AN AGENT BASED MODEL OF COMMUNITY AUTHORITY STRUCTURE RESILIENCE

by

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DEDICATION

This is dedicated to my patient and loving wife Rachael and my daughter Naia.

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ABSTRACT

AN AGENT BASED MODEL OF COMMUNITY AUTHORITY STRUCTURE RESILIENCE

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This dissertation presents a theoretical model based on social exchange theory that explains the resilience and adaptation of authority structures in urban communities. Communities where non-state actors undermine or replace government institutions are a persistent public policy concern in many cities. The structure of instrumental relationships between authorities and residents in these communities is a key variable associated with a wide range of human security and governance challenges. Altering these structures is often necessary to enable other public policy goals. However, there is a lack of theoretical frameworks that address the dynamic characteristics of these structures. This hinders policy development by limiting insights into the effects of efforts to support or undermine particular groups or to alter social conditions on authority structures. The theory developed here describes authority structures as an emergent feature of a community-level complex adaptive social system. In this system, individual actors select relationship partners based on past experiences, preferences, environmental

conditions, and information from other actors. Changes to structure are the result of changes to the set of actors in the system and how these actors value particular relationships. A comparative case study of three sub-Saharan African communities located in Nairobi, Cape Town, and Lagos and several additional experiments are performed using an agent-based model implementing this theory. The results demonstrate the practical application of the theory to public policy analysis and support the choice of social exchange theory as the basis for actor decision-making. More broadly, this effort extends existing theoretical and agent-based models of contentious polities and authority structures. It also demonstrates the utility of computational modeling in advancing the research programs in social exchange theory, political authority, and comparative urban politics.

CHAPTER ONE
INTRODUCTION

This dissertation presents a theoretical model based on social exchange theory (SET) that explains the resilience and adaptation of authority structures in urban communities. The structure of instrumental relationships between authorities and residents in these communities is a key variable associated with wide range of human security and governance challenges. Altering these structures is often necessary to enable other public policy goals. However, there is an absence of theoretical frameworks that address the dynamic characteristics of these structures. This research gap hinders policy development by limiting insights into the effects of efforts to support or undermine particular groups or to alter social conditions on authority structures.

The theory developed here describes authority structures as an emergent feature of a community-level complex adaptive social (CAS) system. In this system, individual actors consider past interaction outcomes, preferences, environmental conditions, and information from other actors in their relationship decisions. Changes to the set of actors in the system and how these actors value particular relationships results in changes to the authority structure.

The dissertation demonstrates the explanatory power of this theoretical framework through a series of experiments using an agent-based model (ABM). These experiments include a comparative case study of three communities: Kibera (Nairobi,

Kenya), Manenberg (Cape Town, South Africa), and Mushin (Lagos, Nigeria). Other experiments investigate the effect of agent communication, corruption, positive and negative group bias, and social stress patterns on authority structure resilience.

There are three key findings. First, a CAS framework is appropriate for modeling the dynamic properties of community authority structures. Within this framework, SET offers a viable decision-making model for individual agents. Second, actor interdependence, specifically, the communication of experiences, is a necessary condition in explaining authority structure resilience. Third, this model accurately represents how a range of conditions affect structure resilience including corruption, reinforcement of constituency membership, and authority capacity to address social stress.

The results demonstrate the practical application of the theory to public policy analysis and support the choice of social exchange theory as the basis for actor decision-making. More broadly, this effort extends existing theoretical and computational models of contentious polities and authority structures. It also demonstrates the utility of computational modeling in advancing the research programs in social exchange theory, political authority, and comparative urban politics

This chapter consists of four sections. The first section introduces the subject of community authority structures. It describes the motivation for studying this phenomenon and outlines the general approach to this research. Section 1.2 reviews the relevant literature and discusses current shortfalls in the existing research. This is followed by a detailed discussion of each research question in section 1.3. Finally, section 1.4

summarizes the purpose of this dissertation and introduces the methods for investigating the research questions.

1.1. Motivation

1.1.1. Community Authority Structures

The principal purpose of this research is to better understand why community authority structures form and change. An authority structure is defined as the network of instrumental exchange relationships between and among authorities and individual residents in a defined space, during a specified timeframe, and concerning a particular social issue (see Ferguson & Mansbach, 1996).

Authorities and residents are the primary actors in an authority structure. Authorities can mobilize social resources and compel compliance with directives in the pursuit of group goals (Eckstein, 1973; Ferguson & Mansbach, 1996). In urban communities, authorities include state and local institutions, non-state actors, and individuals such as politicians or community leaders. In describing an authority structure, residents can be considered as individuals or aggregated into social groups. Social groups share an identity that is relevant to the analysis (Eckstein, 1973).

The fundamental relationship between any two actors in an authority structure is based on an exchange of value. The formation and dynamics of these relationships and a wide range of other social relationships are formally addressed in the SET literature. The basic proposition of SET is that social relationships strengthen and weaken based on their

ability to satisfy actor-defined needs and the frequency with which the relationship is reinforced through positive exchanges of value, or needs satisfaction (Blau, 1964; Cropanzano & Mitchell, 2005; Homans, 1958; Molm, 1997). When multiple actors are considered, the social network describing their exchange relationships can be described as a structure. SET and its integration into the model developed for this research is described in greater detail in sections 1.3.1 and 2.1.2.

The relationship between authorities and residents is addressed in the literature on political authority. As defined by Ferguson and Mansbach (1996, p. 36), "authority…is an exchange phenomenon where loyalties and other resources are provided in return for value satisfaction (or relief from value deprivation)." Figure 1 translates this definition into a systems perspective. The relationship between an authority and society is dependent on the strength of the exchange history between them. These relationships are asymmetric with respect to relative power (Eckstein, 1973; Ferguson & Mansbach, 1996; Keehn, 1974). They also represent a degree of interdependence between the actors. Consequently, the relationship endures, or has resilience, as long as the basis for interdependence persists.

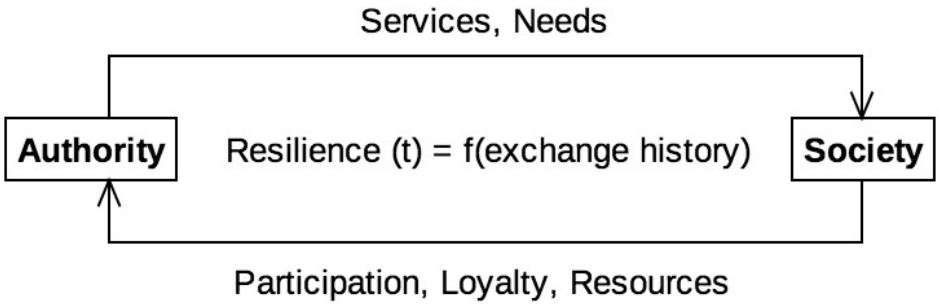

Figure 1. Systems diagram of the exchange relationship between an authority and society.

The theoretical framework for analysis presented in this dissertation takes the perspective that community authority structures are a distinct social phenomenon. As illustrated in Figure 2, the structure of relationships between community actors influences actor behaviors and strategies (Arias, 2010; Barnes, 1986; Singerman, 1995). These actions directly and indirectly influence how a community experiences a wide range of socio-natural conditions and challenges. In addition, these actors are often linked to other communities through political, economic, or social ties. Thus, the effects of a particular structure in one community can have secondary effects in other communities.

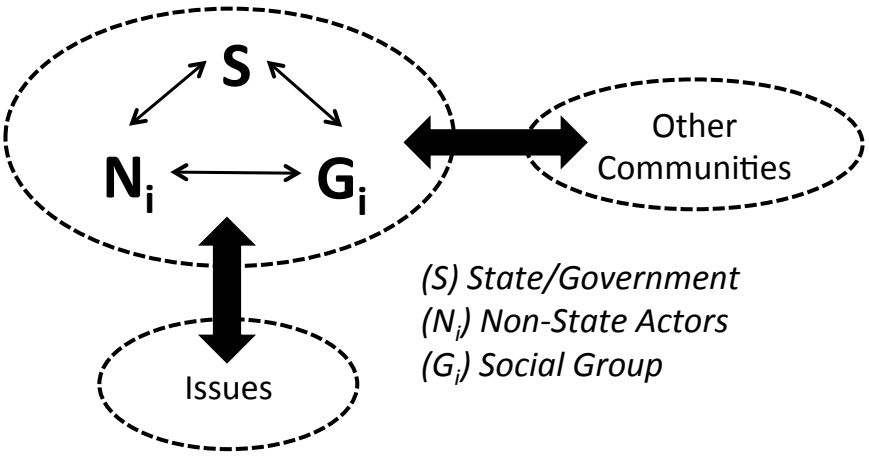

Figure 2. Community authority structure phenomena.

Authority structures are relevant to any effort to alter or preserve community conditions or linkages to achieve public policy goals. However, *a widely applicable theoretical framework for understanding the dynamic properties of community authority structures does not exist.* To help resolve this shortfall, this dissertation presents a model of community authority structure resilience that can be used for this purpose.

The model focuses on two inter-related features of complex adaptive systems, *resilience and adaptation*. According to Bennet et al (2005, p. 945), resilience is a "...measure of the amount of change or disruption that is required to transform a system from being maintained by one set of mutually reinforcing processes and structures to a different set of processes and structures." System actors constantly adapt to conditions. In some cases, this adaptation reinforces the current state. In other situations adaptation causes resilience to fail and the system undergoes a state change (Folke, 2006; Gunderson & Holling, 2001).

In a community setting, structure resilience refers to the ability of the existing structure of resident-authority relationships to persist under stress. As shown in Figure 3, various states for a community authority structure are possible depending on the number of actors in the system. The resilience of any particular state depends on the ability of the actor relationships comprising the structure to provide value. Changes in system conditions or actor characteristics can reinforce or undermine structure resilience by stimulating a re-calculation of the value of a particular relationship. When community actors adapt to conditions by changing their preferred relationships, then resilience has failed and a new authority structure emerges.

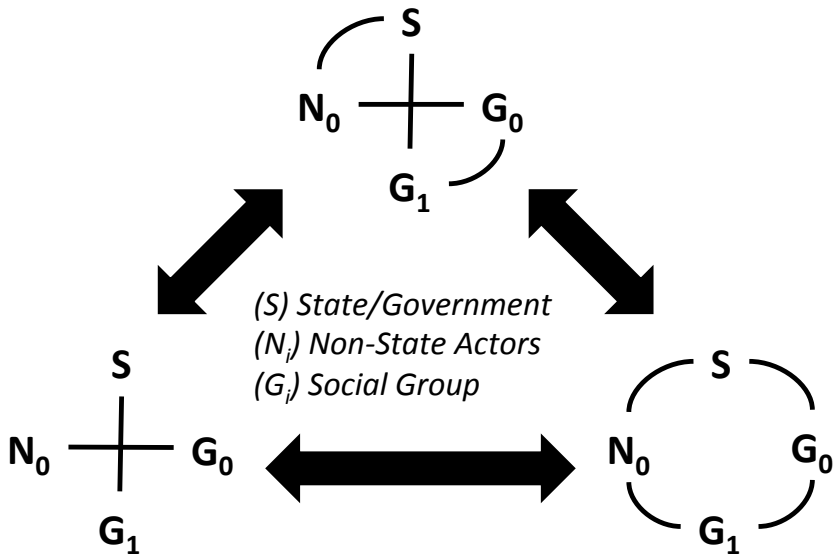

Figure 3. Community authority structure resilience and adaptation.

1.1.2. Public Policy Challenges

This dissertation is concerned primarily with *contested* authority structures in urban communities. Contested structures share two necessary conditions. First, residents form relationships with multiple authority actors operating in a community. Second, a universally accepted authority hierarchy is absent. Authorities claim autonomy over a combination of territory, social control, and freedom of action. They pursue strategies that reinforce autonomy through cooperation or conflict with other authorities and community residents. Multiple overlapping structures may exist simultaneously in a particular community.

Contested authority structures add complexity to the human development and security challenges that communities confront. They complicate governance by reducing

the influence of state institutions. Under these conditions, corrupt, extra-legal relationships between authorities can emerge that exclude civic participation and influence over governance decisions. In democratic political systems these relationships may result in voter suppression or intimidation campaigns directed by political candidates and executed by community authorities (Arias, 2006; De Smedt, 2009; Klopp, 2001; Patel, Crooks, & Koizumi, 2012). They also ensure a degree of immunity from arrest for non-state actors involved in illegal activity. Examples of enduring, corrupt relationships between criminal organizations and security services are found in Rio de Janeiro, Cape Town, and Nairobi (Arias, 2010; Klopp, 2001; Leggett, 2004b; Pint, Crooks, & Geller, 2010).

