these events to also drive adoption of policy innovations. For example, some cities have begun using geographic information systems models to improve response to urban flooding emergencies (Price and Vojinovic 2008); others have taken preventative measures against water scarcity by adopting desalination (Floyd et al. 2014); and others have implemented new water treatment systems that use advanced oxidation processes to remove water pollutants (Qu and Fan 2010).

When the geographic extent of an urban water policy subsystem is defined by its jurisdictional boundaries, environmental shocks of pollution, flood, and drought may emanate from within or outside these limits. Examining water policy issues at the extent of the watershed, for example, has been a point of growing interest for water management, especially since the boundaries of municipal jurisdictions rarely ever align with the watersheds in which they are located (Schlager and Blomquist 2000). There are several instances where shocks can occur within or outside the municipal boundary, which may include non-point source pollution (Lubell et al. 2002) or urban wastewater pollution (Pivo 1996); drought, which can impact local and statewide groundwater and surface water levels (Mishra and Singh 2010); and flooding in cities can stem from highly variable weather and hydrological events such as precipitation and flows, and excessive flows can stem from urbanization with increased impervious areas and inadequate infrastructure (Cettner et al. 2013; Jha et al. 2012).

This raises the question, then: if we think of shocks without regard to their geographic position in relation to the policy subsystem, how do we know when policy-oriented learning occurs? This question contributes to a broader agenda to refine aspects of the policy process as conceptualized by the ACF. In a review of the ACF, Nohrstedt and Weible (2012) identify exogenous shocks, endogenous shocks, and policy-oriented learning as three major pathways to policy change and explain that each is 'necessary, but not sufficient' to bring change to the policy-core. Thus, they suggest that understanding the linkage between these pathways and policy change could be better developed. They propose that a theoretical area of inquiry that needs further examination is interdependencies of these paths, such as when events internal and external to the subsystem lead to learning (133).

One interdependency I focus on in this study is how to identify a significant relationship between shocks and policy-oriented learning. Borrowing a concept developed by Nohrstedt and Weible (2010), we may be able to think about shocks in terms of their *policy proximity*.[11] The policy

[11] *Policy proximity* was originally developed with the intention to guide inquiry relating to crises which "represent periods of disorder and de-institutionalization, which are phenomenologically distinct from objective accounts of threat (exogenous or endogenous)" (Nohrstedt and Weible 2010, 17).

proximity of a shock can be thought of in terms of how strongly it illuminates deficiencies in current policy subsystem strategies, or need for policy alternatives. For example, a policy proximal shock would have the same effect on two policy subsystems to the extent that these "share policy design components, such as…statutes, laws, and policies, including the instruments, ideas, and symbols therein" (17).

Looking at this from another perspective, a shock may have closer policy proximity for one policy domain than another. Take, for example, two recent events that impacted Sonoma County, California. Several deaths in the 2017 Tubbs Fire led county officials from the local sheriff's and fire departments to recognize that future evacuation processes would need to use the US federal alert system to notify those in jeopardy (St. John and Kohli 2017). After identifying a shortfall in the current alert systems, the Sonoma County Board of Supervisors unanimously agreed to embrace new technologies to prepare for the future, potential fire events (Johnson 2018). For Sonoma County's water policy domain, however, the fire could be considered comparatively less relevant. Although the fire cut power necessary to pump groundwater, this problem would more likely lead policy actors from the power utility or emergency services to reconsider their strategies. On the other hand, a comparatively proximal event has been ongoing drought that is linked to dropping levels in that same groundwater. More than 600,000 residents from Sonoma and Marin Counties rely on this resource, so the Sonoma County Water Agency has begun to adopt policy innovations, such as rebate programs for high-efficiency appliances, Water Smart Home evaluations, and development and implementation of conservation-based curricula for their Water Education Program (Sonoma County Water Agency 2015).

In this section, I have identified ways in which policy-proximal shocks may transcend geographic boundaries. This alone, however, does not explain the process between shocks and policy-oriented learning. In the next section, I discuss the ACF's model of the individual belief system and discuss how policy-oriented learning may be detected through social network analysis.

Belief Systems

To understand the behavior of stakeholders in the policy subsystem, the ACF offers a model of cognition, explaining that actions are guided by three different levels of beliefs. Most fundamental are *deep-core* beliefs, or worldviews about causal processes and what is most valued. At this level, perceptions are very well-established and changing these would be "akin to religious conversion" (Sabatier 1986). Deep-core beliefs span multiple subsystems and guide how individuals think about phenomena such as their receptivity to change (Schwartz 1994; Stern et al. 1998; Stern et al. 1999), and the relationship between human behavior and environmental wellbeing (Steg and Sievers 2000). These are hypothesized to influence *policy-core* beliefs at the second level, which are ontological and normative perceptions about different facets of the policy subsystem, such as problem severity, causal drivers of these problems, and effective solutions (Sabatier and Jenkins-Smith 1999). Finally, *secondary beliefs* comprise operational views about how best to achieve goals associated with policy-core beliefs. These are day-to-day strategies, such as expansion of a program or its budget, or changing the boundaries of a service provision area.

The ACF identifies beliefs at the policy-core level as most closely-linked to policy outcomes, and suggests that policy behavior will remain consistent over time because individuals only gradually update their policy-core beliefs as they gain new knowledge and experiences, a process referred to as *policy-oriented learning* (Sabatier 1988; Sabatier and Weible 2007b). The ACF suggests that this occurs because of a process called *biased* assimilation, where beliefs serve as perceptual filters to novel information, and individuals only accept new knowledge that is consonant with their prior beliefs (Lord, Ross, and Lepper 1979; Munro and Ditto 1997; Munro et al. 2002). To that end, marginal changes to beliefs at the secondary level are much more likely to occur (Sabatier and Jenkins-Smith 1999).

Shocks, however, drive policy actors to question, and in some cases, discredit current policy (Alink, Boin, and T'Hart 2001; Boin and Hart 2003; Nohrstedt and Weible 2010; Birkland 2006). From this, they may also revise their policy objectives. Yet, it is not always clear when shocks drive policy-oriented learning: it has been found that not all shocks and not all instances of learning result in policy change (Mintrom and Vergari 1996). The ACF explains that other mediating factors aside from policy learning could also influence policy change, including heightened public attention, agenda change, redistribution of resources, or opening and closing policy venues for assistance, such as from congressional committees, state regulators, or the public (Sabatier and Weible 2007b; Jenkins-Smith et al. 2014; Baumgartner and Jones 1991). Because of this wide variety of possibilities, several scholars have indicated a need to clarify what mechanisms explain the relationship between shocks and policy change (Nohrstedt 2005; Weible, Sabatier, and McQueen 2009; Nohrstedt 2009).

One promising way to delineate policy-oriented learning from other mediating drivers is by observing change in policy coordination network. When policy stakeholders interact over long periods of time to affect policy change, they comprise a policy network (Sabatier and Jenkins-Smith 1999).The ACF posits that policy stakeholders form relationships with those of similar policy-core beliefs through processes of *homophily* to coordinate and achieve shared policy goals (Mcpherson, Smith-lovin, and Cook 2001; Zafonte and Sabatier 1998; Henry, Lubell, and McCoy 2010). Alternately, those with divergent beliefs are suggested to have an aversion to one another (Sabatier, Hunter, and McLaughlin 1987). This leads to segregation in the network (Figure 2.1 where ties primarily occur only among actors with similar attributes (Schelling 1971; Henry 2011a). Empirical literature has shown evidence of both homophily and segregation in policy networks (Weible 2005; Gerber, Henry, and Lubell 2013); 2017). Yet shocks can drive major belief change at the policy-core level (Jenkins-Smith et al. 2014). Following network concepts, these changes could lead policy actors to dissolve ties with those to whom they have an aversion, or to form new ties with those sharing similar policy-core beliefs. Following this logic, I propose the following hypothesis:

Policy proximal, environmental shocks drive segregation in policy coordination networks.

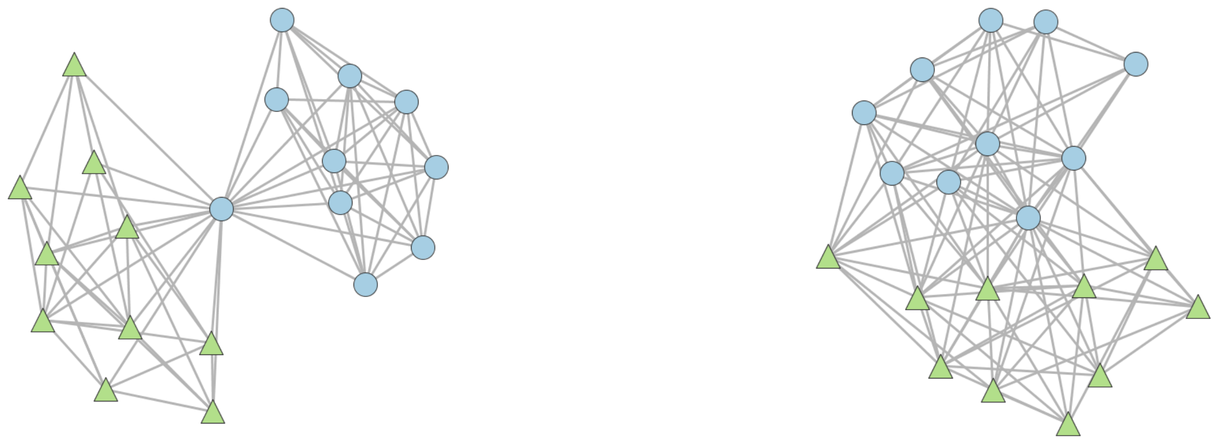

Figure 4.1 Examples of Network Segregation. Both networks exhibit instances where actors select like others. The network on the left shows segregation with two distinct clusters, while the network on the right is more cohesive.

<u>Research Setting: Shocks to the Tucson Water Policy Subsystem</u>
This study examines the urban water policy network in Tucson, Arizona. The city faces a dynamic array of governance challenges, in that it is concerned with not only with long-term water security, but how to manage punctuated effects of urban stormwater and floods. Over time, water stakeholders have also responded to both ongoing and intermittent events that have negatively affected the city's water quality.

Tucson is situated in a unique biophysical and institutional context that has driven it to adopt innovative water technology over the past several decades. Historically, the state of Arizona has relied primarily on groundwater, but has faced challenges of over-extraction (Feller 2003). In 1968, the federal government authorized the Central Arizona Project (CAP), which would deliver water from the Colorado River to central Arizona (Central Arizona Project, n.d.). CAP was intended to mitigate use, but consumers instead continued their current rate of groundwater extraction in addition to the new CAP resources. The state responded by passing the 1980 Groundwater Management Act (GMA). The Act designated much of Arizona's central region (encompassing Tucson) as active management areas (AMAs), regulated by goals pursuant to the GMA. One of these goals would be to achieve 'safe yield' standards by 2025, in which annual withdrawals of groundwater would not exceed the amount recharged (ADWR 2016). To achieve these goals, municipalities would be required to implement at least one or more conservation practices, which increase in proportion to the number of service connections in their respective jurisdictions (Larson, Gustafson, and Hirt 2009). To meet GMA requirements, Tucson's water portfolio is comprised of available groundwater, CAP water, and recycled supplies (Tucson Water 2013).

Nevertheless, Tucson still faces potential cuts to its supply. In 1968, Arizona sued California over the US Supreme Court's ruling to apply the prior appropriation doctrine across state lines, which could allow California to claim senior water rights to the Lower Colorado River if it were to use the river's resources first (Central Arizona Project, n.d.). After Arizona could ensure its own rights to allocation, it sought Congressional approval for the construction of CAP. To gain necessary support from California, Arizona had to accept junior priority status to water rights should a shortage be declared on the Lower Colorado River (Water Education Foundation and UA WRRC 2007). Under these conditions, Tucson would lose its annual allocation to California. Declaration of a shortage, however, is moving closer to becoming reality, as Lake Mead's levels have continued to decline since the early 1990s (Davis 2016a). Nevertheless, the city has prepared for this possibility by recharging its excess annual CAP allocation into the ground to store for future use; this technique doubles as a natural filtration and neutralization system for potable supply, as the CAP water has a high level of acidity.

Long-term weather trends are also imposing stress on Tucson's future water supply. Since the turn of the 20th century, the US Southwest has seen an increase in average annual temperatures and long-term drought (USEPA 2016). In response to these conditions, Tucson has begun to adopt additional, innovative policy strategies to promote water conservation. Examples include regulatory mechanisms, such as the City's 2008 Commercial Rainwater Harvesting and Residential Graywater Ordinances (Huckelberry and Letcher 2009) and incentive-based approaches, like its 2012 Rainwater Harvesting Rebate Program (City of Tucson and Pima County 2009; City of Tucson 2017a).

Increases in climate variability have brought greater frequency of storms and flooding events. Although Tucson anticipates the Annual North American Monsoon, flooding has been responsible for approximately half of the damages caused by extreme events, as well as multiple deaths and injuries (Bakkensen and Johnson 2017; Pima County 2012). Several policy stakeholders have been proactive to reduce negative effects of Tucson's annual floods. For instance, the Pima County Regional Flood Control District and the Watershed Management Group, a local non-profit organization, have offered workshops to educate Tucson residents about green infrastructure, and how reducing impervious areas can mitigate floods, sedimentation, and erosion (MacAdam 2012; Watershed Management Group and Pima County Flood Control 2015). The City and County have also sought to minimize risk by developing flood-prone reference maps and an automated local evaluation in real time (ALERT) system and website to offer real-time data on current weather conditions (TDOT 2015; Pima County 2018).

Tucson's water governance network has also faced challenges linked to water quality. Possibly the best-known, historical pollution challenge in Tucson has been the trichloroethylene (TCE) plume that was discovered near the Tucson International Airport in 1983. TCE is carcinogenic to humans, can negatively affect fetus development, and is detrimental to respiratory health, immune system function, and the central nervous system (USEPA 2018). The US Environmental Protection Agency has designated the TCE plume area as a superfund site, and the cleanup process (i.e., the Tucson Airport Remediation Project) has since installed an Advanced Oxidation Process Water Treatment Facility to remove 1,4 dioxane (Tucson Water 2018a). This chemical is suspected to be carcinogenic to humans and can cause nausea and irritation to the eyes, nose, and throat (USEPA 2017). In addition to the remediation project, there have been comparably innocuous issues over time, such as high ammonia effluent levels from regional treatment facilities. This, nevertheless, has also driven installation of innovative ammonia, nitrogen-, and nutrient removal process systems at the recently-expanded Tres Rios Water Reclamation Facility (Prevatt 2015). Finally, the city must respond to ongoing discovery of antiquated, lead piped systems that are dangerous for potable supply. The utility has developed a response and inspection process to field customer notification of suspect infrastructure, and has provided guidelines to help consumers reduce potential exposure (Tucson Water 2018b).

In the next section, I discuss how I examine ways in which these and other extreme events have impacted change in the policy coordination network. I discuss how I collected the data, and the operationalization of the independent, dependent, and control variables.

Research Design: Water Policy Coordination Network and Shocks in Tucson

Data Collection through Content Analysis

I used content analysis to gather information on local water organizations, the programs and events (i.e., water policies) in which they have participated, as well as emergent shocks and crises (covered in Chapter 2). Content analysis was well-suited for this study because it allowed me to develop a holistic view of change in the policy network over ten years. Although media content can be biased in its coverage of relevant policies and actors (Yi and Scholz 2016), it is a low-cost, unobtrusive method. Surveys may have solicited network information in greater depth (e.g., a record of policy beliefs), but this would have presented some challenges. For example, respondent attrition could diminish sample size over time, and retrospective responses could be subject to issues of recall in policy participation (Weber and Stern 2011), as well as those with whom respondents have coordinated (Henry, Lubell, and McCoy 2012).

Boundaries of the water policy network were limited to policy stakeholders participating in Tucson water policies. To identify relevant actors and policies, I first reviewed the US Census of Governments (US Census Bureau 2006). Organization Functions and Activity codes, which are based on spending in water-related areas. From this, I derived seven water-related functional areas. I paired each of these with 'Tucson' to identify relevant policies and actors (refer to Table 1.1 on page 11). A systematic search produced gray literature comprising media such as news articles, city plans, ordinances, brochures, and information websites. For each search combination (e.g., 'stormwater Tucson'), I selected the first ten unique relevant[12] results and included additional sources with a snowball sampling technique. As discussed in the previous chapter, I identified 784 water-related policies and 440 actors. From this, I reviewed organizations that had adopted, implemented, and/or promoted policies (i.e., programs and events). If two or more actors had any of these roles in the same policy, they were interpreted as sharing coordination ties with each other. From this, I rendered annual water policy coordination networks for Tucson, Arizona for each year from 2008 to 2017 and measured descriptive network features of each (Table 2.1).

[12] Sites that did not offer an information relating to water management in Tucson were not included in the sample.

Finally, I sampled shocks mentioned in the gray literature. I included these events regardless of whether there was explicit mention of their role in driving policy change, or behavior of relevant policy actors. Although this study focuses on the effect of environmental shocks, I also included all mentions of political and economic shocks, which I explain further in my discussion on control variables. A more comprehensive review of data collection is discussed in Chapter 2.

Table 4.1 Descriptive Statistics of the Urban Water Network, 2008 – 2017

Year	*Vertices*	*Edges*	*Density*	*Triads*	*Modularity*	*Segregation*
2008	170	898	.05	.367	.413	.049
2009	219	1569	.056	.592	.455	.323
2010	246	1688	.048	.554	.456	.291
2011	249	1714	.048	.539	.448	.295
2012	248	1827	.049	.534	.446	.365
2013	261	2094	.051	.516	.46	.371
2014	283	2453	.052	.563	.479	.435
2015	261	2066	.05	.527	.457	.378
2016	267	2108	.048	.511	.459	.402
2017	268	2122	.048	.508	.455	.398

Dependent Variable: Annual Percent Change in the Policy Network Structure
I used annual change in the structure of a unipartite (actor-actor) coordination network in Tucson water governance as the dependent variable. Actors were assigned a coordination tie if they both implemented or promoted at least one policy together in roles such as leadership, sponsorship, or partnership. Although ties between the actors were undirected, they were weighted. Weights represented the number of policies in which actors jointly participated. The greater number of instances of coordination, the greater the weight (see Chapter 2 for more information on network construction).

To measure structural change, I took several network features into account. First, I measured the annual percent change in the number of policy stakeholders, or *vertices*, as well as the coordination ties, or *edges* between them. I also examined change in the *density* of these ties, which measures the proportion of extant ties to all possible ties in the network (Wasserman and Faust 1994). Next, I measured annual change of three structural features related to density: transitivity, modularity, and segregation. *Transitivity*, described earlier, is a process that drives the formation of triads, where actor *A* creates ties with actors *B* and *C*, thus increasing the likelihood that *B* and *C* will also form a tie (Holland and Leinhardt 1971). *Modularity* occurs in a network when densely-connected subgroups of actors share fewer ties between their respective groups (Newman 2006). Finally, *segregation* refers to extent with which homogeneous actors (in this case, those participating in the same types of policies) tend to form ties, but not with those who are different (Schelling 1971).

Independent Variable: Environmental Shocks
Environmental shocks occurring within and outside of Tucson, which included pollution events, floods, and drought comprised the independent variable. Including shocks outside the subsystem

could have hypothetically introduced considerable noise, but content from the systematic web search directed focus to shocks that were relevant to the stories and reports.

For each year, I summed the number of shocks to create an annual score. For example, if Tucson were to i) detect unsafe levels of lead in the water, and experienced ii) a water shortage and iii) a flood in 2007, that year would have a score of 3. Crises extending multiple years would also be counted each year for which they existed. Arizona's 20-year drought, for instance, also occurred in 2007, so this would raise the score to 4. For a full review of the environmental shocks identified for each year, please see Tables A2.1 to A2.3 in Appendix A.

Political and Economic Shocks

Environmental shocks do not occur in a vacuum—political and socio-economic aspects of governance also play a critical role in the management of water resources (Rogers and Hall 2003). Political shocks may include, for example, changes in the governing coalition, or the introduction of new institutional and legislative approaches. These types of events can drive change in power, as well as related processes, such as redistribution of resources, or agenda change. New policy actors, for instance, may champion novel approaches, whereas incumbents could be reluctant to adopt policy innovations due to concern about liability of novel approaches, about whether experimentation would threaten their job security, or about losing public support (Farrelly and Brown 2011a; Cettner et al. 2013). Political shocks in the form of rules or strategies could coordinate actors to collectively implement new water management technologies, where inaction was once caused by functional fragmentation and uncertainty about how to share responsibilities (Feiock 2013; Sharma et al. 2012; Brown 2008).

Like political shocks, socioeconomic events are driven by the agency of policy actors, and can influence "short-term constraints and resources of subsystem actors" (Sabatier and Jenkins-Smith 1999; Sabatier and Weible 2007; Jenkins-Smith et al. 2014). Socioeconomic factors also play an important role for decision makers that use the *triple bottom line*[13] approach in sustainable governance (Van Leeuwen and Marques 2012). Thus, when a socioeconomic crisis occurs, this can be closely linked to political interests in the policy subsystem. An economic recession, for example, may result in delinquent water customer accounts or a growing number of provision shutoffs (Vanderwarker 2012). This could lead decision makers to revisit their instrumental views about budgeting or price structures. In other instances, new federal mandates could raise the cost of water management, reducing funding for water-related project in other areas, such as infrastructural development (USEPA 2002). Finally, other shocks influencing change in constraints or resources could potentially offer support to policy stakeholders. These might include, for example, financing opportunities through grants, donations, prizes, or awards (Tucson Clean and Beautiful, n.d.; Tropp 2007).

Again, for human-caused shocks, I sum the number of events for each year that occur both within and outside the geographic scope of the policy subsystem (see A1.2 and A1.3 in the

[13] The triple bottom line approach to sustainability equally considers the long-term wellbeing of social, economic, and environmental aspects of a governance system.

Appendix). I do not distinguish between exogenous and endogenous shocks because jurisdictions for some policy actors may overlap, whereas others may be defined not by administrative boundaries, but by natural features such as hydrologic basins (Feiock 2007; Pahl-Wostl et al. 2010). Similarly, major economic events such as cuts or increases in funding can stem from outside or within the geographic boundary of the policy subsystem.

Models

I used a longitudinal, ordinary least squares (OLS) regression to estimate the effects of shocks on change in the network structure. The unit of analysis was percent annual change in the whole network structure for ten years of networks; observations of change for each year were then included in a single model to measure the effect of environmental, economic, and political shocks over time. [14] Shocks were operationalized as the annual sum of events for each year. For instance, there may be 3 environmental shocks, 2 political shocks, and no economic shocks for the year 2008. Effects of shocks on the network structure were lagged by one year, so, I examined the effects of events at *t-1* on change at time *t*. Changes in the network structure included updates in i) the number of actors or *vertices*, ii) the number of ties (edges), among them, iii) density of edges, iv) triads, v) modularity, and vi) segregation. A formal equation of the modeled effects of shocks on change in the network structure is as follows:

$$G_t(m)\text{-}G_{t-1}(m) = \beta_0 + \beta 1Shocks^{eviro}{}_{t-1} + \beta_2 Shocks^{pol}{}_{t-1} + \beta_3 Shocks^{econ}{}_{t-1} + e, \text{ where}$$

- $G_t(m)$ and $G_{t-1}(m)$ are the measured change in the graph structure at the first and second time periods
- $\beta_1 Shocks^{eviro}{}_{t-1}$, $\beta 1Shocks^{eviro}{}_{t-1,}$ and $\beta_3 Shocks^{econ}{}_{t-1}$ are the number of environmental, political, and economic shocks at the prior time period
- β_0 is the constant coefficient
- e is the error term that captures explanatory variables for change in the network structure that are not accounted for by shocks

For a sensitivity analysis, I also regressed change in the network structure on aggregated and simplified variations of the model to examine how well other scenarios explain change in the network structure (Appendix B); I then estimated the effects of these models where the time lag was two years and three years. After this, I estimated the effects of shocks when examined as exogenous and endogenous events (Appendix C). Endogenous environmental shocks had no significant effect, but exogenous shocks had a significant, positive effect on segregation, triads and vertices.