Non-state actors can also complicate public safety and undermine the formal judicial system. Their actions undermine state authority and inevitably create conflict dynamics of their own. For example, vigilantes and other organized non-state actors have been accused of assaulting or killing suspected criminals in communities in Nairobi, Cape Town, Lagos, Johannesburg (Anderson, 2002; Enechojo, 2013; Guichaoua, 2009; Samara, 2011). Efforts by the state to re-assert control over public safety often increases violence and insecurity in contested communities as the targets of these operations fight back and residents are injured or killed (Arias, 2006, 2013; Landau, 2005; Samara, 2011; Venkatesh, 2008). As occurred in the late 1990's in Cape Town, these conflicts often reinforce the control that well-resourced non-state actors exercise over a community (Samara, 2011).

Contested communities are associated with multiple economic development challenges. Economic underdevelopment drives many residents to participate in some manner, even as consumers, in the illicit economy. These communities are often nodes in local, national, and transnational illicit networks. Non-state actors such as organized criminal enterprises typically control access to these local markets and derive needed resources from them (Meagher, 2006; Samara, 2011; Skaperdas, 2001; Venkatesh, 2008). Residents benefit from the re-investment of profits back into the community by these groups. Government efforts to eliminate these groups, as exemplified by operations in Tunis and Cape Town in the 1990's, can have an immediate negative effect on the local economy and motivate public opposition (Bennet, 2012; Ketterer, 2001).

Physical isolation from the economic core of the city can reinforce the influence of non-state actors over the community economy (Barnes, 1986; Kleemans & de Poot, 2008). This isolation may be due to physical barriers such man-made infrastructure or natural features, as in Kibera, Nairobi (Neuwirth, 2006), or their location on the urban periphery as in the Cape Flats communities in Cape Town (Robins, 2002). Poor public transportation infrastructure can exacerbate physical isolation.

The challenges of delivering services such as education and training to these contested, isolated communities creates long-term employment issues for residents, particularly youth who are trying to enter the workforce. These are problems in many low-income communities. However, the presence of non-state actors increases the danger faced by government employees and non-governmental organizations and can reduce

program investment due to the high financial risks. This increases the complexity of the public policy response required (Bennet, 2012; Lambrechts, 2012; Neuwirth, 2006).

Due to the leadership role that non-state actors play in the economic, political, and social dynamics of contested communities, they are very often nodes in regional, state, and international networks. For example, transnational criminal organizations link non-state actors in communities in Cape Town, Rio de Janeiro, and Karachi to groups in other countries through distribution networks and financial flows (Miklaucic & Brewer, 2013; Samara, 2011; P. Williams, 2010). This interconnectedness increases the difficulty of altering relevant community conditions.

Political mobilization and conflict participation is another way that non-state actors in contested communities extend their influence. Hezbollah's use of its territory as a base for operations across the Middle East is one example (Szekely, 2012). Another example is the regional influence of the O'odua Peoples Congress, a Yoruba Nigerian political movement with great deal of local authority in its home community in Lagos (Abdulazeez, 2013; Ikelegbe, 2005). The ability to maintain a safe-haven in a particular community is a key factor in the success of these groups.

1.1.3. Research Goals

Given the importance of understanding the resilience and adaptation of authority structures to developing effective policy, three broad questions guide this research: (1) Why do authorities and residents interact and form enduring relationships? (2) What

explains the resilience of those relationships? (3) What explains changes in these structures or adaptation? These general questions are the basis for the three specific research questions that frame this analysis:

- RQ1: Is social exchange theory a viable framework for modeling authority and resident decision-making with respect to partner selection in small communities?
- RQ2: Is an authority structure a network phenomenon or an aggregation of independent exchange relationships between two actors?
- RQ3: Why and how do particular conditions such as corruption, actor resources, persistent in-group bias, event frequency, and issue/stress patterns affect the resilience of authority structures?

These research questions address issues that are central to the development and testing of a theory explaining the resilience and adaptation of community authority structures. Question 1 investigates the viability of one theory that can explain how and why individual authority-resident relationships develop and break apart. These relationships are the fundamental building block of authority structures. The second question addresses whether communication of experiences with respect to authority relationships influences actor decisions. This has implications for modeling community systems as well as when considering the second order effects of policies on goals. The third question addresses the interest in understanding how a wide range of conditions associated with contested communities affects structure resilience. These questions are discussed in greater detail in section 1.3. The methods used to investigate them are discussed in section 2.6.

1.2. Literature Review

This review presents an overview of relevant research on the social dynamics of contested communities. It consists of six sections each corresponding to a theme that is relevant to understanding the dynamic characteristics of authority structures. The theory and research in each section contributes knowledge that is critical developing the model of community authority structures presented here. It concludes by identifying the gaps in these efforts that have motivated this particular research project.

The review first addresses relevant sociopolitical theory and models in section 1.2.1. It focuses on theoretical models of coherent and contested or contentious polities. Section 1.2.2 reviews research describing community level authority structures. It also describes how community members access authority resources. Section 1.2.3 summarizes relevant features of resident-authority interactions. It is organized in three parts corresponding to the willingness, opportunity, and capacity of residents and authorities to interact with one another. This is followed by section 1.2.4 which describes the effects of socio-natural conditions on authority structures. Section 1.2.5 reviews several relevant ABMs of authority, polity stability, social structure, and urban social dynamics. The review concludes in section 1.2.6 with a summary of key gaps in the research and theory with respect to community authority structure dynamics.

1.2.1. Sociopolitical Systems Theory and Models

The systems model introduced by Easton (1957) is the basis for a behavioral understanding of a political system. This model, shown in Figure 4, has the basic elements of any adaptive system. It places the target system within a complex environment where multiple variable conditions are present. Conditions and actors drive system adaptation. Most important the model explicitly links the dependent variable, decisions and policies, back to the independent variables, demands and support, through feedback.

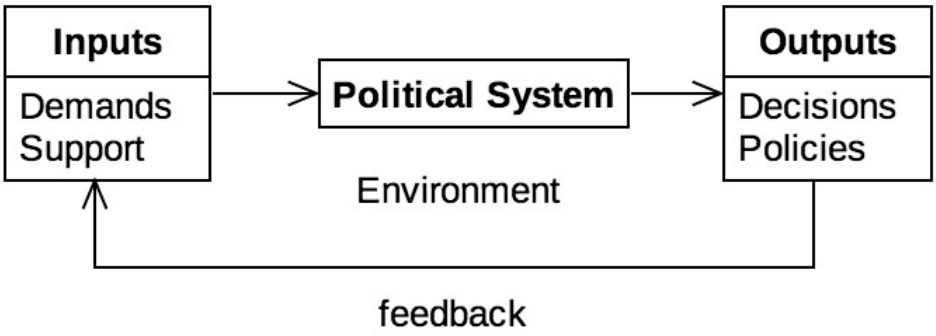

Figure 4. Systems model of political behavior (adapted from Easton 1957, 384).

The polity model offers an alternative, but complementary perspective on political systems. According to Ferguson and Mansbach (1996, p. 34), "a polity (or political authority) has a distinct identity; a capacity to mobilize persons and their resources for political purposes, that is, value satisfaction; and a degree of institutionalization and hierarchy (leaders and constituents)." From this perspective, the relationship between

authorities and citizens is the central to understanding how and why political systems change.

Figure 5 illustrates the basic polity model (Cioffi-Revilla 2008). The polity consists of a government, society, and a set of issues. The government develops policies to address social issues. Society's support for the government is based primarily on this relationship. This model is relevant to governance at any scale including sub-state and international levels. A defining feature of the model is that there is a single set of formal institutions, the government, with the responsibility and authority to resolve public issues, mobilize public resources, and compel compliance with decisions (Eckstein, 1973; Ferguson & Mansbach, 1996).

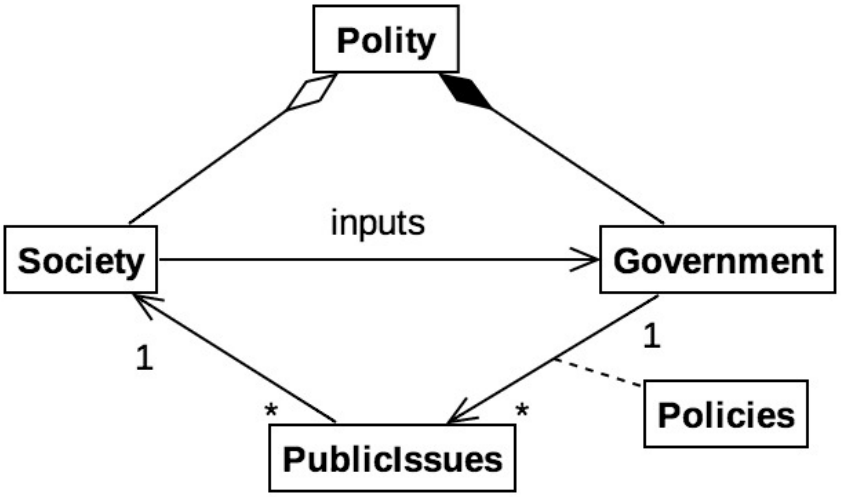

Figure 5. Low resolution version of SimPol polity model (adapted from Cioffi-Revilla, 2008, p. 35).

The contentious polity model shown in Figure 6 expands on the basic polity model (Cioffi-Revilla, 2011). It adds non-state actors with the willingness and capacity to

resolve public issues and take on the role of an authority. These actors are capable of polity-like functions such as service delivery and resource mobilization and are potential competitors for social control. Socio-natural issues confronting society and the policy responses to these issues are responsible for varying public support for state and non-state actors. Ultimately, polity survival is dependent on the effective integration of all actors under a single authority (Cioffi-Revilla, 2011). If integration fails, then the polity breaks up.

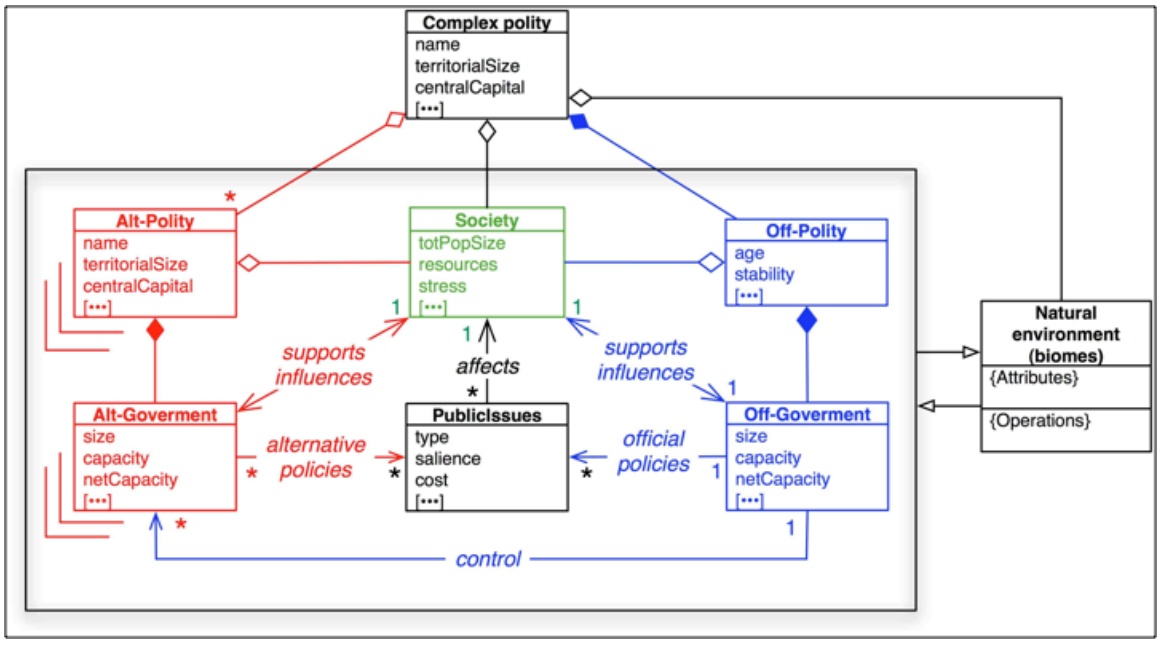

Figure 6. The contentious polity model (source: Cioffi-Revilla, 2011, p. 9).

1.2.2. Community Authority Structures

The literature on community authority patterns describes two basic structures corresponding to the basic, or coherent, and contentious polity models. *Coherent*

structures have a single authority, either the state or a non-state actor. Much of the urban studies literature focuses on political dynamics in these polities. Generally speaking, the ultimate legitimacy and authority of the government is not in question, though studies of non-state actors such as gangs often consider criminal activity (Kaplan & Dubro, 2003; Kleemans & de Poot, 2008; Venkatesh, 1997).

The relevant research on coherent authority structures addresses how various state and non-state actors influence one another to achieve goals for themselves and their constituents. The emphasis is on how groups leverage legal processes and informal relationships to achieve these goals (Banfield & Wilson, 1963; Dahl, 1961; Jacobs, 1961; Stone, 1989). A central theme throughout this literature is the constant state of competition for influence over public policy by individuals, government and non-state actors, and residents. The competition between and within municipal agencies in a city is also a research focus (Ostrom, Tiebout, & Warren, 1961). The literature also addresses how city socio-political patterns fit within national level dynamic (Peterson, 1981). This highlights the hierarchy and interdependence that exists between different levels of government.