[14] The relationship between shocks and change in the network structure was not estimated annually because there was only one observation for each year.

Results

Table 4.2 summarizes correlations between environmental, political, and economic events and updates in the policy network structure. Although the constant was negative and thus difficult to interpret, what we can learn is that from 2008 to 2017, the model's results suggest that environmental shocks have a significant, positive effect on segregation in the network. This lends support to the proposition that shocks drive segregation linked to updates in policy-core beliefs. Unlike environmental shocks, political shocks tended to drive a *decrease* in the network's edges, triads, modularity, and segregation.

Because the unit of analysis was the change in the network structure over ten years, this model was not able to capture more observations, namely individual behavior *within* the network. Nevertheless, the adjusted R^2 (apart from effects on modularity and number of vertices) was moderate-high for models that examined the effects of extreme events on the whole Tucson water policy network.

New Policies, New Actors, and Segregation

One reason we may observe growing segregation following environmental shocks is that new programs and events are being introduced each year. From 2008 to 2017, Tucson's water policy network saw a 56% increase in the number of ongoing programs and events. Given our data assume that all actors participating in the same program or event share coordination ties, this could explain why we see an increase in nodes, ties, density, and triads with growth in the number of policies over time (Table 4.1). If these new actors are not highly involved in many other types of policies, or if they only jointly participate the same policies together, this could theoretically drive an increase in segregation.

Limitations in Measurement of the Shocks Data

Despite these findings, there are ways to improve how the shocks data have been measured. Currently, there are aspects of measurement that are ambiguous and could be clarified to improve the internal validity of the study. Namely, three areas to improve are i) how to differentiate between large and small shocks to the subsystem, ii) how an annual summation of

Table 4.2 Effects of Shocks on the Annual % Change in Network Structure, 2008 – 2017

	Dependent Variables					
Independent Variables	Vertices	Edges	Density	Triads	Modularity	Segregation
Enviro. Shocks $_{t-1}$	**.046***	**.125****	.026	**.124****	.019	**1.056****
	(.017)	**(.030)**	(.011)	**(.021)**	(.010)	**(.279)**
Economic Shocks $_{t-1}$	.031	.034	-.022	.068	.020	.893
	(.028)	(.050)	(.017)	(.035)	(.016)	(.463)
Political Shocks $_{t-1}$	-.066*	-.176**	-.042*	-.150**	-.046*	-1.436*
	(.026)	(.046)	(.016)	(.032)	(.015)	(.427)
Constant	-.104	-.252	-.044	-.395*	-.058	-3.518
	(.088)	(.157)	(.055)	(.110)	(.050)	(1.446)
Adjusted R^2	.480	.723	.591	.823	.493	.664

* $\rho < .05$; ** $\rho < .01$; *** $\rho < .001$ (two-tailed tests)

shocks should consider qualitatively different types of events (e.g., magnitude of the event, or whether this impacts water scarcity or water quality), and iii) whether or not shocks can be considered negative events for the water governance subsystem.

Differentiating the Magnitude of Shocks
Moving forward, there are several possible ways to operationalize the magnitude of shocks. One approach may be to examine the extant biophysical conditions of the policy subsystem (Ostrom 2005). Cities in water-scarce areas, for example, may consider year-long droughts to be much more detrimental to the future of urban water supply than municipal areas where water is abundant and droughts are anomalies. A related consideration is how crises and shocks affect different types of losses. For example, some estimates of magnitude may take into account the percentage of deaths resulting from water-related disasters (WWAP 2015), or how a severe drought may impose greater costs on population-dense cities, as compared to municipalities with lower water demand (Cook et al. 2007). Yet another aspect to investigate further is the urgency with which a city needs to respond to a shock, and the barriers to addressing the challenges presented by these events (Floyd et al. 2014).

Annual Summation of Shocks
In retrospect, however, the idea that environmental shocks drive network segregation may be biased by the data. An overview of the shocks from 2007-2016 shows that there is an exceptional number of environmental shocks that took place in 2009 (Figure 4.2). As a robustness check, I regressed network change on shocks without any record of events in occurring in that year. The findings indicate the *opposite* of what I had hypothesized: environmental shocks have a significant relationship with a decrease in segregation (Table 4.3). This shows that there tends to be more integration following environmental shocks. This may suggest, then, that following environmental shocks, incumbent actors become increasingly involved in new programs and events. It could also indicate that new actors in the network are increasingly involved in a wide variety of programs and events. Although effect suggest integration by participation in different types of policies, we may examine other types of heterogeneity in the network. Figures 4.3 and 4.4 show that there was an increase in the diversity of sectors involved in the policy network from 2008 to 2017.

Table 4.3 Robustness Check: Effect of Shocks Sans 2008

	Dependent Variables					
Independent Variables	Vertices	Edges	Density	Triads	Modularity	Segregation
Enviro. Shocks $_{t-1}$	-.046	-.112	-.009	-.105	-.011	**-1.117***
	(.024)	(.048)	(.015)	(.048)	(.015)	(.440)
Economic Shocks $_{t-1}$	-.029	-.119	-.046*	-.084	-.003	-.509
	(.028)	(.056)	(.018)	(.055)	(.018)	(.506)
Political Shocks $_{t-1}$	.012	.025	-.014	.038	-.024	.420
	(.043)	(.084)	(.027)	(.083)	(.027)	(.769)
Constant	.224*	.586**	.088	.433	.064	4.166*
	(.072)	(.143)	(.045)	(.142)	(.045)	(1.299)
Adjusted R^2	.297	.542	.436	.420	.196	.464

* $\rho < .05$; ** $\rho < .01$; *** $\rho < .001$ (two-tailed tests)

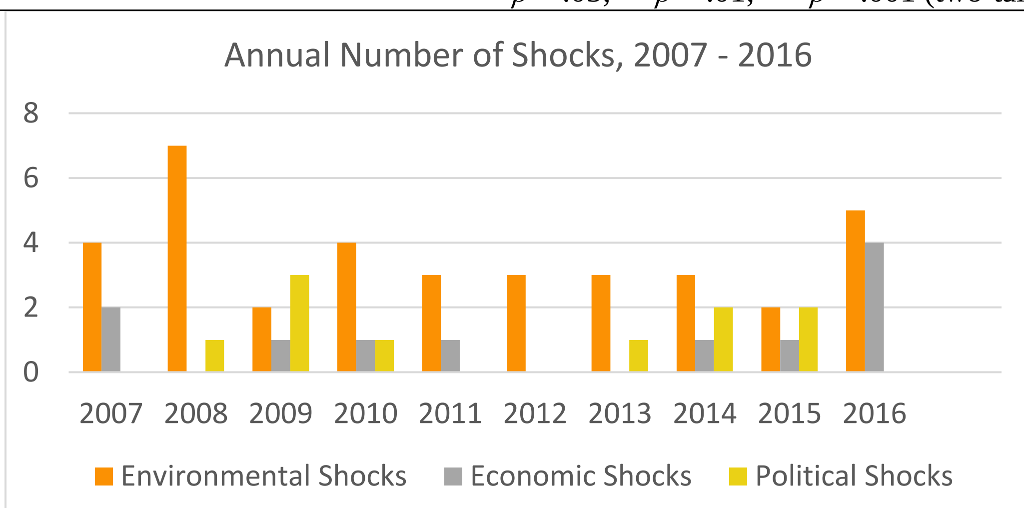

Figure 4.2

Integrating diverse stakeholders has been identified as an important feature for fostering water sustainability in urban settings. This approach has been described as a way for diverse policy stakeholders to overcome challenges relating to individualistic (and sometimes) competing policy goals, which may include detraction of finite resources at the expense of others, opting not to pay for goods and services consumed, and the negative transboundary effects this behavior can cause (Portney 2003). Such integration is viewed as a way to not only improve general water sustainability, but to link diverse sectors and communities in response to immediate challenges such as water shortage (Beniston et al. 2011). It is also identified as an adaptive approach worldwide to address sustainability needs, and is considered a mechanism to help link diverse knowledge with water resource management (Jacobs et al. 2010).

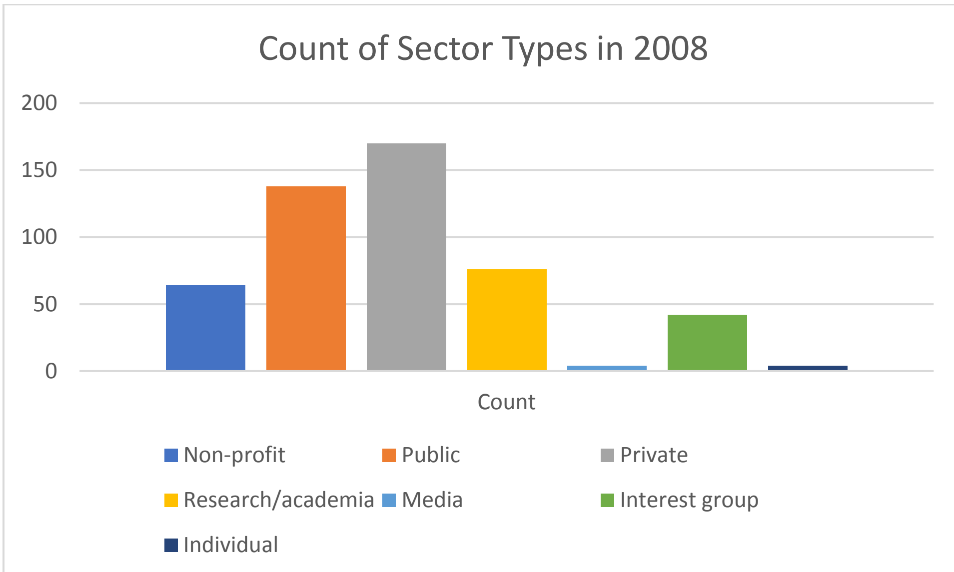

Figure 4.3

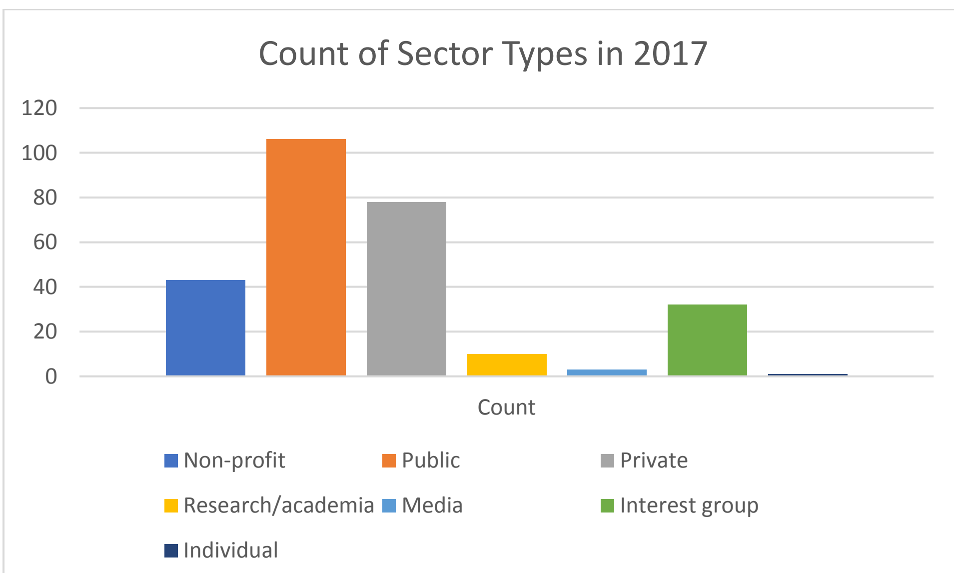

Figure 4.4

Distinguishing Effects of Positive from Negative Economic Shocks
Another challenge to consider is how the model tested the effects of economic shocks without parsing events that have beneficial or detrimental effects on the water governance subsystem.