There is more limited research concerning coherent authority structures where non-state actors dominate territory within a recognized state. Within these territories there is a single authority that controls nearly every aspect of economic, political, and social life. There are no viable challengers to the status quo. Beirut and Karachi are two examples (Akar, 2012; Bollens, 2013; Gazdar & Mallah, 2013; Szekely, 2012). In these cases, state weakness and the capacity of alternative authorities to govern results in large

urban areas that are completely outside of state control. In both Beirut and Karachi, these alternative authorities also happen to participate in formal state institutions even as they reject state authority within the communities they control.

Contested structures are defined by multiple authorities asserting various degrees of influence over a particular community. Non-state actors including vigilantes, organized criminal enterprises, ethnic militias, and proscribed political opposition movements attain a level of freedom of action that actively undermines state authority (Chabal & Daloz, 1999; Clunan & Trinkunas, 2010; Ketterer, 2001; Migdal, 1988; Skaperdas, 2001).

Contested structures involve a mixture of cooperation, competition and conflict relationships between authorities as they pursue organizational goals (Chabal & Daloz, 1999; Cioffi-Revilla, 2011; Doornbos, 2010; Lund, 2006; Marshall, 2008; Migdal, 1988; Rice & Patrick, 2008; Robinson & Acemoglu, 2012; Rotberg, 2003). Cooperation occurs when representatives of state institutions and non-state actors form instrumental relationships that can undermine or supersede formal processes (Arias, 2013; Klopp, 2001; Lund, 2006). Individual officials of government institutions such as police officers may find cooperation with non-state actors preferable to pursuing organizational goals, such as arresting criminals. This cooperation occurs within the context of broader competition and conflict between these government and non-state actors. The result is a complex set of relationships between individuals that undermines state control and diffuses authority between multiple actors.

Contested urban communities are embedded in city, regional, and state-level socio-political structures. Community-authority relationships both affect and are in turn responsive to multi-scale political and security dynamics. For example, the South African state security services led operations in the Cape Flats suburbs of Cape Town in the 1990's to decrease street gang influence and to eliminate a vigilante organization that the U.S. government had designated as a terrorist organization (Samara, 2010).

Community authority structures are also categorized by whether residents access authority resources directly or indirectly. Direct interactions are found in communities where residents go to an authority representative to request services. A resident that calls the police for assistance is one example. Indirect interactions require another actor such as a patron or community representative to mediate between a resident and an authority.

In contested communities, strong, direct interpersonal ties often characterize the interactions between individual residents and members of non-state actors. The literature on street gangs consistently refers to these relationships (Arias, 2004; Browning, Feinberg, & Dietz, 2004; Lambrechts, 2012; Leggett, 2004a; Venkatesh, 1997). Family ties established through generations of recruitment and gang participation integrate the gang into the community. Even when residents do not have a close relationship with a gang member they may know someone that does. Residents engage with gangs for economic, security, and social reasons. Gangs leverage these relationships to avoid arrest and attack by other gangs.

Traditional authorities are another example of strong, direct ties that exist in many communities. The authorities in these cases are generally individuals or groups that are

well known through long-standing presence in the community (Haenni, 2011; Joireman & Vanderpoel, 2010; Singerman, 1995). These authorities provide an alternative to participation in state institutions. In some cases, these institutions are partially integrated into the formal state political system under certain conditions. The acceptance of some Muslim legal practices in the 2010 Kenyan Constitution is one of many examples (Government of Kenya, 2010). In other cases, these alternative authorities are proscribed or their decisions are not recognized by the state.

With indirect access, requests for assistance and resources pass through a patron or intermediary that is independent of the authority. Examples of indirect access include patron-client networks involving traditional authorities or community leaders acting as intermediaries between residents and formal institutions or non-state actors.

Patron-client networks offer multiple benefits to all parties and are a common way of accessing resources in many urban communities (Barnes, 1986; Eisenstadt & Roniger, 1980; Marx, Stoker, & Suri, 2013; Singerman, 1995). At the local level, patronage networks are a relatively stable, self-reinforcing structure. However, they are also dependent on the consistent flow of resources down to residents and expressions of loyalty back up. Traditional authorities with local influence are often connected to formal institutions that residents might have trouble accessing on their own (Haenni, 2011; Marx et al., 2013; Singerman, 1995).

Finally, another example of indirect access is leaders representing community interests in interactions with state and non-state actors (Arias, 2006; Bennet, 2012; Lambrechts, 2012). These relationships are observed in situations where individual

efforts prove insufficient and there is a community consensus that organized action is required. The use of intermediaries outside of patron-client or traditional structures is less frequent and usually in addition to rather than instead of individual relationships between residents and authorities.

1.2.3. Resident-Authority Exchange Dynamics

A common theme in the existing research is that community-authority relationships persist because they provide value to the actors. This is consistent with the theoretical literature on authority dynamics discussed in section 1.1 (Eckstein, 1973; Ferguson & Mansbach, 1996; Keehn, 1974; Migdal, 1988; Rosenau, 1992). Given sufficient reinforcement, these instrumental relationships can form the basis for authority legitimacy.

Non-state actors increase their competitiveness with respect to the state by providing services and resources that are in demand. They establish themselves as a viable alternative through repeated interactions with residents. For example, street gangs in Cape Town developed strong community ties over several decades through recruitment and the financial contributions and employment opportunities of illicit activities (Samara, 2011). Simultaneously, the government failed to meet the economic development needs of these communities. In addition to the labor pool provided by young male residents, the community was less likely to turn-in gang members to police particularly during security operations (Lambrechts, 2012). In Mushin, Lagos, the O'Odua People's Congress (OPC)

maintained an operational presence for several years before establishing itself as the dominant security provider in the Yoruba community (Ikelegbe, 2005). The weak performance of government security forces in Mushin left a security need that vigilantes traditionally filled. The OPC saw an opportunity to leverage its resources to increase its local influence. Voter support for OPC initiatives and favored candidates in the late 1990's are examples of the Yoruba population returning value to the OPC (Guichaoua, 2009).

Despite the existence of mutually beneficial relationships between non-state actors and residents, these relationships do not imply full public approval. The interactions are driven primarily by need. Polling in Lagos and Cape Town, for example, indicates that many residents prefer a stronger government role, but necessity drives existing relationships (Alemika & Chukwuma, 2005; Enechojo, 2013; Leggett, 2004a).

The research on contested communities describes authority-resident interactions in terms of the *willingness, opportunity, and capacity* for one actor to engage with or provide value to a partner. This categorization of the literature is based on the necessary conditions for political events outlined in Cioffi-Revilla and Starr (1995), and highlights the basis for modeling these interactions.

The *willingness* to engage is based on a calculation that a relationship with a partner is acceptable to the actor's goals. This acceptability calculation is different from assessing the value of the relationship. From one perspective it concerns the issues addressed in the research on why individuals join groups and accept group authority (Lind & Tyler, 1992; Tyler & Blader, 2003). Willingness is also related to non-value

based reasons for engaging in social relationships (Lawler, 2001; Lawler, Thye, & Yoon, 2008). However, it also expresses reasons actors have to reject certain relationships due to biases, security concerns, or any other factor unrelated to the actual value of the partner to needs.

A review of relevant case studies identifies three willingness considerations that repeatedly stand out as factors in the resilience of authority structures. These considerations are the perception of the community as a whole, the biases toward or against the social identity of the partner, and the timing of public events. These considerations are most relevant to authority decisions.

Community perceptions express an authority's relationship with the entire community. When the community has greater value to an authority, it is more willing to engage with residents (Abdulazeez, 2013; Anderson, 2002; Bennet, 2012; Smith & Bertozzi, 2012; Venkatesh, 1997). Police unwillingness to enter an area, ineffective resource allocation decisions, or failure to provide services are expressions of low community perceptions (Alemika & Chukwuma, 2005; Arias, 2006; Bennet, 2012; Macharia, 1992; Neuwirth, 2006). For example, polling in Manenberg, Cape Town in 2003 expressed the apparent unwillingness of officers to investigate crimes as a key problem with police effectiveness (Leggett, 2004a). Generally speaking, this community perception variable applies to all residents.

Authorities and residents may also take a particular social *identity* into account when selecting partners. This is consistent with theories concerning homophily in social network formation (Kossinets, 2009; McPherson, Smith-Lovin, & Cook, 2001) and in-

group out-group distinctions (Tajfel & Turner, 1979). Many non-state actors such as the OPC in Lagos and the Mungiki in Nairobi openly support one social group and reject relationships with members of competing groups (Abdulazeez, 2013; Anderson, 2002; Joireman & Vanderpoel, 2010). These preferences are also found in state institutions. Legal restrictions on services available to non-citizens, or employment quotas are examples (Gopal & Karupiah, 2013; Lochery, 2012). Preferences are also the result of individual biases expressed by individuals performing their duties such as police or local government officials (Lochery, 2012; Marx et al., 2013; Morris, 1999; O'Regan & Pikoli, 2014).

Certain *events* can also alter the willingness to engage with particular partners. Authorities may alter service delivery patterns around times when there is a need to mobilize public support for a specific goal. Strategies that encourage support from in-groups or that suppress and alienate out-groups can precede elections and other political events. For example, voter mobilization and suppression were prevalent election strategies in Kenya in the 1990's and 2000's (Anderson, 2005; Klopp, 2001; LeBas, 2013). Increased attention by authorities to community welfare around anniversaries of key events, or other public celebrations are strategies to increase community support (Arias, 2006). These interactions all serve to maintain a connection between the community and an authority even when they are infrequent.

The *opportunity* to pursue a relationship is based primarily on access issues. Authorities with low barriers to access increase the opportunity to engage constituents particularly in low-income communities (Arias, 2010; Gazdar & Mallah, 2013; Morris,

1999; Neuwirth, 2006; Venkatesh, 1997). Government institutions may require significant outlays of time or resources by an individual. This may be due to the complexity of the bureaucracy, its competence, or efficiency. Specialized knowledge may be required to access the judicial system or other institutions. In poor communities, this presents a significant barrier to access. Taking a day to visit a government office may result in losing a job. A fee for a service may be higher than a resident's resources to pay. In some cases surrogates or patronage networks may reduce costs, but these options are rarely without monetary or social costs of their own (Barnes, 1986; Singerman, 1995).

Corruption also increases costs for government services and is commonly cited as a reason for decreased participation in government institutions (Alemika & Chukwuma, 2005; Arias, 2006; Enechojo, 2013; Leggett, 2004a; O'Regan & Pikoli, 2014; Wrong, 2010). Corruption also undermines the legitimacy of state institutions, raising issues of justice and fairness for residents.

Communication between authorities and residents can play a role in access challenges. For example, an extensive analysis of policing in Cape Flats, Cape Town identified language differences as contributing to poor community-police relations (O'Regan & Pikoli, 2014). This is a persistent concern in communities where migrants come from other countries or speak other languages (Landau, 2005; Lochery, 2012).

Another perspective on access is *community presence*. Authorities that are not available in the community, or that do not have a regular presence are often at a disadvantage. Presence may be the result of membership considerations as discussed earlier. However, it is also related to unintended consequences of public policy choices.

The placement of police stations outside some communities, as in Manenberg, South Africa, government offices that are inaccessible without public transport, or even the infrequent visits of officials or political representatives affect access (Bennet, 2012; Joireman & Vanderpoel, 2010; Robins, 2002). On the other hand, non-state actors with close, persistent ties to or presence in a community can significantly improve access (Enechojo, 2013; Ketterer, 2001; Venkatesh, 1997).

Finally, the ability to provide value is directly related to the *capacity* to engage a partner. Government and non-state actors generate revenue from a wide variety of sources including taxes, service fees, and rents, investments, corruption, and illicit activities (Anderson, 2002; Cioffi-Revilla, 2008; Lambrechts, 2012; Skaperdas, 2001; Smith, 2004; P. Williams, 2010). Insufficient resources are a persistent challenge for most authorities, even in wealthy states. This is often attributed to policy decisions and priorities tied to more complex political, social, and economic dynamics.

As described here, the exchange process between an authority and a resident is complex. However, when the literature is organized to describe how the interactions take place and the barriers to their success, the exchange process is clarified.

1.2.4. Socio-natural Environment

Changes in socio-natural conditions can affect structure resilience by altering the value of particular partners. Some changes affect authority resources. Increased street

gang control over international narcotics trafficking routes through the western Cape region in the 1990's increased the resources they could put into the communities where they operated (Lambrechts, 2012). In contrast, the steady downturn in the Kenyan economy in the 1980's reduced the already low resource base the government had available to resolve issues in poor urban communities (Branch, 2011; Kahl, 2006).

The rate that issues affect the community is another widely cited driver of structural change. Crime waves and social conflict, all increase the stress on communities (Anderson, 2002; Bennet, 2012; Enechojo, 2013; Samara, 2011; Venkatesh, 2008). Natural events such as droughts, floods, and other natural disasters, may interrupt or increase the need for services during and after the event. For economic reasons, increased vulnerability to natural and man-made disasters is also associated with many of these communities including Kibera in Nairobi, Mushin in Lagos, and Cape Flats in Cape Town (Adelekan, 2010; Bull-Kamanga et al., 2003; Ernstson et al., 2010). Increases in issue rates place stress on formal institutions to resolve issues (Cioffi-Revilla & Rouleau, 2010). Even in wealthy states, breakdowns in institutional effectiveness can create shortfalls in government services (Sobel & Leeson, 2006).

Population increases have a similar effect as they increase demand for services even when all other factors remain constant. Stress on the community increases the stress on authority resources (Kahl, 2006). These conditions create opportunities for actors to develop relationships within the community, but they also create the opportunity for failure .

The entry and exit of authority actors in a community is another notable condition. Most of the research focuses on the effects of the entry of non-state actors. Political movements such as the OPC in Lagos, Hezbollah in Beirut, the MQM in Karachi established themselves in a vacuum of state capacity to resolve basic resource and service needs of large urban areas (Abdulazeez, 2013; Akar, 2012; Gazdar & Mallah, 2013). The efforts of religious fundamentalist movements to gain authority in various Cairo communities in the 1990's is another example (Haenni, 2011). However, the exit of these actors can also have significant effects on a community authority structure. The violent vigilante group People for Against Gangsterism and Drugs (PAGAD) in Cape Town suppressed gang activity over a period of 3 years in the late 1990's (Bennet, 2012; Leggett, 2004b). However, its demise as a result of government security operations left a gap in community policing that the gangs then filled. This was possible in large part because PAGAD was no longer an organizational threat to the gangs.

Changes in social, political, and economic structures cover a number of related issues. As these structures evolve, the value of certain communities, groups, and even authorities also changes. In the 1980's and 1990's, as the Kikuyu population in Kibera, Nairobi decreased and the Luo population increased, the political value of Kibera increased for Luo politicians (De Smedt, 2009). When the apartheid era government in South Africa collapsed in 1993, communities that were perceived as African National Congress voting blocks reportedly saw an increase in re-development resources (Leggett, 2004a). The high value to landlords and their patrons of informal permits to build

structures in Kibera has integrated the slum into political and economic power structures in Nairobi (Amis, 1984; Dafe, 2009; De Smedt, 2009).

Environmental and social conditions are interdependent. Changes in a single condition always has first and second order effects on others. For example, an increase in migration into a community increases the demand for services and places stress on resources. This may have political effects as residents look to alternatives to formal institutions. In many situations, the linkages between conditions are not always clear.

1.2.5. Agent-Based Models

ABM's are a category of social simulation models that illustrate how interactions among social actors and with their environment give rise to observed social structures and group behaviors (Cioffi-Revilla, 2014; Epstein, J. M. & R. Axtell, 1996). An ABM is particularly useful when the target phenomenon is the result of complex, multi-scale dynamics (see Cioffi-Revilla 2014; Crooks, Castle, and Batty 2008).

This section reviews ABMs that have been used to investigate social phenomena that are relevant to community authority structures. It focuses on two models, RebeLand (Cioffi-Revilla & Rouleau, 2010) and Qawm (Geller & Moss, 2008) that demonstrate differing approaches to studying authority using computational methods. While neither ABM directly addresses the research focus of this dissertation on urban communities, they represent the polity framework and general exchange interactions that are the basis for the community authority structure model described in Chapter 2.

The RebeLand ABM investigates political stability in the context of a complex polity (Cioffi-Revilla & Rouleau, 2010). In RebeLand, stability refers to the persistence of government control, or polity survival. The model integrates social and environmental conditions, physical terrain features, and a large population of agents. In the model, polity residents increase or decrease their support for the government based on the effectiveness of government policies in several areas. Support for rebel groups opposing the government varies in response to their activities and government effectiveness. The ABM also integrates several additional conditions such as corruption, taxation, and conflict. Overall, RebeLand demonstrates a viable approach to research into socio-political dynamics that accounts for the complexity of the real world systems. Further, it demonstrates an implementation of the contentious polity model in an ABM to answer research questions related to those asked in this dissertation.

The Qawm model illustrates how local power structures emerge from the interactions between individual actors (Geller & Moss, 2008). In this model, agents consider the strengths and weaknesses of other agents and make endorsements to other agents. From these interactions, structures emerge that reflect the network of actor alliances. The model is relevant because of its focus on authority structures, but also because it is derived primarily by using qualitative methods to investigate why actors make the decisions that they do. This recognizes the challenge of studying real world authority structures where reliable statistical data is rarely available and often not relevant.

In addition to these two models, there are a range of ABMs that address relevant urban or social phenomena. Pujol et al (2005) modeled the development of a complex social network composed of hundreds of agents based on social exchange principles. This model illustrates how large community-sized structures can emerge from exchange interactions. Patel et al (2012) described the spatial growth of slums based on economic and political factors. This ABM illustrates how authorities or local power centers can affect social dynamics in poor urban neighborhoods. Pint et al (2010) modeled the emergence of organized crime in an urban community as individual agents address basic human needs. This is relevant for its focus on the relationship between community conditions and the decision to join non-state actors.

1.2.6. Review of Literature Gaps

The principle gaps in the research concern theory and methods that are directly applicable to understanding the dynamic properties of community authority structures. With respect to theory, the existing work on authority that is central to political science has found little direct application to investigating the emergence of authority structures. The exchange perspective on authority (Ferguson & Mansbach, 1996; Migdal, 1988) offers a viable foundation for developing a theory of community authority structure dynamics. However, this theory at the community level currently does not exist.

The basic and contentious polity models describe authority-society interactions within a CAS framework (Cioffi-Revilla, 2008, 2011). However, a companion model of

individual actor relationship dynamics, a central component of structure resilience, is not specified. Implied in both models is that actors pursue goals within the context of system conditions and make decisions accordingly as implemented in the RebeLand ABM (Cioffi-Revilla & Rouleau, 2010). The question remains, how do the relationships depicted or implied in these polity models form, dissipate, and stabilize? What decisions do individual actors make and how? This is a related but fundamentally distinct research problem. It focuses on why the polity structure exists in the first place, or how it emerges.

Another issue is that the polity concept is presented and described in the context of analysis of large-scale state-level political phenomena. It is, in fact, relevant at any scale, including the urban communities that are the focus of this analysis. One advantage of the CAS perspective is that explanations of phenomena at one level are often relevant at higher or lower levels of hierarchy (Simon, 1962). However, there are no existing ABMs that apply the polity structure to analysis of urban communities.

There is also an absence of theoretical frameworks for comparative analysis of community authority structures. As is evident from the literature review presented in sections 1.2.2 – 1.2.4, there is a vast body of existing, relevant research concerning authority structures and their dynamics. However, due primarily to the challenges of applying experimental or field research to study this phenomenon, the single case study concerning a narrow set of research questions over a limited timeframe remains the prevalent approach. One example of the effect of these challenges is the relatively limited comparative urban political research (Denters & Mossberger, 2006; Moncada, 2013; Pierre, 2005; Ward, 2010). As outlined in Pierre (2005), an emphasis on rich descriptive

analysis of individual cities, the narrow emphasis on western, or U.S. cases, or an aversion to reductionist explanations in the field may all contribute to this.

The use of computational methods such as social simulations offers the opportunity to develop theory by unifying this vast body of research and testing its viability through social simulations (Axtell, 2000; Cioffi-Revilla, 2014; Epstein, J. M. & R. Axtell, 1996). However, the collection of ABM's that address related phenomena either do not address authority structures as the dependent variable, fail to address the relationship between authorities and society, or do not address urban community dynamics. RebeLand is an example of an implementation of the polity model, but it does not address the formation and disintegration of authority-resident relations directly. The Qawm ABM investigates how particular authority structures emerge, but does not address their resilience directly, nor does the population play a significant role (Geller & Moss, 2008). Models of urban phenomena such as slum formation (Patel et al., 2012), unrest (Pint, 2014), and gang membership (Pint et al., 2010) include authority-resident interactions, but do not investigate authority structures directly.

In summary, the concept of a community authority structure as a target of analysis is under-researched. There is no existing theory explaining the resilience and adaptive behavior of these structures. Finally, viable methods for developing an appropriate theory, such as social simulation, have not been applied directly to this phenomenon.

1.3. Research Questions

This dissertation investigates three research questions (RQ's). These questions are designed to test a preliminary theory of community authority structure dynamics and form the basis for future research and model refinement. They focus on the core social dynamics that can help explain resilience and adaptation of these structures.

- RQ1: Is social exchange theory a viable framework for modeling authority and resident decision-making with respect to partner selection in small communities?
- RQ2: Is an authority structure a network phenomenon or an aggregation of independent exchange relationships between two actors?
- RQ3: Why and how do particular conditions such as corruption, actor resources, persistent in-group bias, event frequency, and issue/stress patterns affect the resilience of authority structures?

1.3.1. Research Question 1

Is SET a viable framework for modeling authority and resident decision-making with respect to partner selection in small communities?

This question pursues two goals. First, it tests the argument that SET can help explain the formation of relationships between authorities and constituents. Second, it tests the SET hypothesis in a systems or behavioral setting. This approach acknowledges the analytic value of the CAS framework with its emphasis on actor adaptation.

Some form of value exchange is argued to be the basis of authority (Eisenstadt & Roniger, 1980; Ferguson & Mansbach, 1996; Gluck, 1975; Waldman, 1972). This basic relationship is illustrated in Figure 1. An authority executes programs that provide resources and services to members of a society. These members, groups and individuals,

participate in institutions and provide resources to the authority. The resilience of this relationship at the system level is based on value exchanged between individual actors in the past. Value is a primary consideration when an actor evaluates the resources to invest in continued participation. Relationship value to authorities and constituents alike varies (Ferguson & Mansbach, 1996; Keehn, 1974; Migdal, 1988). Many conditions can influence value including the introduction of new actors into the system, changes in issues or social stress, or changing resources available to authorities, among others (i.e. Migdal 1977; Keehn 1974).

Social exchange theory is a collection of related research programs that attempt to explain the dynamics of social relationship formation (Cropanzano and Mitchell 2005). While it is potentially relevant in any situation where actors establish social relationships, SET is most commonly used to study small group dynamics, primarily in organizational research (Cropanzano & Mitchell, 2005). Perceived organizational support (POS) and leader-member exchange (LMX) are two research programs that are broadly relevant to political authority dynamics. Both POS and LMX attribute variations in employee support for leaders or their organizations to the support for their needs that they attribute to these actors (Eisenberger, Huntington, Hutchison, & Sowa, 1986; Masterson, Lewis, Goldman, & Taylor, 2000; Settoon, Bennett, & Liden, 1996)

The various SET perspectives share a common goal of explaining how social structures emerge from the exchange of material and non-material resources between social actors, individuals or organizations (Blau, 1964; Cropanzano & Mitchell, 2005; Emerson, 1976; Homans, 1958; Molm, 1997). The decision to engage with a particular

partner is based on information from previous interactions (Molm, 1997). Consistently positive, or strong, relationships 'lock-in' over time due to their value and reliability. Strong relationships also offer the opportunity for actors to influence one another's behavior (Blau, 1964; Molm, 1994, 1997). The degree of influence is partly dependent on the availability of suitable, alternative exchange partners.

However, there are two concerns with applying SET to studying authority structures in large groups. First, is the question of whether instrumental exchange is the relevant dynamic at work in authority relationships. Conflict and coercion, family and traditional ties, patronage networks and other social structures all have influence over the decision to engage with a particular authority. However, though these structures influence partner selection, they are argued to be contributing factors in the more fundamental pursuit of value. This model focuses exclusively on instrumental value exchanges, and leaves open the potential of the model to expand to include these additional features.

The second concern is the ability of SET to scale up to describe social structures in relatively large populations. Blau (1977), one of the pioneers in SET research, expresses this concern in his efforts to describe the emergence of macro social structure. The issue is that as populations get larger, institutions form to regulate social activity that are not clearly emergent from micro social structures created through social exchange. The effects of these institutions on partner decisions must be taken into account. This is particularly valid in this analysis. However, it is argued that at the level of an urban community, the basic interactions between individual residents and authorities remain the relevant relationships, not those that form macro-structures such as institutions.

Finally, one notable effort by Waldman (1972) attempted to link SET explicitly to various political phenomena including authority legitimacy. A critique by Easton (1974) argues that Waldman attributed too much explanatory power to SET. However, Easton (1974) did acknowledge that SET is most applicable, if at all, in situations where there are clear patterns of value exchange that define loyalty between groups, individuals, and institutions. Easton (1974) argued that SET could be relevant as a way to translate variation in system inputs into adaptation, but within the context of a systems model of political behavior. This critique was based on the behavioral, systems perspective and as such was not considering authority in terms of the polity approach taken here. The difference is that in the polity approach, the emphasis is on the structure of relationships between various social actors. This increases the relevance of SET as it directly addresses the dynamics of these relationships, rather than the policy decisions that come out of the political system, the focus of the systems perspective.