From 2007 to 2016, the gray literature only reported two events that may have placed constraints on policy adoption and implementation: the peak of the economic recession in 2008, and major cuts to the Pima County Regional Wastewater Reclamation District Capital Improvement Project budget for 2014 through 2018 (City of Tucson 2016; Pima County Wastewater Reclamation 2016). Otherwise, most socioeconomic shocks included instances such when the Wolslager Foundations provided matching funds to Tucson Clean and Beautiful and the Pima County Juvenile Court for their Youth Landscape Maintenance and Training Program (Tucson Clean and Beautiful, n.d.). This program, introduced in 2010, provides vocational training to at-risk youth about desert landscape and maintenance skills, which include water and plant management, and rainwater harvesting. Another example was when the Water Finance Infrastructure Authority of Arizona gave the Pima County Regional Wastewater Reclamation Facility funding to fulfill projects associated with its Regional Optimization Master Plan (Pima County Regional Wastewater Reclamation Department 2009). This facilitated the development of innovative programs such as its Water Reclamation Campus. The campus uses a bardenpho treatment system, which a non-chemical process that removes nutrients from water, like nitrogen and phosphorus. It also hosts a central laboratory facility and a solar power project (Pima County, Tucson Water, and CAWCD 2008). Finally, political shocks (with the exception of one event) consisted entirely of officials moving in and out of elected and appointed positions. I used two separate models that examine the effects of positive and negative economic shocks on change in the policy network (Tables 4.4 and 4.5). Neither positive nor negative shocks show a significant effect on change in the structure of the network over time; removing 2008 observations from both models produced the same outcome. A larger sample would likely increase the variability in types of economic shocks, and increase the internal validity of the study, which I discuss further in the next section.

Table 4.4 Shocks with Positive Economic Events on Annual % Change in Network Structure

	Dependent Variables					
Independent Variables	Vertices	Edges	Density	Triads	Modularity	Segregation
Enviro. Shocks $_{t-1}$	.062**	.146**	.022	.139**	.027*	1.199*
	(.016)	(.031)	(.013)	(.024)	(.010)	(.343)
Positive Economic	.063	.083	-.025	.089	.033	1.013
Shocks $_{t-1}$	(.028)	(.055)	(.022)	(.042)	(.018)	(.602)
Political Shocks $_{t-1}$	-.080*	-.195**	-.037	-.167**	-.053**	-1.616*
	(.022)	(.043)	(.017)	(.033)	(.014)	(.473)
Constant	-.172	-.353	-.037	-.438**	-.086	-3.751
	(.077)	(.153)	(.061)	(.117)	(.049)	(1.681)
Adjusted R^2	.669	.784	.577	.837	.600	.630

$^{*}\ \rho < .05$; $^{**}\ \rho < .01$; $^{***}\ \rho < .001$ (two-tailed tests)

Table 4.5 Shocks with Negative Economic Events on Annual % Change in Network Structure

	Dependent Variables					
Independent Variables	Vertices	Edges	Density	Triads	Modularity	Segregation
Enviro. Shocks $_{t-1}$	.044*	.125**	.033*	.103**	.016	.741
	(.018)	(.030)	(.011)	(.026)	(.011)	(.334)
Negative Economic	-.040	-.076	-.020	.037	-.007	.880
Shocks $_{t-1}$	(.057)	(.096)	(.037)	(.086)	(.035)	(1.085)
Political Shocks $_{t-1}$	-.070	-.186**	-.047	-.138*	-.046*	-1.208
	(.029)	(.048)	(.019)	(.043)	(.018)	(.545)
Constant	-.040	-.182	-.089	-.255*	-.017	-1.680
	(.069)	(.116)	(.045)	(.103)	(.042)	(1.309)
Adjusted R^2	.423	.730	.509	.722	.368	.509

$^{*}\ \rho < .05$; $^{**}\ \rho < .01$; $^{***}\ \rho < .001$ (two-tailed tests)

Sample Size and Internal Validity

In addition to refining measurement of shocks, the study's internal validity can be improved with a larger sample size. With only ten observations, it is difficult to make reliable inferences about how what shocks affect the policy subsystem, and how this may affect other policy domains. From a theoretical standpoint, it is also difficult to say whether observed change in the network structure is indeed occurring as a product of shocks. The ACF has traditionally assumed that policy change requires a minimum of ten years to take place (Jenkins-Smith et al.2014). At least three more decades would be useful to assess the effect of shocks on change in the policy network structure.

Data Availability by Year

One way to improve the sample size is to examine shocks that have occurred over the past several decades. However, data from more than two decades ago may be comparably limited since the internet was still new to many users. A brief review of search results for the systematic search terms 2007-2017 showed that there was not much variability in the quantity of available content. However, earlier searches going back at least two decades showed relatively fewer sources, and a tendency to display government documents and peer-reviewed journal articles.

Sampling only documents that meet the definition of gray literature may produce a biased data set if documents come mainly from one source. To speak to this concern, future studies could use a sensitivity analysis to examine how bias in reports over different time periods (e.g., from the public sector) affect model results.

Conclusion

To strengthen the ACF as theoretical basis for understanding the policy process, one agenda item is to improve the conceptualization and measurement of belief systems. The goal of this chapter is to improve our understanding of how environmental shocks affect change in the structure of policy networks. This study uses a longitudinal ordinary least squares model to examine how environmental shocks affect the network structure of coordinating policy water stakeholders over time. Results offer new insights that may improve our understanding of the relationship between shocks and policy-oriented learning.

Results show that extreme environmental and economic events drive significant structural change, namely an increase in segregation. Nevertheless, a robustness check that eliminates an exceptional year alternately suggests a negative relationship, where environmental shocks tend to drive more *integration* among coordinating policy stakeholders. The network literature suggests that segregation can occur over time on the basis of homophily and slight aversion to dissimilar others. However, the urban water governance literature does emphasize the importance of heterogeneity of stakeholders to improve sustainability and adaptation to environmental pressures, such as those caused by climate change.

Findings may have been influenced by limitations in measurement and in the data. Future areas to address, included ways to differentiate between ‘large’ and ‘small’ shocks, which events are included in analysis and how this influences the number of shocks per year, as well as whether shocks have negative or positive implications and for whom. A sample with more than ten observations will also likely improve the validity of the findings, but this will need to be generated with care, as earlier availability of gray literature on the internet may be limited or the nature of the content may be biased.

Theoretically, this study lends support to the ACF assumption the stakeholders in the policy network indeed coordinate based on shared policy-core beliefs. It also supports the idea that extreme events closely tied to the subsystem’s policy domain tend to update beliefs of policy network actors. From a methodological standpoint, this study shows promise for the use of SNA to further investigate the assumption that behavior reflects beliefs, and to improve our understanding of how extreme events affect actors in the policy subsystem. Nevertheless, both areas require further investigation.

Chapter 5

<u>Introduction</u>

The previous two chapters have relied on data derived from gray literature to investigate theoretical concepts in the Advocacy Coalition Framework. Like all data, that which is collected through content analysis has a certain extent of bias. Without random sampling, researchers must carefully consider the criteria that guide selection of observations. To avoid making biased inferences, it is necessary to think about i) the parameters (e.g., a policy subsystem) that guide a systematic search, and ii) how observations from the corpus of literature are coded.

In this chapter, I test the validity of the data I used for the studies in the previous two chapters. The data in consideration are derived from a systematic search of the gray literature on urban water policy governance. A consistent theme throughout this dissertation has been coordination, which the ACF views as a central component of achieving shared policy goals, and filling principal roles, such as brokerage and policy entrepreneurship. Therefore, I use a quadratic assignment procedure (QAP) to compare measures of coordination derived from the gray literature and data gathered through survey techniques. Findings show a significant, positive correlation between networks rendered from joint policy participation I identify in gray literature, and those designed from a series of questions on different interaction types.

Coordination in social networks is a key component that facilitates resolution of policy-related problems. This concept is defined as instances when groups work together, sometimes sharing resources or exchanging information (Margerum 2011). Through coordination, stakeholders address urban water policy challenges such as conservation in times of severe or impending shortages, or responding to declining or degraded quality from various pollutants, and flood risk (UN Water 2013). Recent literature in urban water governance, then, has called for greater coordination among decision makers and managers in the water policy domain (Tropp 2007; Farrelly and Brown 2011b). This coordination is seen as a pathway to foster integrated water resource management, or a ‘one-water’ approach, said to improve environmental performance, as well as resilience and social equity of systems (Shafer and Fox 2016; WWAP 2015).

In this chapter, I ask: are data from gray literature a valid alternative to that gathered through survey techniques? Surveys and content analysis are common methods researchers use to gather information on relevant actors and coordination-based ties, and there have been ongoing efforts to improve these approaches. A recent advancement has been the development of a hybrid roster and free-recall method to solicit the names of those with whom respondents share relationships (Henry, Lubell, and McCoy 2012). Other scholars have begun to advocate for expansion refinement of content analysis techniques. Yi and Scholz (2016), for example, use quadratic assignment procedure models and exponential random graph models to compare water coordination networks developed from analysis of hyperlinks between websites of relevant policy actors, media reports about relevant policy issues, and partnership through voluntary application for matching grants.

Content analysis is a worthwhile approach, as it can be used frequently and requires comparatively less cost and time than survey distribution and management (Macnamara 2006).

This is evident in a review of empirical works on aspects relating to drivers of the policy process: studies relying on questionnaire data ranged from one to ten years, whereas content analysis spanned ten to 200 years (Weible et al. 2011). Regardless of whether one chooses survey methods or content analysis, it is useful to know that each is a valid proxy for the other.

In the next section, I review different examinations of coordination from a variety of theoretical lenses to illustrate how proper measurement of this concept is critical to understanding policy processes. Next, I explain how data for this behavior can be collected, and some of the key challenges these approaches can present. This is followed by the QAP model, results, and discussion. Methodologically, this study offers two insights: 1) that there is validity in measurement of 'coordination' from selected survey measures of interaction and content reports of joint participation in policy implementation and adoption, and 2) that content analysis is a promising alternative to survey techniques, which warrants further investigation.

Coordination in Policy Networks

Coordination is an integral component in policy and public administration literature, and has been used in various pathways of theoretical investigation. The Advocacy Coalition Framework sees coordination as a means for policy stakeholders to reach shared policy goals that may otherwise be unachievable (Sabatier 1999), and it underpins many empirical ACF studies. ACF scholars, for instance, have studied explanatory drivers of coordination, such as belief similarity and resource dependence (Weible 2005; Matti and Sandström 2011; Henry 2011b). Others have investigated how to identify coordination in nascent subsystems when policy stakeholders have not yet established clear policy perceptions (Ingold, Fischer, and Cairney 2017).

In the collaborative governance literature, coordination is conceptualized as an activity that plays a supporting role for structures and processes voluntarily established to carry out public objectives (Scott and Thomas 2017; Emerson, Nabatchi, and Balogh 2012). It facilitates collaboration under changing conditions, when goals are unclear, or when processes are interdependent (Margerum 2011). Bodin and Nohrstedt (2016), for example, find that coordination through division of labor is a key facet of effective collaboration in the face of emergent, natural disaster. In a study of a collaborative called the Florida Everglades Restoration Program, coordination is a way for organizing actors to address planning, technical, and implementation issues, and to solicit input from citizens and stakeholders from different sectors (Gerlak and Heikkila 2011).

Much like collaborative governance literature, the institutional collective action (ICA) framework also focuses on the role of inclusive governance. The ICA draws from the institutional analysis and development (IAD) framework, and extends theories of collective action to governments and organizations (Feiock 2009; Ostrom 2003). For ICA dilemmas, coordination is considered a means to resolve inefficiencies of fragmentation, assuming policy actors can overcome various transaction costs (Feiock 2013). Berardo and Scholz, for example, study how estuary policy actors self-organize, seeking ties that offer efficient information transmission for policy coordination (2010).

The ecology of games framework expands the ICA focus to devote greater attention to complex interaction among policy arenas (Feiock 2013). Through this lens, there are multiple institutions, or rules and norms that govern decision making; when collective action problems arise from fragmentation, institutions can serve a coordinating function (Lubell 2013). An empirical study of coordinating actors and institutions in the San Francisco Bay water policy domain illustrates that collaborative institutions, as well as state and federal actors foster coordination across geographic boundaries (Lubell, Robins, and Wang 2014).