1.3.2. Research Question 2

Is an authority structure a network phenomenon or an aggregation of independent exchange relationships between two actors?

The basis for this question lies in the CAS perspective adopted for this analysis. Complex systems consist of interdependent actors (Miller & Page, 2007; Page, 2001; Schelling, 1978). Interdependence is the condition where actor decisions and actions influence the behavior of other actors. The result is emergent behavior or patterns at various levels of hierarchy. These patterns may form identifiable social constructs such as

institutions or informal groups with relatively dense ties (Cioffi-Revilla, 2005; Gilbert & Troitzsch, 2005; Simon, 1996).

In this analysis, authority patterns are the emergent structure of interest. However, it is an open question if the CAS framework is actually applicable. Whether the system is complex or not, structure emerges primarily from individual relationship choices over time. As Keehn (1974, p. 337) notes, "authority is a dynamic rather than a static concept, a continuous rather than a dichotomous variable." The relationships that form to resolve immediate needs are the basis for recognizable institutions, behavioral norms, and social classes that develop over longer timeframes (Cioffi-Revilla, 2005). However, it is not clear that interdependence between these actors plays any role in the patterns that emerge.

The implications of this question are significant for understanding authority dynamics and related phenomena. If interdependence does not play a role, then one can understand authority structures as a linear phenomenon that requires no further understanding of the influence of other actors on exchange partner selection decisions. However, there is significant evidence that this is not the case. Studies of street gangs show that residents of a community will protect gang members from arrest due to their recruitment from the community (Browning et al., 2004; Samara, 2011; Venkatesh, 1997). Informal authority networks in communities are sustained through social connections as much as direct resident-authority interactions (Barnes, 1986; Singerman, 1995; Uehara, 1990). Examples of community mobilization and outreach to various organizations to change their relationship with other actors clearly indicates a level of interdependence between actors (Arias, 2006; K. Williams, 1995).

There are also implications for designing models of community authority dynamics. If interdependence matters, then the theoretical model must integrate some mechanism for the collection and integration of information external to an individual actor's experiences. Computationally, this makes a model more complex. Actors must have some rudimentary social network with spatial, temporal, or other boundaries. The timing of these social interactions will have an effect on emergent relationship patterns. When actors acquire information will also influence the decisions they make.

1.3.3. Research Question 3

Why and how do particular conditions such as corruption, actor resources, persistent in-group bias, event frequency, and issue/stress patterns affect the resilience of authority structures?

The first two research questions establish the validity of designing a model of community authority structures based on SET within a CAS framework. The third research question tests whether the model can produce adaptive behavior that is consistent with several conditions associated with authority structures. This is an important goal because it helps explain the effects of a range of conditions on authority structure dynamics using the same CAS/SET framework.

This effort is consistent with the goal of unification of several strains of research on community authority dynamics. Conditions such as corruption, social stress, under-resourced authorities and institutions, organizational and individual group preferences and bias are often studied separately. However, in the context of authority structures, they all serve as barriers or filters on exchange partner selection. Each of these conditions

drives system adaptation away from the expected, balanced authority structure that would otherwise represent a 'practical equilibrium' state.

Bias and preferences are found in numerous studies of contested communities. This is found most often in descriptions of authorities. Often non-state actors are explicitly biased towards one group. This is common in communities where there is a high level of inter-communal conflict or tension (Anderson, 2002; De Smedt, 2009), or when the government expresses hostility towards a particular social group (Abdulazeez, 2013; Guichaoua, 2009). Bias may be expressed only during certain times, most often during elections when favors are bestowed on constituents, or withheld from opposition supporters (Arias, 2010; Branch, 2011; Klopp, 2001). These biases heavily influence how authority structures change during periods of stress, ineffective service delivery, or conflict. Residents quickly identify whom they can go to for assistance based on the response of these groups to requests.

The cost of accessing authorities is also featured in analyses of contested communities. Corruption is particularly noteworthy. Corruption undermines the legitimacy of institutions by imposing costs that are perceived as illegitimate. It is also a burden on residents with limited incomes, a common feature of contested communities (Alemika & Chukwuma, 2005; Leggett, 2004a; Marx et al., 2013). When costs matter to residents when resolving issues, then corruption costs may have effects on authority structures outside of perceptions of fairness and justice.

Finally, system stress brought on by insufficient authority capacity to meet demand influences the development of authority structures and can drive large-scale

societal adaptation (Cioffi-Revilla, 2008). This condition is often associated with loss of government legitimacy (Eckstein, 1973; Ferguson & Mansbach, 1996; Keehn, 1974; Migdal, 1977). Institutional ineffectiveness during acute periods of stress such as natural and man-made disasters are one example of conditions that can undermine legitimacy (Jha, Miner, & Stanton-Geddes, 2013; Tanner, Mitchell, Polack, & Guenther, 2009). Stress can also emerge from crime waves or conflicts where the government fails to provide effective security (Ebohon & Ifeadi, 2012; Fourchard, 2008; Leggett, 2004b; Skaperdas, 2001). Economic stress also creates a demand for employment and increases the attractiveness of the illicit economy. This increases the likelihood of residents becoming more closely involved with non-state actors. It also raises the profile of these groups and increases their value (Samara, 2011; Venkatesh, 2008).

1.4. Summary of Methods and Contributions

This dissertation develops an original theoretical model of community authority structure resilience. This model is developed within a CAS framework. It is derived from existing polity models describing the basic interactions between multiple authorities, society, and environmental conditions (Cioffi-Revilla, 2008, 2011). It extends these theoretical models by focusing on the individual relationships that develop between residents and authorities as they assist or fail to assist each other in achieving goals. It pursues in greater depth the essential decision-making processes through which authority

structures form through the application of SET. These structures are the basis for the higher level relationships found in the existing polity models.

This theoretical model is implemented in an ABM that is used to answer the research questions. This computational approach to studying complex adaptive systems is found throughout the research on conflict, international relations, and many other socio-political phenomena (Axelrod, 1995; Bhavnani, Miodownik, & Nart, 2008; Carley et al., 2006; Cederman, 1997, 2001; Cioffi-Revilla & Rouleau, 2010; Louie & Carley, 2007).

One critical difference between this ABM and existing, related computational models is in its emphasis on understanding structural resilience. This is in contrast to actor-centered models where the emphasis is on explaining why and how particular actors gain and lose power, or on their survival. In this analysis the structure of relationships between system actors rather than the actors themselves is the dependent variable.

The focus on structure rather than actors does not exclude actor decision-making. The decisions that these actors make with respect to partner selection are central to understanding an authority structure. Another original aspect of this model is the application of SET as the decision-making framework through which actors select relationship partners. This is particularly appropriate given the focus of SET on structure rather than actors (Cook & Whitmeyer, 1992).

This research also extends SET into areas that the experimental research program has not fully investigated. Community authority structures involve a mixture of exchange structures, large populations, and extended timeframes. The analysis of these structures requires the aggregation of individual interactions and organizational actors to assess

group-authority relationships. Applying SET principals to this phenomenon extends the relevance of this perspective on the formation of social structures. The use of computational methods in this model demonstrates how the SET research program might benefit from these methods to overcome challenges with traditional experimental methods.

The use of an ABM here is also consistent with recent efforts to increase the body of comparative political analysis in urban studies (Pierre, 2005). Computational methods allow the theoretical model to be applied to multiple scenarios to test its validity and improve public policy analysis. This helps to overcoming many of the challenges associated with field research including funding, time, and security. Finally, it suggests relevant feedback pathways linking urban community-level authority dynamics and larger scale urban social, economic, and political patterns. This is accomplished by developing a framework for research into how multiple authority structures in various locations interact in time and space (Cioffi-Revilla, 2011; Ferguson & Mansbach, 1996; Rosenau, 1992; White, 2008).

1.5. Summary

This chapter introduces the concept of community authority structures and their public policy relevance in section 1.1. Section 1.2 summarizes research and theory that is relevant to understanding the adaptation of community authority structures. It concludes by identifying gaps in theories that explain the dynamics of community authority

structures and methods that are appropriate to studying these dynamics. The motivation for each of the three research questions is detailed in section 1.3. The chapter concludes in section 1.4 by summarizing the methods used to investigate the research questions and the original contributions to CSS, CAS, SET, political science, and public policy of this research.

The remainder of the dissertation is presented in four chapters. Chapter 2 outlines the methods used to answer the research questions. It outlines the community adaptation model, a theoretical framework for analyzing the resilience properties of an authority structure. It describes an agent-based model that implements this theoretical framework and the methods for analyzing the model's output. It then describes the methods used to answer each of the research questions. Chapter 3 describes the results of each of the experiments for each research question. Chapter 4 discusses the results of each of the experiments and the contributions of the key findings to theory and public policy. The chapter concludes with a description of future research directions. Chapter 5 provides a summary of this research and its contributions.

CHAPTER TWO
METHODS

This chapter outlines the methods used to answer the three research questions. It describes the community adaptation model (CAM). The CAM is a theoretical model for analyzing the resilience of community authority structures. Sections 2.1 and 2.2 describe the design and implementation of an ABM based on the CAM. Verification and validation procedures are described in sections 2.3 and 2.4. The theoretical framework for analyzing authority structure resilience and the methods used to analyze ABM output is found in section 2.5. The chapter concludes with a description of the experimental methods used for each research question in section 2.6. This includes a detailed outline of each of the community case studies.

2.1. Community Adaptation Model Design

An ABM is used to answer the research questions. An ABM is a category of social simulations that illustrate how interactions among social actors and with their environment give rise to observed social structures and group behaviors (Cioffi-Revilla, 2014; Epstein, J. M. & R. Axtell, 1996). An ABM is particularly useful when the target phenomenon is the result of complex, multi-scale dynamics (see Cioffi-Revilla 2014; Crooks, Castle, and Batty 2008). ABMs are also an effective research method in

situations where ethical, financial, or logistical challenges limit experimentation or field research. Their use in studying the behavior of urban systems is also increasing (Batty, 2008; Bettencourt, 2013a, 2013b; Bretagnolle, Daude, & Pumain, 2003). This is due primarily to the ability to investigate the relationship between social phenomena and spatial features of urban areas over time (Bell & Irwin, 2002; Patel et al., 2012).

For this dissertation, there are three primary advantages to using an ABM as opposed to other methods. An ABM can be used to perform comparative analysis of multiple scenarios, a requirement for theory development. This feature is also valuable for public policy analysis supporting scenarios outside of those addressed in this research. The model can perform experiments involving hundreds or thousands of agents that are logistically infeasible with human subjects. Finally, the model is easily extended to include additional features or integrated with other ABM's. These advantages make the ABM developed for this dissertation of interest to researchers investigating urban community dynamics, social exchange relationships, or other social phenomena where authority structures are a component of a related research problem.

The CAM extends the conceptual framework of the contentious polity model, shown in an adapted form in Figure 7. The CAM describes a community level polity embedded in an urban socio-political system. It illustrates how the society-authority relationships described in the polity model emerge at the local level (Cioffi-Revilla, 2008, 2011).

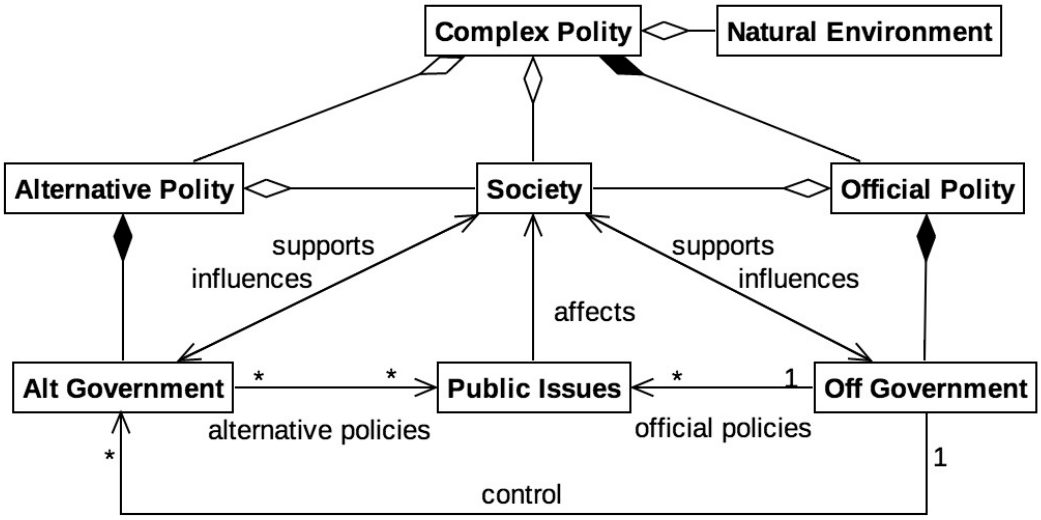

Figure 7. Adapted version of the contentious polity model (adapted from Cioffi-Revilla, 2011, p. 9)

In the CAM, an authority structure consists of a physical space, a timeframe, a single issue, and a set of actors. In the real world, actors are embedded in multiple overlapping social structures that have varying degrees of influence over their decisions (Ferguson & Mansbach, 1996; Rosenau, 1992; White, 2008). A complete understanding of a community requires defining how these structures influence one another. However, the goal of this dissertation is to describe the dynamic properties of a single structure that can be used as a building block for more complex community structures.

The structure and dynamics of the CAM are illustrated in Figure 8. Socio-natural issues, or social stress, affect community residents and authorities. Residents petition government and non-state actors (authorities) for assistance in resolving these issues. These authority actors secure the support of constituencies composed of sub-sets of community residents by resolving issues and satisfying social needs through institutions

and policies (Ferguson & Mansbach, 1996; Keehn, 1974; Lund, 2006; Migdal, 1988). This interdependence is the basis for understanding how authorities and residents influence one another to meet their goals, or political behavior (Blau, 1964; Molm, 1994, 1997).

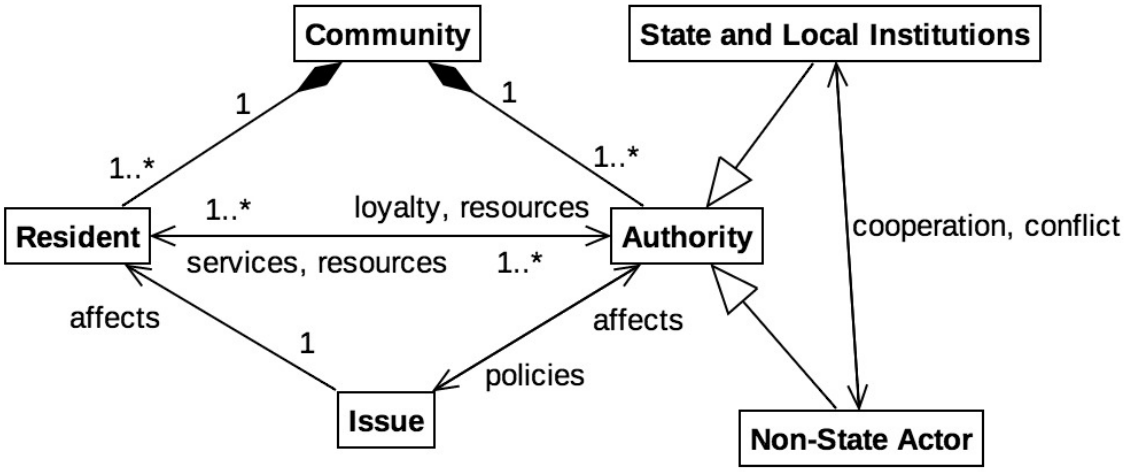

Figure 8. Community adaptation model class diagram.

The exchange relationship between authorities and residents conforms to the basic assumptions of SET (see Molm, 1997). Residents and authorities seek relationships that provide items of value and avoid those that do not. The strength of the relationship is a function of the frequency of positive, reinforcing items of value from a partner. The strongest relationships tend to 'lock-in' over time to the exclusion of other partner options. Mature, positive relationships are far more resilient to change than new, untested relationships.

The exchange process as implemented in the CAM is illustrated in Figure 9. A resident identifies an issue or need that requires an authority to resolve. It then selects an authority. The resident sends a request for assistance to the partner, thereby providing value through participation in its institutions (Eckstein, 1973; Ferguson & Mansbach, 1996; Keehn, 1974; Migdal, 1988). Next, the authority determines if it will assist the resident. If this decision is positive, then it resolves the issue. As depicted at the bottom of Figure 9, conditions and preferences influence both resident and authority exchange decisions. The decision to provide value is based on the willingness, opportunity, and capacity to interact with a specific partner.

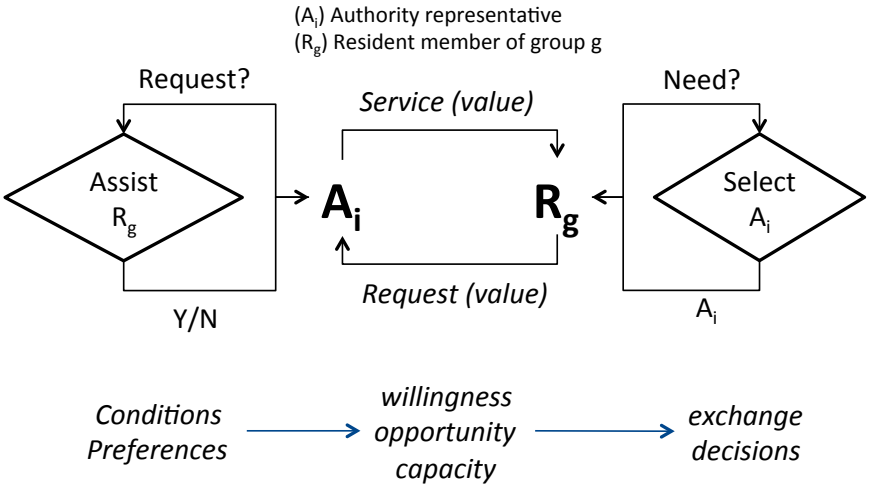

Figure 9. CAM actor exchange model.

2.1.1. Model Environment

The ABM consists of resident and authority actors. Actor attributes determine how individuals interpret community conditions and select partners. The goal of an authority is to maintain the loyalty of a constituency by allocating resources to resolve the issues of constituency members. The same set of attributes defines state and non-state actors. Authorities enter and leave the simulation according to a preset schedule. Residents try to resolve issues by engaging an authority. Residents select authorities based on resources, past experiences, and information from other residents. They are heterogeneous in selected parameter values as described in this section.

Residents live in a community. This community is defined by its physical boundaries, the timeframe of interest, the net population flow rate, and the group segregation rate. These factors determine who residents will communicate with when they seek advice for resolving an issue, as described later in this section.

Communities have a physical boundary. Most communities comprise several city blocks. There are notable cases of contested authority at larger (district) and smaller (block) scales (Assefa, 1990; Bollens, 2013; Gazdar & Mallah, 2013). However, these extremes are not the focus of this analysis. The ABM consists of a 10 x 10 space grid representing an urban area approximately 500 meters square. This area can have widely varying populations. In the communities studied in this analysis, this area corresponds to populations ranging from a few hundred to tens of thousands of residents. As there is no infrastructure, physical terrain, or other physical features represented in the ABM, all

spaces are available for residents to live in. These features are associated with the ability of non-state actors to embed in communities (Jacobs, 1961; Venkatesh, 2008). However, they are omitted to simplify the model's behavior and to better focus on the effects of other conditions on structure resilience.

A simulation takes place over a specified number of days, usually totaling more than several years. An authority structure can be defined at any point in that simulation time period. Variations in structure are identified by comparing ABM data from different timeframes. However, some social issues may arise relatively infrequently. Thus, the number of daily exchanges between agents may be very low and insufficient to reveal how the system is adapting. For this reason, the number of simulated days that define a single timeframe for purposes of defining a structure can vary as appropriate to the scenario goals. Timeframes of 30-days are used for all experiments conducted for this research. Though scenarios vary, 30-days will record the interactions of 33% to 100% of the resident agents, an amount sufficient for analysis. One simulated day represents one day in the real world.

Community segregation reflects the overall level of inter-group social interactions. Segregation drives two related community features. First, it is the probability that an agent will settle in the vicinity of other members of its own social group. Second, it is the probability that an agent will form a social relationship with another agent from its same social group.

The population increases or decreases according to the needs of the scenario. New residents are assigned to a community location based on the segregation level. Group

territory is an ABM parameter consisting of community spaces assigned to each group. If U [0,1] is less than the community segregation value, then the resident is assigned to a random patch in its group territory. Otherwise the resident is assigned to any random patch. When new agents are added, randomly selected existing agents are removed. This ensures the net flow rate is maintained. This simulates the turnover of residents that all communities experience. From a computational perspective, this feature prevents the community from artificially locking-in on a particular structure simply due to the longevity of the agents in the simulation. The rates of resident entry and departure are set based on available statistical sources when available. This process is explained in detail in Appendix 2.

Resident agents maintain a social network. A resident queries members of this network for experiences with authorities. The size of the resident's network is drawn from an approximately scale-free distribution with a mean of 6, a minimum of 5, and a maximum of 9. Each member of the network is selected as follows. If U[0, 1] is less than the segregation value, then the resident selects any resident from the community from the same social group. Otherwise, the resident selects any community agent. The effect of this approach is that group spatial segregation is directly related to the level of spatial homophily in the resident agent networks (Blau, 1977; Kossinets, 2009; McPherson et al., 2001). To ensure the replacement of agents that leave the community and to simulate the natural changes in an individual's social contacts, there is a 5% probability that an active resident will replace a member of its network.

Social issues drive actor decision-making and adaptation. The model addresses the dynamics of a single-issue structure. This simplifies the ABM by reducing the number of parameters and the overall complexity of agent decision-making and interactions. This makes verification and validation more straightforward and focuses the analysis on the research questions posed. Examples of social issues include security (Arias, 2006; LeBas, 2013), dispute settlement (Barnes, 1986; Singerman, 1995), and basic needs (Bennet, 2012; Lambrechts, 2012).

The ABM can represent spatial, and group/random issues. Spatial issues affect a certain percentage of randomly selected agents at a pre-set number of randomly selected locations. Criminal activity and disasters are two examples of spatial issues. Group issues affect residents of different social groups at different rates. Crime may affect members of different identity groups or social classes differently (Meagher, 2006; Skaperdas, 2001). When the group rates are equal, then the issue is considered random.

Issue rates are set according to research goals and available information from statistical or secondary sources. The rates may vary during the simulation. Issue rates reflect what residents experience after the implementation of any public policy or community interventions. Institutional processes, decision-making, and policy implementation are not part of the model, though this is possible to include in future versions as was done in the RebeLand ABM (Cioffi-Revilla, 2008; Cioffi-Revilla & Rouleau, 2010). Every simulated day, a share of the resident population is selected to experience an issue based on the issue type. Active residents attempt to resolve their issue through the exchange process.

2.1.2. The Resident-Authority Exchange Process

Exchange interactions between residents and representatives of authorities are the core model process. These interactions comprise the ABM's main simulation loop and are illustrated in Figure 10. An interaction begins with a resident agent addressing an issue. Next, the model transitions between resident and authority actions until one of the agents refuses to continue the interaction. The resident registers the value exchange only if the resident accepts the authority costs. The actor decision-making process is based on Figure 9 in section 2.1.1 and described in greater detail in this section.

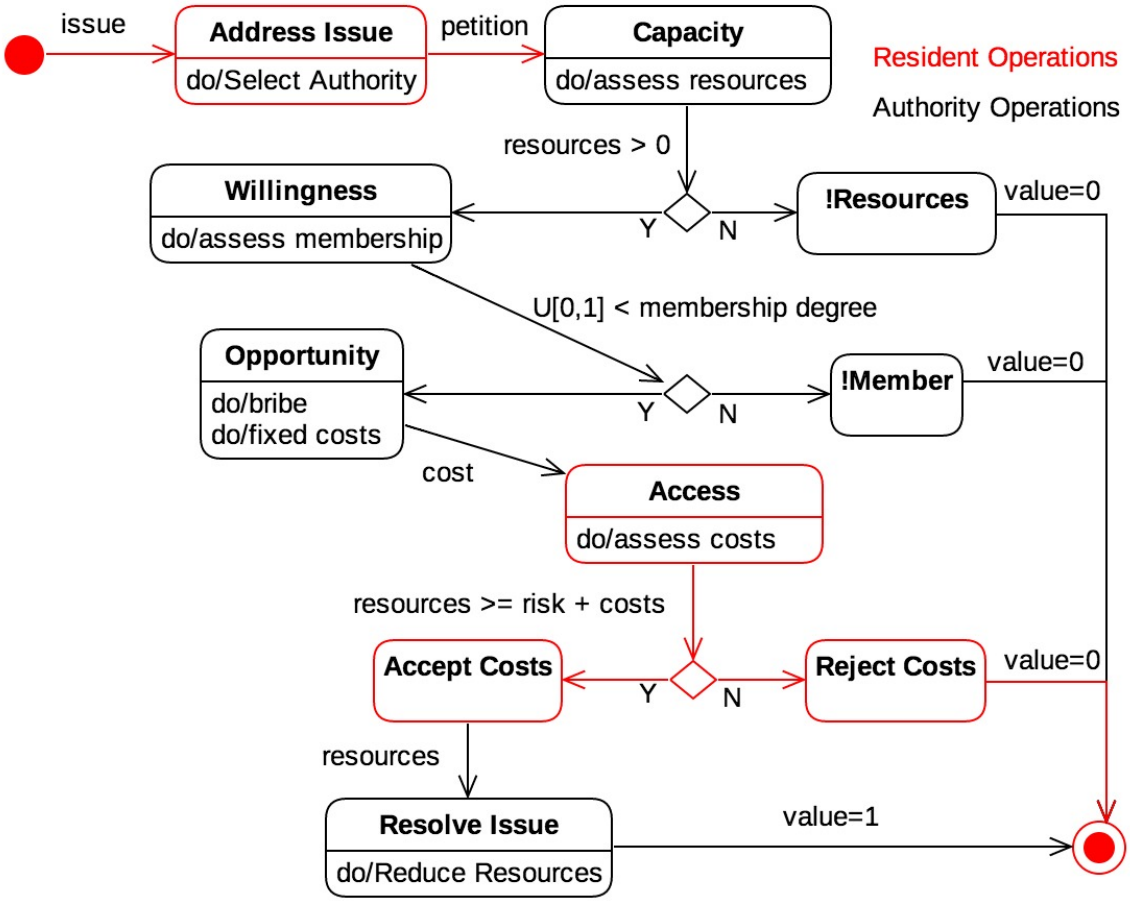

Figure 10. ABM main simulation loop. Resident operations are in red font. Authority operations are in black font.