A common theme among these theoretical areas of investigation is that actors form relationships, or *ties* for coordination, which collectively comprise policy networks. Through social network analysis (SNA), researchers can examine the topology of networks and linked actors with unique attributes to learn about coordination processes. The ACF’s assumption that actors form ties based on belief homophily, or attraction to those with similar preferences (a concept adapted from McPherson et al. 2001), has been associated with distinct network structures. Segregation, or the emergence of tightly-knit communities of homogeneous actors with few ties to dissimilar others, has been found in an agent-based simulation that models behavior of policy actors that update their beliefs over time (Henry 2011a). Following belief change, actors are found to rewire their connections so that they are no longer connected to dissimilar others, and instead form new ties with those whom share similar policy preferences.

In collaborative networks, centrally-located actors sharing direct ties with many others are found to be well-positioned to coordinate joint activities among heterogeneous actors in ecosystem-based management (Bodin, Sandström, and Crona 2016). A study by Berardo and Scholz (2010), mentioned earlier, uses SNA to illustrate low-risk coordination by the types of network ties policy actors form. They find that actors seek efficient lines of access to policy coordination information by forming *bridging ties* with well-connected, popular partners. In the SNA literature, these types of ties are conceptualized as connections that span *structural holes*, or separations between non-redundant contacts (Burt 1992; Burt 2000). Relatedly, Lubell, Robins, and Wang (2014) find that actors operating on larger areas tend to form ties that span geographic regions, whereas local actors and neighbors share central institutions and form ties that comprise cohesive subgroups (i.e., dense subgroups often comprised of triadic structures that share few ties with other groups).

In short, behavior of network actors is somewhat dependent on their ties to others. SNA is a powerful tool that offers insight into the nature of these relationships, but researchers need to, first, clearly conceptualize and measure what they seek to explain through network configurations. In the social sciences, this is especially important because all measurement and observation is imprecise (King, Keohane, and Verba 1994). Furthermore, such clarity allows researchers using SNA to identify relevant actors and types of relationships to be investigated. This selection of components that make up the *network boundary* can be specified by choosing at least one of three components: actors, types of ties, and/or the events or activities in which they jointly partake (Laumann, Marsden, and Prensky 2017). Relatedly, researchers need to consider how to collect network data in a way that best represents the real world in order to generalize findings to populations in consideration. Networks are mathematical abstractions that are inherently limited in the amount of information they can convey about the actors and relationships of interest. Scholars often use survey and content analysis techniques, and have dedicated much effort to examining ways to refine each. Nevertheless, it is still uncertain how well data collected from content analysis serve as valid measures of what would be collected with survey methods, and vice versa.

The goal of this study is to test whether content analysis offers a valid measure of what is detected through survey techniques, and vice versa. I use data collected through survey techniques and analysis of gray literature (i.e., non-peer-reviewed bodies of work, such as news reports, white papers, information brochures, or websites) to construct two versions of the same network of organizations that coordinate in water policy in Tucson, Arizona. I then estimate correlations of the coordination networks to examine how well survey and content analysis techniques detect the same actors and ties, given a common network boundary specification. In the next section, I review the strengths and limitations found in survey methods and content analysis. Next, I discuss some of the steps that have been taken to improve each method. Following the methods, model, and results, I discuss future pathways for scholars to test the validity of survey and content analysis methods.

Types of Data Collection and Methodological Challenges

To measure inter-organizational ties in the policy network, scholars often use content analysis and survey methods (Marsden 1990). When soliciting information about those with whom actors coordinate, there are a variety of ways to operationalize these relationships. Two types of coordination activities in the ACF literature are information sharing and coordinated strategies such as working simultaneously in different venues to lobby government or capturing the attention of media (Weible 2005; Weible and Sabatier 2005). Joint policy or program implementation is another way to measure coordination among policy actors (Henry, Lubell, and McCoy 2012), which may include activities such as consulting, or sharing funding, or other resources (Scott and Thomas 2015).

Bias in Data Collected from Surveys and Content Analysis

These approaches are straightforward, but there can still be challenges in data collection. Instrumentation bias can emerge from the design of the survey. For example, if there are constraints on the number of choices of contacts a respondent can nominate, this can produce a distorted version of the true network structure (Holland and Leinhardt 1973). A similar challenge can stem from recall bias, whether respondents tend to nominate those with whom they interact most frequently, those that are most important, or only a handful of people they can remember from the whole list (Bernard et al. 1984). In developing a hybrid roster and free-recall method, Henry, Lubell, and McCoy (2012) find that they can collect a diverse sample of network contacts that extend beyond those offered in a roster. Nevertheless, they indicate that the utility of this approach may be limited to certain network contexts. In networks with

Content analysis techniques offer alternative methods to bypass some of the challenges found in survey approaches. For example, it can offer information on actors of interest where nonresponse has been an issue. Compared to survey implementation, it is a cost-efficient way to observe the policy network over time, and does not run the risk of respondent attrition (Macnamara 2006; Jenkins-Smith and Sabatier 1993). On the other hand, Yi and Scholz (2016) note that the content itself can be biased in what it covers. They suggest, for example, that media from larger cities may provide a sufficient overview of the policy network, whereas smaller cities may be limited to comparatively fewer media sources. Also, regardless of size, some accounts of policy behavior may direct attention primarily to those with well-established reputations in the policy network, or to new policies and problems, with little to no regard for regular or ongoing policies or participants. In cases where this is omission more pronounced, the observed network can lose actors that serve a critical role in the policy process, creating a distorted view of the true network configuration.

The Implications of Bias

When we use data from survey methods or content analysis to construct an observed network, challenges such as difficulty in recall or partiality in coverage can render this quite different from the true network structure. Furthermore, this raises the question: if measurement error and bias can have a significant effect on the validity of measures produced by these respective approaches, does each technique produce sufficiently similar observed networks? A convergent validation of these two approaches allows us to examine the strength of association between two ways to operationalize the same concept (Adcock and Collier 2001). Furthermore, it can offer insight into the extent to which the limitations of each approach generate differences in observed networks.

To date, there have been several efforts to compare data from content analysis and surveys. Some researchers have compared crime statistics to reports of citizen concern about crime (Krippendorff 2012), and the recall of regular meeting participants and attendance records of previous meetings (Freeman and Romney 1987). A more recent study compares network data from internet hyperlinks and Twitter interactions with survey responses to compare collaborative policy networks among organizations involved in ecosystem restoration and recovery in the Puget Sound area (Hayes and Scott 2017). The authors find a significant, but small correlation between internet ties and relationships measured through survey responses. They call for efforts in future work to compare data collection methods with greater attention to the multiplexity (i.e., satisfying multiple, different types of interaction) of policy ties. This study responds to that need.

Research Design

Collection of Survey and Content Data

For this study, I examined the water policy coordination network in Tucson, Arizona. Surveys instruments collected information on whether organizations interact, as well as different types of activities selected to operationalize coordination. I then compared these data to coordination I identified in the gray literature, which was operationalized as frequency of joint participation in Tucson's water programs and events. Although the survey was distributed to municipalities across Arizona, content analysis was limited to Tucson. To address this variation in scope, I subsampled respondent organizations from the survey that matched those identified in the content.

I used purposive sampling techniques to identify local water organizations (LWOs) throughout the state. Key areas of water management were identified through a review of expenditures in the US Census of Governments (US Census Bureau 2006). These expenditure areas were then refined to seven water domains, including water supply, water quality, groundwater, stormwater, wastewater, conservation, and flood. Next, I conducted a manual, systematic web search of these domains for all 91 census-incorporated towns and cities in Arizona (e.g., 'stormwater Tucson'); special irrigation districts were also incorporated in the search. From the first ten search results for each combination, we selected contacts from different water-related organizations at the municipal and county levels, such as public utilities, engineering divisions, planning and zoning districts, and flood control districts. The initial search produced a seed sample of 416 respondents, who received our survey in January 2018. These respondents comprised exclusively government employees, but their nominations of additional contacts diversified the sample to include interest groups, as well as private and non-profit organizations. Through snowball sampling, I identified 1016 total respondents, all of whom received four reminders to complete the survey. I collected data through March 2018, and received responses from 220 informants, with a response rate of 22 percent (see Chapter 2 for more information on data collection and coding). From this, I identified 76 respondents from 26 organizations also listed in the gray literature data. These respondents then nominated 39 additional organizations with whom their respective organizations interact.

To measure coordination in the survey, respondents were asked to list organizations with which they had interacted on a required or voluntary basis as a part of their role in water management. Respondents nominated up to ten contacts (fewer than half met this limit). The survey then asked about more specific types of interactions to operationalize different facets of coordination.[15] My second source of data came from gray (non-peer-reviewed) literature, which included documents and media, such as city and county ordinances, news articles, informational pamphlets and presentations, websites, meeting minutes, and white papers. The systematic web search used the same water domains searched for the survey contacts, but I limited my search explicitly to Tucson. The first ten unique documents per combination were sampled to comprise a corpus of gray literature of 844 documents.[16] From the gray literature, I derived information on relevant actors and the policies on which they coordinated. In total, I identified 437 organizations. I conceptualized coordination ties as joint participation in water-related programs and events. Participation, however, was limited to leadership, implementation, adoption and promotion of the policy of interest; I did not include less-involved participants, such as recipients of rainwater harvesting rebates or attendees at water conservation workshops.

Not all participants affiliated with organizations identified in the gray literature responded to the survey (see Figure 3.1). Therefore, to select the observed networks I would compare, I selected a subsample of organizations that appeared in data from both the survey and content analysis methods. In total I found 73 survey respondents that represented 26 organizations; individual responses were aggregated to the organizational level. The respondents nominated additional organizations with which they had ties, however, so these were also included in the coordination

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[15] The survey also offered an option to list any other types of relationships we may not have included, but there were very few responses.

[16] Some of these documents were identified through a snowball sampling process.

matrix. In total, the networks comprised 79 organizations that appeared in both the survey data and gray literature.

Model and Results

To estimate the correlation between the two networks, I used quadratic assignment procedure (QAP). This model can be used to examine the relationship between two variables of interest in a network setting. Researchers could use this model, for example, to investigate whether friends or other types of relationships also share advice (Krackhardt 1987), or if resource users with similar belief structures are more likely to coordinate in collaborative partnerships (Calanni et al. 2014). In this case, I examine whether those detected through gray literature data as coordination are also engaging in more specific types of interaction, as measured in the survey. The QAP is an appropriate model for networks because I cannot not assume independence of the observations (Krackardt 1987), and is one of the most common statistical methods to examine policy networks (Lubell et al. 2012). The QAP randomly permutes the rows and columns of the matrix, controlling for the underlying structure (i.e., maintaining the same dependence between the elements in the original rows and columns); from a distribution of simulated correlations, the model discerns the probability that the observed relationship is a result of a random permutation (Krackhardt 1988; Henry and Ingold 2013).

Table 3.1 shows the QAP correlation estimates. All correlation estimates between the gray literature network and survey networks were positive, with high statistical significance. This supports the idea that gray literature reports of joint policy participation is a valid way to measure coordination, which can capture many of the same relationships identified through survey techniques. Nevertheless, the coefficient for some coordination activities are larger than others. Exchange of consultation (.146) and funding (.176) had the smallest relationship to the gray literature network, whereas jointly advocating for policy had the strongest relationship (.257), closely followed by sharing information and data (.226), attending the same meetings (.226), and jointly implementing programs and policies (.224).

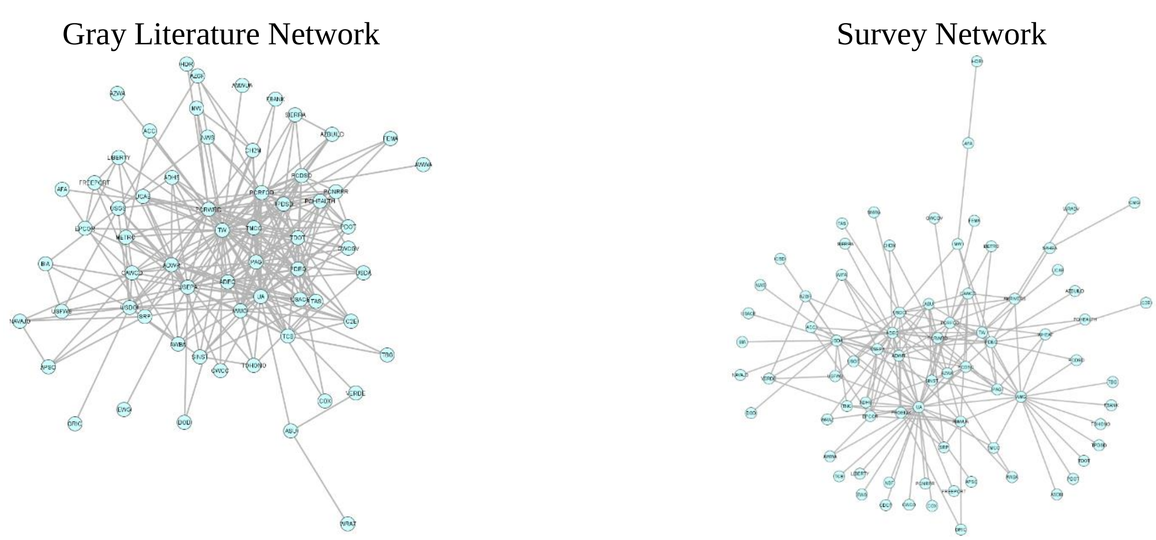

Figure 5.1 Coordination Network of Overlapping Actors Sampled Through Surveys and Content Analysis

Table 5.1 QAP Correlation of Survey Networks with Content Network

Survey Networks	
Interaction in water management (binary)	.217***
Attend the same meetings	.253***
Jointly implement programs or policies	.238***
Seek and/or provide consulting services	.158***
Share information or data	.248***
Seek and/or provide advice	.219***
Seek and/or provide funding for physical resources	.198***
Jointly Advocate for Policy	.286***
Multiplex (sum of all types of interaction)	.275***

* $p \leq .05$ ** $p \leq .01$ *** $p \leq .001$

From this pattern, it is evident that observed joint policy participation in the gray literature network data represent multiple activities. To develop a better idea of just how well content analysis captures this nuance, future studies could specify additional parameters to operationalize different facets of coordination, such as meeting attendance or sharing funding. Yet, we might expect that reports in the literature would not grant the same degree of attention to each activity. As Yi and Scholz (2016) mention, there is bias in reporting, with greater attention directed to new policies or problems. In this case, advocacy would indeed be prominent, especially if minor coalitions are trying to challenge the status quo and introduce new policies in the subsystem (Sabatier 1999).

Survey data are not inherently less biased, however, and can show similar challenges. As discussed by Henry, Lubell and McCoy (2012) – survey respondents may be more inclined to report those with whom they interact more frequently or intensely (Granovetter 1973). This could help explain why consultation, which has been identified as a low-intensity activity (Scott 2016), has a small coefficient, and makes up the smallest network, with 46 organizations (Table 5.2).

Table 5.2 Descriptive Network Statistics

Content Network:	*Vertices*	*Isolates*	*Edges*	*Density*
Frequency of joint participation in policies	63	2	279	.152
Survey Networks:				
Interact as role in water management	63	0	135	.071
Jointly implement programs or policies	48	16	93	.082
Seek and/or provide consulting services	39	24	58	.078
Share information or data	51	12	115	.090
Seek and/or provide advice	49	14	99	.028
Seek and/or provide funding for physical resources	45	19	70	.071
Jointly Advocate for Policy	39	24	74	.100
Multiplex (sum of all activity types)	63	2	130	.328

Discussion

Implications of Findings and Utility of Gray Literature

The QAP findings suggest that coordination networks rendered from analysis of gray literature can approximate ties reported by survey respondents. The content network offers a comparatively gross estimate of coordination when compared to survey measures (i.e., it is impossible to parse unique activities from these data). In the context of urban water governance, this variation in the extent with which local water organizations interact in different activities (e.g., joint policy implementation or sharing funding) may indicate different degrees of willingness to interact based on the transaction cost of the activity (Gerber, Henry, Lubell 2013). This could also indicate other types of coordination in water governance that these studies did not capture, which would require further study.

Data from gray literature and survey techniques can complement each other by illuminating relevant organizations in the true network that have either not been detected through sampling procedures, or through systematic, online searches. From this, researchers can develop a more holistic picture of the true network structure. This can also offer insight into social processes in the policy network driven by structural features, such as segregation. Conflictual settings, for example, may draw media attention (Yi and Scholz 2016), but not offer a complete picture. On the other hand, conflict may not be readily detected through reports, especially in face-to-face settings (e.g., Weible 2005). Yet, if reports of coordination and shared policy preferences were to yield segregated networks, content data could help flesh out instances in which this was driven by conflict, and not just tie formation based on the degree of actor similarity (Schelling 1971; Henry, Pralat, and Zhang 2011).

Gray literature networks can also be instrumental for examining longitudinal policy processes. As discussed earlier, survey respondents can have challenges with recall, and the cost and time of survey implementation over a long period of time could be astronomical. Some work has already used this mixed-methods approach. In a study on the role of policy brokers in Swiss climate policy from 1990 to 2008, Ingold and Varone (2012) supplement a one-time (2005) survey with analysis of official documents to identify policy preferences of the climate policy elite for 1990-2000. The authors' concern is that respondents would report having the same policy preferences in the previous decade as they did in 2005, even if these had changed. Reports from the survey, however, are used to flesh out policy preferences for the 2000-2008 period. With repeated survey implementation over time, scholars could conduct similar studies and use content analysis to interpolate network information for the interim periods. Furthermore, content analysis could attend to challenges introduced by survey sample attrition. In sum, this technique could reduce error and the cost of consecutive, annual survey distribution.

Limitations of the Data

Google Algorithms and Limited Samples by Year

A key challenge to the validity of this study, however, is that gray literature data were not sampled in a private browsing session, which may have biased results. In 2005, Google personalized searches for all users with Google Accounts, such that search results would be tailored based on previous searches (Google 2018b). A private search would likely reduce the extent with which the browser dynamically updated results, as previous work has found that

Google Chrome searches in private mode to not raise major concern for storage of web browser artefacts (Flowers, Mansour, and Khateeb 2016).

Furthermore, sampling the first ten documents by domain for each year may have created measurement error such that the observed network did not represent many of the relevant actors in the subsystem. Although I do not yet have access to the final survey data, a comparison of the data sampled for the survey and for content analysis will help elucidate the shortcomings of the ten-document sampling approach. It may be difficult, however, to know the true extent with which this method is able to produce valid data, since Google's search algorithm uses a ranking system to return pages that are most relevant to the query (Google 2018a).

Representativeness of the True Network Structure

Another limit is how well both survey and content data not only capture the same actors, but how well they each represent the true network. Of the survey data, we sampled the data of 76 individuals who were members of 26 organizations identified as Tucson-water subsystem actors in the gray literature. These actors nominated 62 other organizations, 37 of which were also found in the gray literature data. In sum, there were 63 organizations identified through survey participation and nominations that overlapped with the gray literature data, which accounted for 72% of the total survey organizations identified in the Tucson subsample. These 63 organizations, however, made up only 24% of the 268 organizations identified as active in the Tucson water subsystem in 2017.

Although it is common that observed networks often do not fully capture the true structure, this small overlap suggests that it is worthwhile to further consider the internal validity of this approach. A review of the data collection process can help us infer potential reasons for the minimal relative overlap. First, surveys may have produced generally fewer contacts because of respondents' difficulty in recalling those with whom they interact, or because of a tendency to mention those from frequent encounters. Second, water subsystem organizations were selected by their participation in an event or program; this could generate a much more comprehensive sample of network actors.

An interesting feature of the observations that warrants further investigation is the high representation of government actors. A little over half of the overlapping organizations (35) were from the public sector. This suggests that public actors are important actors in Tucson's water policy subsystem, which was discussed in Chapter 3. Public organizations also made up the majority of the non-overlapping organizations for both survey and gray literature data (Table 5.2). These preliminary findings may suggest, then, that survey and content analysis of gray literature may best detect coordination in the public sector. Nevertheless, because of the measurement challenges discussed earlier, it is important to take caution with regard to generalizing findings to other policy coordination scenarios.

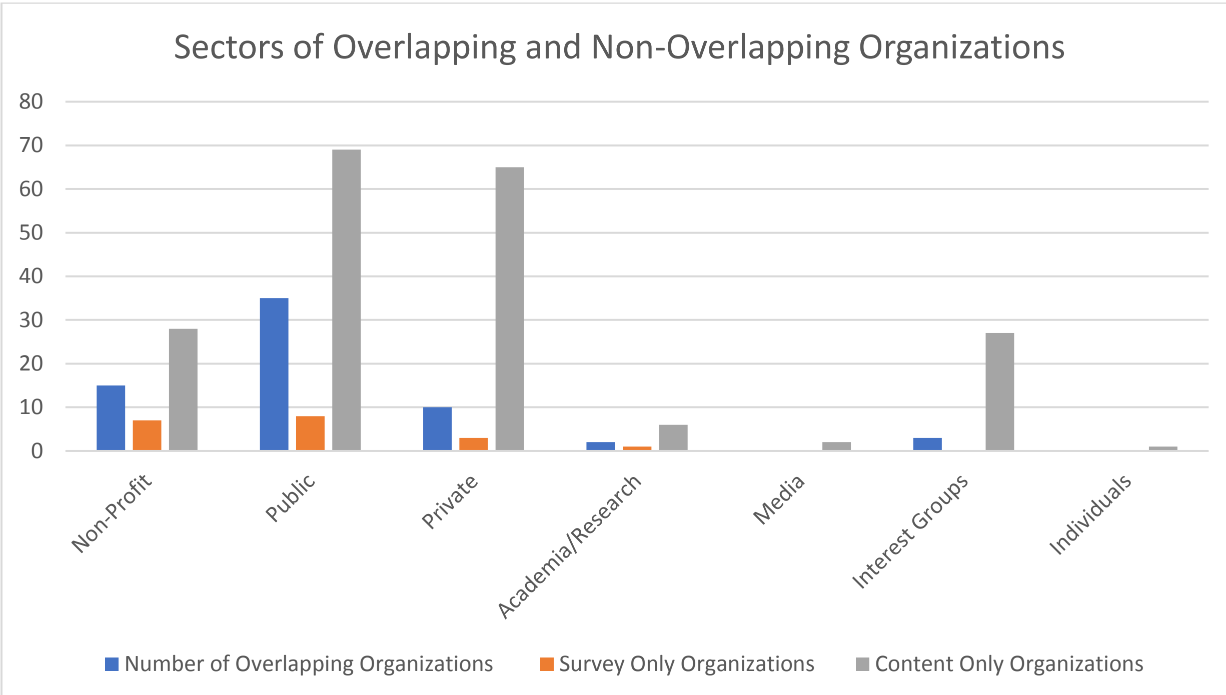

Figure 5.2

Conclusion

This chapter presents a comparison of policy network data collected through content analysis of gray literature and through survey methods. Coordination in the content analysis is operationalized as joint participation (i.e., adoption, implementation or promotion) of urban water policies, such as programs and events. The survey measures coordination through reports, broadly, of interaction related to roles in water management. It also captures more detailed types of activities, such as attending meetings together, jointly advocating for policy, and explicitly implementing policies together.

Findings indicate that data from gray literature can detect some coordination recorded through survey methods. However, small correlation coefficients between networks of content and survey data suggest that researchers should keep these limitations in mind if they choose one approach over another. Ideally, using both methods can render a more holistic view of the network. This can be especially useful if content data help fill in gaps where survey response is limited, or declines over time.

Moving forward, it is worthwhile to consider other studies that examine the utility of gray literature networks. Particularly, a comparison of longitudinal data from surveys and content analysis could better illuminate the degree of bias in either approach, and the extent with which each detects the dynamic structure and processes that characterize policy networks over time.