A resident begins the exchange process when it experiences an issue. First, it adjusts its satisfaction score. Satisfaction measures a resident's overall success in resolving issues based on past exchange decisions. The resident does not attribute satisfaction to a particular partner. Satisfaction scores range from 0 to 10. Satisfaction decreases by 1 when the resident experiences an issue and increases by 2 if an issue is resolved.

Next, the resident selects an authority as an exchange partner. The choice is a random selection of an authority from an experience set equal to $\{A_i + E_n + E_d\}$ where:

- E_n is each experience from the social network included three times.
- A_i is each authority operating at the agent's location included once.
- E_d consists of the agent's last 20 direct experiences.

To collect the set of network experiences (E_n), the agent polls members of its network. This approach is similar to that used by Pujol et al. (2005) in their ABM implementation of a social exchange network based on SET. The number of members that each resident polls remains constant throughout the simulation, but varies throughout the population in a roughly Poisson distribution. The resident randomly selects a positive experience from each partner's recent exchange history.

This design has three important effects. First, the communication of network experiences replicates the effect of resident social interactions. Second, as in the real world, there remains a non-zero chance of selecting any available agent (see Molm 1997). Third, as an agent's relationship with a preferred authority matures, the effect of network communication declines (Pujol et al., 2005). See Appendix 2 for a comparison of the effect of varying the number of authorities and the degree of network support for an authority on the probability of selecting a particular authority.

After a resident selects an authority, it petitions it for services or resources. This is reciprocal, rather than negotiated exchange. The resident provides loyalty/legitimacy value to the authority without knowing if this will elicit resources (Molm, 1997).

The authority response to a resident is based on the willingness, opportunity, and capacity of the authority to act on behalf of a resident (see Cioffi-Revilla & Starr, 1995).

Willingness to act reflects an authority's determination that a resident is a *member* of its constituency. Opportunity to act is based on the resident's acceptance of any costs associated with *accessing* authority resources. Finally, an authority has the capacity to act if it has sufficient *resources*.

As shown in Figure 10, the authority first determines if it has remaining resources, or capacity to act. An authority has resources that can be applied each day to resolve resident issues. Authority resource levels reflect community investment levels. An authority's daily resource level is set based on two questions: Are the authority's resources sufficient to meet demand? Are an authority's resources greater or less than other authorities?' In the ABM, resource levels are expressed as the percentage of the population that it can assist each day. Issue rates are also expressed in terms of a percent of the population to assist in comparing capacity to demand.

If the authority has the capacity to assist it then evaluates its willingness to do so. Authorities set conditions for membership in a constituency. This determines who is eligible to receive resources. In practice, the boundary between members and non-members may not be clear. Due to variations in individual preferences, biases, and other conditions, individual authority representatives may exclude a member or include a non-member.

Constituency membership is implemented as fuzzy set composed of all residents (Cioffi-Revilla, 1981; Epstein, Mohring, & Troitzsch, 2003; Hassan, Salgado, & Pavon, 2011; Izquierdo, Olaru, Izquierdo, Purchase, & Soutar, 2015; Zadeh, 1969). Authorities assess constituency in four areas: community (C), identity (I), event (E), and territory (T).

A resident's overall constituency membership degree is the intersection (multiplicative) of its weighted membership degree in each of the four areas. The membership degree (D) can accommodate weighted values of C, I, E, and T. The weights, α, β, γ, and σ, allow for a wide range of authority models as appropriate for the scenario.

$$D = \alpha T * \beta I * \gamma C * \sigma E; D\ [0, 1]$$

The constituent membership function (M) relates the membership degree (D) to the probability that an authority will assess a resident as a constituent. The basic model takes the form:

$$M = \mathrm{D} * \mathrm{K}$$

The value of K is an exponential function with shape parameters κ, θ, and μ.

$$\mathrm{K} = \left(\frac{1}{(1 + e^{-\kappa * (\theta - \mu)})}\right); K\ [0, 1]$$

The function K allows M to take on a wide range of forms including further lowering low M-values and raising high values. This use of an exponential weighting in a membership function is used in the friendship model described in Hassan, Salgado, and Pavon (2011). When implemented in the ABM, if U [0, 1] is less than M, then the authority considers the resident a constituent for that interaction.

For the experiments conducted in this analysis, K and the weights for D are set to 1.0. This leaves M equal to C * I * E * T. The decision to reduce the membership function to a linear product of the raw values was for two reasons. First, there is no indication of the actual weighted preferences of the authority agents in the scenarios. Second, there is sufficient variation in the actual parameter values for C, I, and E between authorities that the further differentiation produced by the exponential function, K, would not substantively alter the overall outcome of the scenario. However, the effect of varying the membership function on structure resilience is a worthwhile area for further research.

A description of each of the four constituency variables, C, I, E, and T follows. More detailed background on how each variable contributes to authority dynamics is found in section 1.2.3. *Community* membership expresses an authority's relationship with the entire community. It expresses the willingness of an authority to engage a resident based on the community it is a member of. Police willingness to enter a community is an example of community membership. The community membership variable ranges from 0.0 to 1.0. This is applied to all residents independent of other characteristics they may have.

Authorities may express varying degrees of membership based on group *identity*. Residents are assigned a single social identity as appropriate to the scenario. This may be ethnicity, class, nationality, or any other relevant factor. Authorities may adjust their willingness to engage a resident based on their identity. The identity membership variable ranges from 0.0 to 1.0.

Certain *events* can alter membership degree when they are imminent. Authority agents decide whether to apply an event-based adjustment to their membership assessment of residents. In the model, there is an inverse, non-linear, exponential relationship between event proximity and selection of an event-based strategy. This function and its derivation are found in Appendix 2. This approach is loosely based on the shifting focus model of psychological responses to approaching deadlines (Lehman, Hahn, Raman, & Alge, 2011). As deadlines approach, attention shifts to ensuring survival or meeting the most critical requirements to continue operations.

The event proximity function produces a probability of selecting an event strategy. It is a sigmoid function where the probability of selecting an event strategy is inversely related to the number of days until the event. This is described in Appendix 2. If U[0, 1] is less than this probability, then the event membership factor is applied to the overall membership function. The event membership factor can range from 0.0 to 2.0. Values greater than 1.0 increase the overall membership assessment. The event proximity assessment is performed every 30 simulated days and is valid for every interaction during that timeframe.

Finally, authorities claim *territory* that may include all or part of the community and may overlap with other authorities. Exclusive territory within a community boundary is common where street gangs are present (Lambrechts, 2012; Radil, Flint, & Tita, 2010; Smith & Bertozzi, 2012; Venkatesh, 2008). In other cases, boundaries may overlap as when vigilantes operate based on who hires them (Enechojo, 2013; LeBas, 2013). If a

resident's location falls within an authority's territory it's membership degree is 1, otherwise it is 0.

The next phase of authority decision making concerns *opportunity*, defined here as access considerations. If the resident is a constituent, then the authority provides an access cost to the resident. Fixed costs are always present. An authority's fixed costs are determined relative to the mean resident resources in the community and relative to one another. These determinations are based on a review of the relevant literature for a particular case. It is rare that actual values are available, so the following guide questions are used: Do residents consider access to authority-A less expensive than access to authority-B? Do few or most residents find authority-X affordable?

Corruption introduces variable costs into the scenario. Corruption in the CAM is modeled as the probability that a government official will demand a bribe during an interaction. Of note, in the RebeLand ABM (Cioffi-Revilla & Rouleau, 2010) corruption is a barrier to the effectiveness of policy implementation at the institutional level. Both perspectives are relevant to understanding government-society relations and the CAM takes both into account. The authority resource parameter reflects degradation in effectiveness due to corruption and other institutional inefficiencies. The authority corruption parameter influences the outcome of individual interactions.

Narrative accounts qualitatively describe perceptions of local corruption, but it is difficult to translate these into model parameters. Thus, an alternative method is applied here. The corruption probability is calculated using the Transparency International corruption rating (TI) for the relevant simulation year (Transparency International, 2015).

This converts the TI rating to a scale ranging from 0.0 to 0.99. This method is detailed in Appendix 2. Bribe costs are set so that total costs satisfy existing descriptions in secondary sources of the relative cost of various authorities.

Residents assess the actual costs demanded by the authority with respect to their own resources and risk tolerance. Poverty and contested authority are correlated in many case studies (Arias, 2010; Gazdar & Mallah, 2013; Morris, 1999; Neuwirth, 2006; Venkatesh, 1997). Resources are often required to access authorities. In poor communities, this presents a significant barrier to access.

Each resident agent is assigned resources drawn from a Poisson distribution with a mean that reflects any differences between social groups. Residents also have a risk factor that establishes the resource to cost ratio they will accept. The same distribution is used in all scenarios. This choice is based on the difficulty in comparing the effect on access of different income levels across cases, even in the same city. Instead, the resource level is fixed and authority access costs are varied appropriately. These resources are applied to access costs. Access costs are acceptable to a resident if its resources are greater than the total costs plus a resource risk acceptability factor.

If the resident accepts the costs, then the authority resolves the issue. This is the only condition where the resident receives value from the authority. If the exchange process fails at any point, the resident gets no feedback. This reflects the basic premise of reciprocal exchange. Actors provide value without any guarantee of reciprocation by the partner (Molm, 1994).

2.2. Implementation in Code

2.2.1. Hardware and Software Selection

The final version of the ABM was written in Netlogo version 5.3.1 (Wilensky, 1999). Both Netlogo and Python were considered and a Python version was developed. Netlogo was ultimately selected because it is a widely accepted platform for agent-based model development; it provides a user-friendly development environment; it is easy to present live simulations; and a single model file is compatible with multiple operating systems. All development and simulations were performed on a MacBook Pro (13") running OSX 10.10.4. The processor was a 2.7 GHz Intel Core i5 with 8GB 1867 MHz DDR3 RAM.

The computational demands of the model were restricted based on analysis goals, hardware and software limitations. A run-time limit of 5 minutes for a 20-year simulation was established. To meet this restriction, simulations were capped at 5,000 agents. Computational efficiency was considered in all design and coding decisions. These restrictions require simple spatial and social dynamics. However, this level of abstraction is sufficient for theory building and optimal for conducting multiple experiments that compare ABM behavior across a range of parameter settings. This was the goal of this research.

2.2.2. Model Parameters

The ABM design accounts for the scarcity of desired statistical data by defining parameters so that qualitative, narrative data can be used (see Yang and Gilbert 2008). Community social structures change over years, even decades. Daily events involving individual residents drive these changes. When available, population, economic, political, and issue related data typically exists for limited time frames. This data is collected with widely varying methodologies, and may come from politically motivated sources such as governments. In contrast, existing case studies often cover the entire timeframe of interest. They also provide insights into the perceptions, preferences, and decisions of residents and authorities in contested communities that are useful in determining simulation parameters. Consequently, parameters are set based on relative and comparative rather than actual values. This approach is also consistent with the emphasis on relative rather than actual value in SET. A detailed description of the methods behind each ABM parameter is found in Appendix 2. The parameter settings for the community cases are found in Appendix 3. The parameter settings for each of the experiments are found in Appendix 4.

2.2.3 Model Execution

A single simulation run consists of two phases. First, the scenario is setup (*setup* button in the Netlogo graphical user interface (GUI)). At the beginning of the simulation,

there are no existing exchange relationships in place. Agents have no interaction history or memory of experiences. Resident social networks are in place. Second, the main simulation is run (*go* button in the Netlogo GUI) for the desired duration. This phase produces data for analysis. System and agent parameters vary according to the simulation scenario. An initial period of 3-5 years without any parameter changes allows the initial system state to stabilize. This initial period is necessary to establish the exchange histories for the agents. These histories determine how agents will respond to subsequent changes in conditions. Without the stabilization period, agents would simply react as if they had never lived in the community. Note that all parameters are set within the relevant procedures in the model code, not through the GUI. This is due to the need to specify trends that change over time for many parameters and the difficulty in using the Netlogo GUI for this purpose.