Chapter 6

This dissertation has used three studies to offer new theoretical and methodological contributions to advance the Advocacy Coalition Framework (ACF). The ACF draws on a diverse base of intellectual roots and offers guidance to studies of the policy process. Its application has grown widely over the past three decades, as it has guided empirical studies worldwide not only in environmental policy but areas including health, finance, education, and technology (Jenkins-Smith et al. 2014). In this chapter, I summarize the lessons from this work, key limitations to consider, and potential next steps for future investigation.

What Have I Learned?

Theoretical Contributions

This study has advanced theory of policy process concepts by introducing new ways to conceptualize different and potentially overlapping roles of important actors in the subsystem. Entrepreneurs and brokers have received considerable attention in the ACF literature, but more recent studies have also extended focus to exceptional actors that can assume both roles (Christopoulos and Ingold 2015). I find evidence to support this idea, and suggest that scholars should also consider circumstances in which policy stakeholders assume leadership positions, and impact policy change without engaging in all the behaviors of an archetypal entrepreneur. Including this option offers greater nuance and a basis for future work to examine the range of behaviors that important actors exhibit.

The second theoretical contribution builds on current work to define shocks on dimensions other than their exogenous and endogenous distinction. The ACF literature generally frames shocks as exogenous or endogenous to the policy subsystem, but recent work by Nohrstedt and Weible (2010) suggests that crises can be thought of by their geographic and policy proximity. I extend this concept to include punctuated events, and investigate how well policy-proximal shocks predict policy-oriented learning when examined without regard to geographic origin. Through a model that combines exogenous and endogenous shocks, I find evidence to support the notion that policy proximity is a better predictor of policy-oriented learning than distance.

Methodological Contributions

Methodologically, this work presents novel applications of extant approaches to investigate theoretical concepts in the ACF. First, this dissertation illustrates how data derived from content analysis of gray literature is a valuable source of information on policy stakeholders, importance, shocks, and policy behavior. Chapters 3 and 4 use gray literature data to illustrate how combining linear methods with social network analysis techniques can yield important information about policy stakeholder attributes, and relational features between actors in the policy subsystem. Chapter 4 also applies the concept of belief homophily in a new way to show how shocks impact change in coordination ties over time. This is novel for network studies, not only because it uses belief homophily to measure policy-oriented learning following shocks, but because it combines social network analysis techniques with an ordinary least squares model. Given that one cannot assume independence of observations in network data, longitudinal models in social network analysis are generally limited to agent-based models and exponential random graph models. Yet, agent-based models are rule-dependent and rely on assumptions about behavior of actors that are largely unknown from content analysis. Exponential random graph models cannot estimate the effects of independent variables like shocks, which are external to the network. Thus, a linear model offers the greatest traction on estimating the effect of shocks on policy-oriented learning, when examined in social networks. Lastly, Chapter 5 presents evidence for the validity of data from gray literature by demonstrating how observations of coordination have a significant, positive correlation with different dimensions of interaction measured through survey techniques. The findings in this final study are particularly exciting because they suggest that when data are collected through content analysis, assumed coordination through joint policy participation may detect multiplex ties. This is encouraging for analysts interested in developing new approaches to detect this nuance.

Generalizability

The use of gray literature advances the framework as a theoretical tool because improves the opportunity for generalizability in ACF-based studies. First, web-based content analysis of gray literature is an efficient data-collection method that policy scholars can use for large subsystems, and for analyses spanning long periods of time. To date, much comparative work in the ACF has only been implicit, which is by no small means due to high costs associated with data acquisition (Jenkins-Smith et al. 2014). Expanding a systematic approach to multiple subsystems or time periods can yield important insights on variation in the policy process across different political systems or temporal dimensions.

Systematic coding and analysis of gray literature in this work has also shown potential for application not only to urban water governance, but to other policy subsystems. Some parameters may need adjustment to fit different policy contexts or geographic settings, but there are several generalizable approaches. First, the concept of important actors can be expanded across multiple policy domains. As mentioned in prior chapters, central actors have been a key point of focus in the policy literature. The role of leadership, however, may be a concept commonly found in water management literature, so this will require further investigation.

Second, analysis of shocks with disregard to geographic delineation may be useful to other areas of investigation that examine mobile natural resources or policy issues. For example, air pollution is highly mobile and can stem from origins outside the territorial scope of a policy subsystem. In Los Angeles, for example, emissions within the municipal boundaries have been a long-term source of the city’s smog (Haagen-Smit 1952). Yet, more recent efforts to reduce emissions in the western US have also been offset by air pollutants stemming from overseas (Lin et al. 2017). This policy issue raises questions not only of how pollution from geographically distal and more proximal sources affect policy-oriented learning and strategies to manage local pollution, but how this affects intergovernmental relations—both areas of consideration for future work. Finally, Chapter 5 demonstrated a technique that can be applied across diverse areas of theoretical foci for which coordination is a key component. The broad application and refinement of this approach collectively bodes well for ACF and non-ACF scholars alike.

Limitations

Although this work has presented new contributions to the ACF, all three studies could be improved with more data. This is especially salient for the study in Chapter 4, which examines the relationship between shocks and policy-oriented learning. Since the whole network is the unit of analysis, ten years of observed change in the network structure offers what can best be considered a proof of concept; gathering at least twenty more years of data would be necessary to improve the statistical power of the model. Thankfully, analysis of gray literature is a low-cost approach, so this is within the realm of possibility for the near future. Although the same challenge does not apply to the correlation of important actors in Chapter 3, this study could also benefit from at least two more decades of observations. Social networks are dynamic, and policy actors can move in and out of important positions over time. Having a larger snapshot of this behavior in the policy subsystem would offer greater explanatory power. The study on measurement of coordination in Chapter 5 did not suffer from too few observations. However, the comparatively small extent of overlap between all actors measured in both the survey and content analysis approaches suggest that there is room to improve data collection techniques that yield a more comprehensive sample of the true network.

Conclusion and Next Steps

The goal of this dissertation was to offer clarification and development of theoretical concepts and ways in which these are measured. It has introduced a few novel contributions within a large research program that continues to be very productive. Ideally, it will be useful for advancing the work of other analysts also working to develop the ACF and to solve important puzzles in the policy process. In the meantime, I offer a few different ways in which to improve the research I have presented.

To understand how well the tools developed in the first and second studies can detect and explain drivers of the policy process, it will be necessary to apply these techniques in other policy domains. Also, the correlation of reports and network measures of important actors in Chapter 2 tells us that the conceptualization of each role coded in the content analysis aligns well with reports of importance. Yet, it is unclear how well the proposed operationalization of important actors corresponds with reports of importance in other types of media. Online media platforms, which have received increasing attention over the past few years, could be worthwhile areas to examine these conceptualizations further. Similarly, it will be necessary to examine the external validity of theoretical developments in Chapter 4. 'Policy proximal' shocks were identified with guidance from a review of empirical literature on the urban water policy domain. Using this approach for other shocks that transcend geographic boundaries of the subsystem could offer new perspective on when and where this approach is viable. Finally, the activities measured through survey techniques in Chapter 5 did not cover all potential types of interactions that could occur in a policy subsystem. I encourage other scholars to expand this measurement of multiplexity for future comparisons with data from content analysis.

Appendix A

Table A2.1 Environmental Events, 2007-2016

Year	Event 1	Event 2	Event 3	Event 4	Event 5	Event 6	Event 7	Sum
2007	Severe drought	Arizona Department of Environmental Quality rules ammonia levels in regional treatment facility effluent too high	Flood event 1, $100,000 in damages	Flood event 2, $5,000 in damages	Tucson Water finds brain-eating amoebas in 11 of its wells			5
2008		Leaking underground storage tanks sites found in Tucson Active Management Area	Monsoon floods, seven people rescued	Flood event 1, $15,000 in damages	Flood event 2, $15,000 in damages	Drugs found in Tucson's water	Monsoon floods, 1 death	7
2009		Tucson Water finds trace organic contaminant perfluorooctane sulfonate in potable groundwater sources						2
2010		Flood event; private property damage, stranded people, damage to Desert Springs Equestrian Center	Flood event; broke out of wash and flooded neighborhood	Filters of 50 public water vending machines test positive for bacterial indicators or human pathogens				4
2011		Tucson's water tested positive for low levels of herbicides atrazine and simazine	Tucson has four-day cold snap, major damage to pipes and water loss					3
2012			Discovery that major water delivery pipes have critical structural weakness					3
2013			Flood event: downed electric lines, woman swept away, three children trapped					3
2014			Suboptimal fluoridation in Tucson Water, according to Center for Disease Control	Flood event: closure of roads, schools, library, and congress; 2 deaths				4
2015			Flood event: SUV washed away, one rescue					3
2016			Heavy rain and flooding – puts Tucson streetcar out of commission; Pima County Supervisor rescued from wash in county-issued car by fire department	Flooding – damages more than 50 businesses and homes (estimated minimum $100,000); requires rescue	Chromium 6 found in Tucson groundwater	Foul odor and eye irritant emanating from Tres Rios Water Reclamation Facility area		6

Table A2.2 Political Events, 2007-2016

Year	Event 1	Event 2	Event 3	Event 4	Sum
2007	Governor Napolitano appoints a new Arizona Commissioner of Real Estate	Robert Walkup elected to third term as Mayor of Tucson			2
2008					0
2009	Central Arizona Project hires new General Manager of Business Planning				1
2010	Pima County Regional Wastewater Reclamation Department receives new director				1
2011	Mike Letcher fired from position as Tucson City Manager, replaced by interim Richard Miranda				1
2012					0
2013					0
2014	Pima County Regional Wastewater Reclamation Advisory Committee receives new members				1
2015	David Modeer retires from Tucson Water but remains a consultant for Central Arizona Project				1
2016	Former City Manager and Police Chief Richard Miranda joins security for Pima County Wastewater Management	New chair joins the Pima County Wastewater Reclamation Advisory Committee	Tucson Water hires new director, Tim Thomure	President Trump signs executive order instructing US Environmental Protection Agency and US Army Corps of Engineers to re-examine whether the Clean Water Act extends to non-navigable waters	4

Table A2.3 Economic Events, 2007-2016

Year	Event 1	Event 2	Event 3	Sum
2007				0
2008	Peak of economic recession			1
2009	Pima County Regional Wastewater and Reclamation Department receives funding from American Recovery and Reinvestment Act	Water Infrastructure Finance Authority provides funding to Pima County Regional Wastewater Reclamation District to finance activities designated by its Regional Optimization Master Plan	US Fish and Wildlife Service provides funding for Watershed Management Group's Water Education Program	3
2010	Wolslager foundation provides matching funds to Pima County Juvenile Court System and Tucson Clean and Beautiful for their Youth Landscape Maintenance Training Program			1
2011				0
2012				0
2013	Tucson Receives IBM Smarter Cities Challenge Grant			1
2014	Governor Brewer gives $200,000 from the General Fund to the Arizona Division of Emergency Management for statewide flooding that also affected Tucson	Major cuts in the Pima County Regional Wastewater Reclamation District Capital Improvement Project budget		2
2015	Tucson Water's Advanced Oxidation Process Water Treatment Facility awarded the Grand Prize in Design from the American Academy of Environmental Engineers			2
2016				0

Appendix B

Below are the models I used for a sensitivity analysis for the main model (results in Table 2.3). In the Model 1, I combine the political and economic shocks into a single 'anthropogenic shocks' variable, and test the effect of this and environmental shocks on percent change in the measured graph structure from time *t-1* to time *t*. In Model 2, I combined all shocks into a single variable and test the effect of this on percent change in the measured graph structure for time *t-1* to time *t*. I follow the same procedure then for Models 3 and 4, examining the effect of environmental shocks, and then the effect of anthropogenic shocks. Results are listed in Tables B2.1 to B2.4.

Model 1

$$G_t(m)\text{-}G_{t\text{-}1}(m) = \beta_0 + \beta_1 Shocks^{enviro}_{t\text{-}1} + \beta_2 Shocks^{anthro}_{t\text{-}1} + e$$

Model 2

$$G_t(m)\text{-}G_{t\text{-}1}(m) = \beta_0 + \beta_1 Shocks^{all}_{t\text{-}1} + e$$

Model 3

$$G_t(m)\text{-}G_{t\text{-}1}(m) = \beta_0 + \beta_1 Shocks^{enviro}_{t\text{-}1} + e$$

Model 4

Table B2.1 Effect of Environmental and Social Shocks for Time *t-1* on Change in the Network Structure at Time *t,* 2008-2017

	Dependent Variables					
Independent Variables	Vertices	Edges	Density	Triads	Modularity	Segregation
Environmental	.029	.086	.022	.083	.008	.624
Events $_{t-1}$	(.020)	(.039)	(.009)	(.036)	(.013)	(.408)
Social Shocks $_{t-1}$	-.021	-.079	-.033	-.049	-.016	-.356
	(.024)	(.047)	(.011)	(.043)	(.015)	(.485)
Constant	-.015	-.059	-.026	-.194	.003	-1.372
	(.103)	(.205)	(.048)	(.188)	(.065)	(2.130)
Adjusted R^2	.119	.420	.612	.372	-.040	.114

* $\rho < .05$; ** $\rho < .01$; *** $\rho < .001$ (two-tailed tests)

$$G_t(m)\text{-}G_{t\text{-}1}(m) = \beta_0 + \beta_1 Shocks^{social}_{t\text{-}1} + e$$

Results for Effect of Shocks at Time *t-1*:

Table B2.2 Effect of All Shocks for Time *t-1* on Change in the Network Structure at Time *t*, 2008-2017

	Dependent Variables					
Independent Variables	Vertices	Edges	Density	Triads	Modularity	Segregation
Shocks $_{t-1}$	.009	.019	-.0007	.030	-.002	.228
	(.018)	(.044)	(.013)	(.037)	(.010)	(.361)
Constant	.000	-.008	-.009	-.153	.010	-1.069
	(.115)	(.282)	(.082)	(.241)	(.068)	(2.334)
Adjusted R^2	-.093	-.098	-.125	-.041	-.121	-.072

* $\rho < .05$; ** $\rho < .01$; *** $\rho < .001$ (two-tailed tests)

Table B2.3 Effect of Environmental Shocks for Time *t-1* on Change in the Network Structure at Time *t*, 2008-2017

	Dependent Variables					
Independent Variables	Vertices	Edges	Density	Triads	Modularity	Segregation
Environmental	.031	.093	.025	.088	.009	.656
Shocks $_{t-1}$	(.019)	(.043)	(.013)	(.036)	(.013)	(.394)
Constant	-.069	-.262	-.109	-.320	-.038	-2.285
	(.083)	(.185)	(.055)	(.156)	(.053)	(1.680)
Adjusted R^2	.141	.285	.234	.348	-.056	.165

* $\rho < .05$; ** $\rho < .01$; *** $\rho < .001$ (two-tailed tests)

Table B2.4 Effect of Social Shocks for Time *t-1* on Change in the Network Structure at Time *t*, 2008-2017

	Dependent Variables					
Independent Variables	Vertices	Edges	Density	Triads	Modularity	Segregation
Social Shocks $_{t-1}$	-.205	-.090	**-.035***	-.059	-.017	-.436
	(.025)	(.056)	(.014)	(.053)	(.014)	(.521)
Constant	.108	.309	.069	.163	-.107	-.436
	(.063)	(.142)	(.035)	(.134)	(.014)	(.521)
Adjusted R^2	-.002	.147	.385	.029	.041	-.034

* $\rho < .05$; ** $\rho < .01$; *** $\rho < .001$ (two-tailed tests)

Table B2.5 Effect of Environmental and Social Shocks for Time *t-2* on Change in the Network Structure at Time *t*, 2008-2017

	Dependent Variables					
Independent Variables	Vertices	Edges	Density	Triads	Modularity	Segregation
Environmental Events $_{t-2}$	.031	.035	-.023	.006	.003	.200
	(.029)	(.076)	(.019)	(.066)	(.013)	(.568)
Social Shocks $_{t-2}$	.005	.003	-.006	-.009	-.005	.114
	(.036)	(.094)	(.023)	(.081)	(.016)	(.700)
Constant	-.123	-.074	.135	.034	.005	-.663
	(.204)	(.538)	(.135)	(.464)	(.090)	(4.016)
Adjusted R^2	-.086	-.280	-.054	-.325	-.270	-.306

* $\rho < .05$; ** $\rho < .01$; *** $\rho < .001$ (two-tailed tests)

Table B2.6 Effect of All Shocks for Time *t-2* on Change in the Network Structure at Time *t*, 2008-2017

	Dependent Variables					
Independent Variables	Vertices	Edges	Density	Triads	Modularity	Segregation
Shocks$_{t-2}$	.023	.025	-.018	.002	.001	.174
	(.026)	(.067)	(.017)	(.057)	(.011)	(.492)
Constant	-.115	-.065	.130	.039	.008	-.637
	(.198)	(.503)	(.130)	(.431)	(.086)	(3.719)
Adjusted R^2	-.029	-.120	.008	-.142	-.143	-.123

* $\rho < .05$; ** $\rho < .01$; *** $\rho < .001$ (two-tailed tests)

Table B2.7 Effect of Environmental Shocks for Time *t-2* on Change in the Network Structure at Time *t*, 2008-2017

	Dependent Variables					
Independent Variables	Vertices	Edges	Density	Triads	Modularity	Segregation
Environmental Shocks $_{t-2}$	.029	.033	-.021	.010	.005	.156
	(.024)	(.062)	(.016)	(.054)	(.011)	(.464)
Constant	-.104	-.061	.110	-.001	-.016	-.197
	(.132)	(-.066)	(.088)	(.302)	(.059)	(2.613)
Adjusted R^2	.067	-.097	.086	-.138	-.108	-.125

* $\rho < .05$; ** $\rho < .01$; *** $\rho < .001$ (two-tailed tests)

Table B2.8 Effect of Anthropogenic Shocks for Time *t-2* on Change in the Network Structure at Time *t*, 2008-2017

	Dependent Variables					
Independent Variables	Vertices	Edges	Density	Triads	Modularity	Segregation
Social Shocks $_{t-2}$	-.014	-.017	.007	-.012	-.017	-.436
	(.032)	(.078)	(.021)	(.066)	(.014)	(.521)
Constant	.083	.155	-.017	.077	.035	1.301
	(.073)	(.180)	(.049)	(.153)	(.036)	(1.317)
Adjusted R^2	-.114	-.135	-.124	-.137	.041	-.034

* $\rho < .05$; ** $\rho < .01$; *** $\rho < .001$ (two-tailed tests)

Table B2.9 Effect of Environmental and Social Shocks for Time *t-3* on Change in the Network Structure at Time *t*, 2008-2017

	Dependent Variables					
Independent Variables	Vertices	Edges	Density	Triads	Modularity	Segregation
Environmental	.012	.017	.001	-.003	.001	-.007
Events $_{t-3}$	(.018)	(.027)	(.017)	(.014)	(.009)	(.031)
Social Shocks $_{t-3}$	.019	.051	.016	.011	.008	.059
	(.022)	(.033)	(.021)	(.018)	(.010)	(.038)
Constant	-.079	-.151	-.051	-.022	-.018	-.038
	(.128)	(.188)	(.119)	(.104)	(.060)	(.220)
Adjusted R^2	-.189	.061	-.238	-.228	-.214	.159

* $\rho < .05$; ** $\rho < .01$; *** $\rho < .001$ (two-tailed tests)

Table B2.10 Effect of All Shocks for Time *t-3* on Change in the Network Structure at Time *t*, 2008-2017

	Dependent Variables					
Independent Variables	Vertices	Edges	Density	Triads	Modularity	Segregation
Shocks $_{t-1}$	.015	.029	.006	.002	.003	.016
	(.015)	(.025)	(.015)	(.013)	(.007)	(.033)
Constant	-.083	-.175	-.061	-.032	-.024	-.084
	(.117)	(.188)	(.113)	(.100)	(.057)	(.252)
Adjusted R^2	-.010	.052	-.138	-.163	-.131	-.125

* $\rho < .05$; ** $\rho < .01$; *** $\rho < .001$ (two-tailed tests)

Table B2.11 Effect of Environmental Shocks for Time *t-3* on Change in the Network Structure at Time *t*, 2008-2017

	Dependent Variables					
Independent Variables	Vertices	Edges	Density	Triads	Modularity	Segregation
Environmental	.000	.000	-.005	-.007	-.002	-.027
Shocks $_{t-1}$	(.027)	(.027)	(.015)	(.013)	(.008)	(.032)
Constant	.042	.042	.008	.022	.013	.186
	(.159)	(.159)	(.087)	(.075)	(.044)	(.185)
Adjusted R^2	-.167	-.167	-.149	-.110	-.148	-.041

* $\rho < .05$; ** $\rho < .01$; *** $\rho < .001$ (two-tailed tests)

Table B2.12 Effect of Social Shocks for Time *t-3* on Change in the Network Structure at Time *t*, 2008-2017

	Dependent Variables					
Independent Variables	Vertices	Edges	Density	Triads	Modularity	Segregation
Social Shocks $_{t-1}$	.013	.042	.015	.013	.008	.063
	(.019)	(.028)	(.017)	(.015)	(.008)	(.032)
Constant	.002	-.037	-.046	-.043	-.015	-.084
	(.042)	(.062)	(.038)	(.033)	(.019)	(.070)
Adjusted R^2	-.081	.152	-.032	-.032	-.012	.292

* $\rho < .05$; ** $\rho < .01$; *** $\rho < .001$ (two-tailed tests)

Appendix C

Here, I use one more sensitivity analysis to examine how the shocks would have affected change in the policy coordination network were shocks conceptualized as occurring exogenously and endogenously with relation to the boundaries of the subsystem. For the models that follow, I present exogenous results in Table C2.1 and endogenous results in Table C2.2.

$$G_t(m)\text{-}G_{t\text{-}1}(m) = \beta_0 + \beta_1 Shocks^{enviro}{}_{t\text{-}1} + \beta_2 Shock^{pol}{}_{t\text{-}1} + \beta_2 Shock^{econ}{}_{t\text{-}1} + e$$

Table C2.1 Effects of Exogenous Shocks on the Network Structure, 2008-2017

	Dependent Variables					
Independent Variables	Vertices	Edges	Density	Triads	Modularity	Segregation
Enviro. Shocks $_{t\text{-}1}$	.049*	-.138***	.030*	.128***	.020	1.143**
	(.012)	(.021)	(.009)	(.015)	(.011)	(.210)
Economic Shocks $_{t\text{-}1}$	.008	-.026	-.036*	-.013	-.001	.113
	(.020)	(.030)	(.013)	(.022)	(.016)	(.305)
Political Shocks $_{t\text{-}1}$	-.014	-.037	-.008	-.010	-.015	-.153
	(.023)	(.035)	(.015)	(.025)	(.019)	(.351)
Constant	-.017	-.052	-.023	-.143	-.020	-1.347
	(.037)	(.054)	(.024)	(.040)	(.030)	(.552)
Adjusted R^2	.584	.848	.647	.893	.192	.777

* $\rho < .05$; ** $\rho < .01$; *** $\rho < .001$ (two-tailed tests)

Table C2.2 Effects of Endogenous Shocks on the Network Structure, 2008-2017

	Dependent Variables					
Independent Variables	Vertices	Edges	Density	Triads	Modularity	Segregation
Enviro. Shocks $_{t\text{-}1}$	-.011	-.003	.016	.027	-.010	.029
	(.734)	(.079)	(.025)	(.065)	(.016)	(.655)
Economic Shocks $_{t\text{-}1}$	.098	.275	.078	.284	.061	2.204
	(.069)	(.170)	(.053)	(.139)	(.034)	(1.406)
Political Shocks $_{t\text{-}1}$	-.047	-.112	-.028	-.139	-.034	-1.329
	(.068)	(.169)	(.053)	(.138)	(.034)	(1.400)
Constant	.084	.085	-.078	-.096	.031	.106
	(.118)	(.291)	(.091)	(.238)	(.059)	(2.412)
Adjusted R^2	.110	.097	-.087	.219	.350	.119

* $\rho < .05$; ** $\rho < .01$; *** $\rho < .001$ (two-tailed tests)

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