An overview of the ABM execution during a simulation run is shown in Figure 11. The simulation runs for the desired number of years. At a pre-set interval agent and environmental parameters update. Every simulated day, the main simulation loop executes as described in section 2.1.2. Each day, the model collects data on all variables. This is output to a .csv file for analysis at the end of the run.

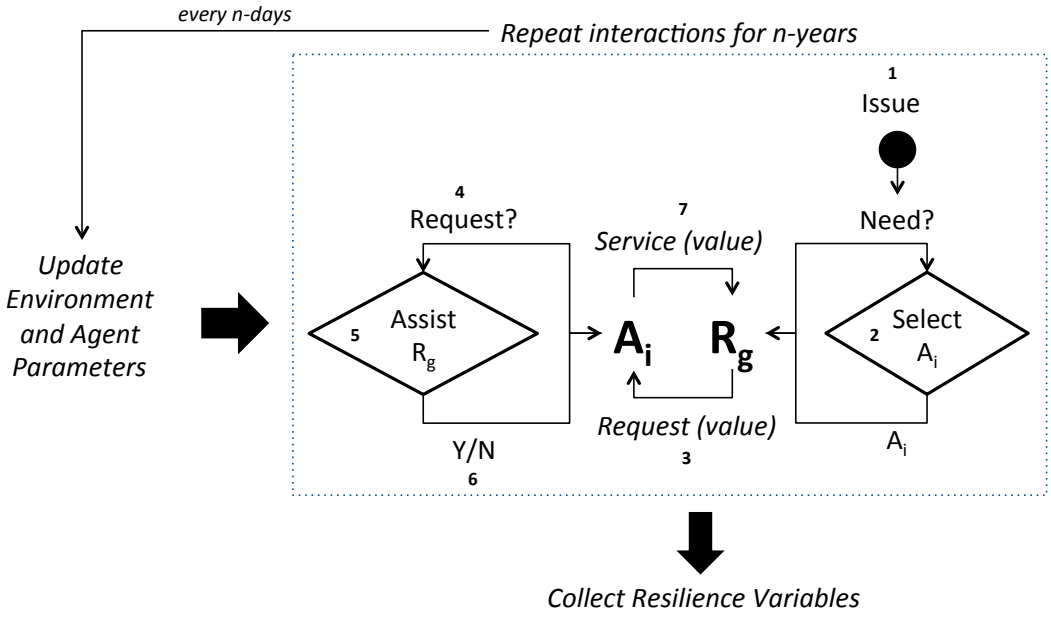

Figure 11. Overview of ABM simulation run.

Figure 12 is a screenshot of the Netlogo GUI during a representative model run. The top left of Figure 12 shows the distribution of patches colored by the preferred authority in each. The top center plots show the adaptation of the system and the target relationship, The stability and satisfaction plots for each social group are shown below the adaptation plot. These output plots are described in detail in section 2.5.

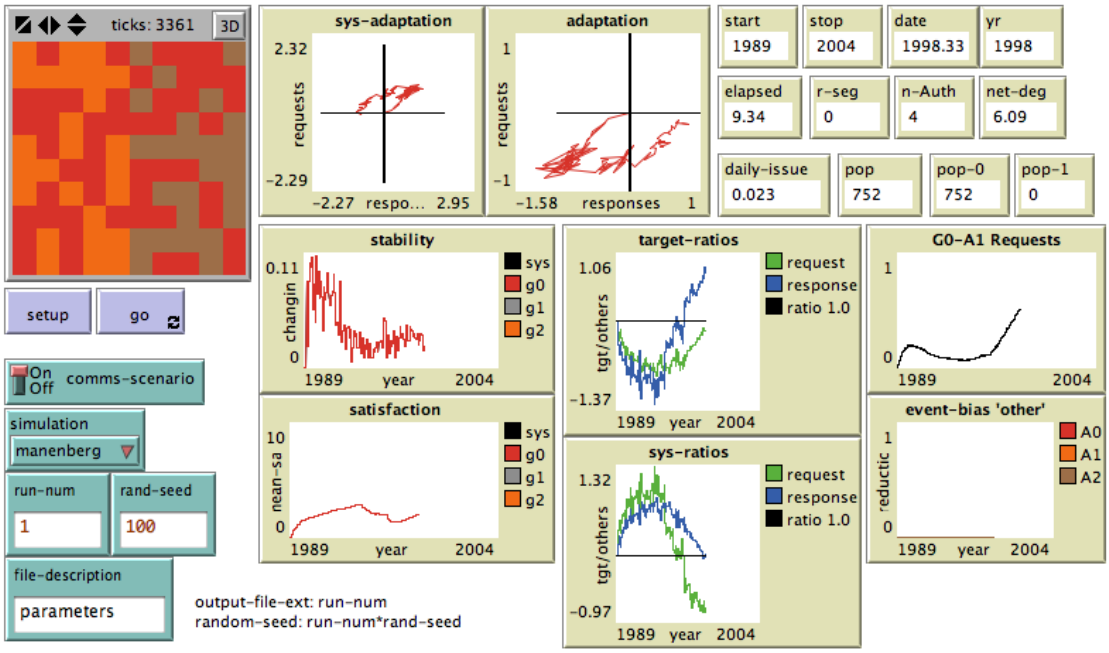

Figure 12. Screenshot of agent-based model graphical user interface during simulation run.

2.3. Verification

The model was verified using code walkthroughs, selected parameter sweeps, and verification code, including agent tracking code (Cioffi-Revilla, 2014). During the portion of the ABM development that was done in Python, agent tracking code was inserted into selected procedures to output the decisions of single agents throughout a simulation run. If a specific agent was active, relevant conditions and decisions were output to a file for evaluation following a run. This was particularly useful for determining if agents were reacting to conditions and making decisions as expected. When the final version of the ABM was re-written in Netlogo, agent tracking code was

simplified to do spot checks of particular procedures, then removed. Output of this code was sent directly to the observer pane in the GUI for review. In addition, simulations were run multiple times to assess the variation in emergent behavior produced by the model.

2.4. Validation

Structural validation concerns two central elements of SET. First, agents should attempt to participate in relationships that provide value and avoid those relationships that do not. Second, exchange relationships should develop in response to repeated rather than single interactions and experiences. The agent tracking code used in the verification process confirmed these basic agent behaviors for individual agents. The results of the experiments conducted for research question 1, as described in section 2.6.1 indicate that changes in authority preferences by residents take place over repeated interactions. This is indicated by the gradual changes in structure over years rather than days.

Behavioral validation evaluates ABM performance in terms of its ability to replicate observations of authority structure resilience for each of the three community scenarios described in section 2.6.1. The ABM demonstrates level 1 performance as defined by Axtell and Epstein (1994). The ABM, "...is in qualitative agreement with empirical macrostructures as established by plotting...the distributional properties of the agent population (Axtell & Epstein, 1994, p. 28)."

The ABM performance is evaluated using four resilience variables: structure, adaptation, stability, and satisfaction. These variables are described in sections 2.5.1 - 2.5.4. All four resilience variables are calculated with respect to a specific target relationship consisting of a social group and authority. The process of behavioral validation also satisfies the data collection requirements for research question 1 as described later in section 2.6.1. All expected values are derived from a review of the existing secondary sources for each community as described in section 2.6.1. This data is qualitative and in narrative format. Despite this it is suitable for the level 1 performance standard of the ABM.

For validation purposes, each community scenario is run 10 times. Based on the limited variation among the results of 10 model runs for each of four resilience variables, the decision was made that further runs were not required to establish the range of responses for the ABM. A scenario is satisfactory if 70% of the runs are satisfactory in all four variables. This metric is arbitrary and intended primarily as a guide for stimulating discussion of areas where ABM performance is consistently not as expected. Given the qualitative nature of the phenomenon and the real world data available to assess ABM performance, descriptive analyses are more useful than a quantitative metric in assessing performance. The ABM is considered satisfactory if two of three scenarios are satisfactory.

The results for structure are satisfactory if the expected change in structure takes place. The edge weights for the target relationship at the beginning and end of the data collection phase must qualitatively match the expected values. The model's performance

is satisfactory with respect to adaptation if two conditions are met: (1) the state transition for the target relationship occurs; (2) the request and response ratios are greater than 0.0 within 1 year of the expected transition period. These ratios are described in section 2.5.1. The model's performance is satisfactory with respect to satisfaction if mean satisfaction value for the target social group at the end of the simulation is as expected. The model's performance is satisfactory if stability decreases over the appropriate transition period. The transition period includes the timeframes where the request and response ratios transition.

2.5. Data Collection and Analysis

The primary purpose of the CAM is to explain the resilience of authority structures. Resilience is the ability of a system to maintain its identity, or state, under changing conditions (Folke, 2006; Gunderson & Holling, 2001). Four resilience variables are selected for this analysis: authority structure, adaptation, stability, and satisfaction (see Bennett, Cumming, and Peterson, G.D. 2005).

Exchange data is accumulated over 30 simulated days for all combinations of group-authority and authority-group pairs. This interval allows for a sufficient number of authority-resident interactions to take place to establish general behavioral trends. An exchange is recorded when a resident or authority passes value to another agent. This data is used to calculate the authority structure and adaptation variables described in sections 2.5.1 and 2.5.2, respectively.

2.5.1. Structure

The primary system identity, or state, is the authority structure. An authority structure is a directed graph describing the community authority exchange network over a particular timeframe as defined in section 2.1.1. The nodes are authorities and residents aggregated at the group level. Exchange resources flow over network edges (Wasserman & Faust, 1994). Edge weights are the share of value going from one node to another. Higher edge weights indicate stronger exchange relationships (Cook & Whitmeyer, 1992; Molm, 1997). Edge weights from groups to authorities are the share of value from the target group to the target authority divided by total value from the target group to all other authorities. Edge weights from authorities to groups are the share of value from the target authority to the target group divided by total value from all other authorities to the target group. This network is represented as a bar chart of edge weights v. edges. This format enables a straightforward comparison between ABM and expected values during analysis.

2.5.2. Adaptation

Two variables, the request and response ratios, describe the system state at a given point in time. This is an adaptation of the operant matching law from behavioral psychology. According to McDowell (2013, p. 1000), “the matching law is a mathematical statement about adaptive behavior in environments that continuously afford

opportunities for choice." Operant matching research has had a significant influence on SET, specifically in explaining the reinforcement of dyadic relationships (see Sunahara and Pierce 1982). The power function version of the operant matching law is:

$$\frac{b_0}{b_1} = \kappa \left(\frac{r_0}{r_1}\right)^p$$

In this equation, b is the ratio of behavior of a subject toward choices 0 and 1; r is the response ratio of the two choices; and k and p characterize the bias and non-linearity of the relationship, respectively (see Baum 1974).

The ratios used in the CAM refer to the interactions between the authority choices and a group of residents, not individual actors. The ratios are calculated using the sum of interactions over the specified timeframe. The numerator and denominator may refer to any combination of authorities relevant to the research question (McDowell, 2013). These ratios are set as an ABM parameter.

With two state variables, there are four possible system states. State transitions or phase boundaries lie at ratio values of 1.0 or 0.0 for log-log plots (see Sole, 2011). The plot of the request v. response ratio for each 30-day timeframe illustrates the system's adaptation path. Clusters of points indicate temporary periods of system stability, or 'practical equilibrium' (see Homans 1958).

Assessment of the adaptation path is performed using the estimated dates when the request and response ratios transitioned, as appropriate. For qualitative data, the adaptation path between these points is estimated using available information. For

simulated data, the transition point is where there are no further future values above or below the transition threshold, as appropriate to for adaptation direction for 1 year. Generally, the scenarios are setup so the system is expected to move from the lower left to the upper right quadrants.

2.5.3. Satisfaction

Mean actor satisfaction indicates how well the authority structure meets community needs. It is also a measure of the potential for change in the existing authority structure. Mean resident satisfaction is calculated every 30 days for the system and each social group.

2.5.4. Stability

Stability is an indicator of how the system adapts to conditions. State changes accompany significant decreases in stability and indicate insufficient resilience (Gunderson & Holling, 2001; Scheffer et al., 2012). Stability is measured as the number of actors changing their top exchange partner. Stability is calculated for each group every 30-days.

2.6. Research Questions Experimental Design

2.6.1. Research Question 1

Research question 1 tests the hypothesis that SET provides a viable basis for modeling the decision-making behavior of residents and authorities. It also serves as behavioral validation for the ABM. Authority structures change under a wide range of conditions in cities across the world. An individual level decision-making model based on SET is argued to provide the strongest explanation for these transitions. The conditions found in these communities such as poverty or high issue rates are important contributing factors, but have secondary explanatory power. The case study offers evidence in support of this hypothesis.

The ABM is used in a comparative case study of three sub-Saharan African communities: Mushin in Lagos, Nigeria; Kibera in Nairobi, Kenya; and Manenberg in Cape Town, South Africa. The locations of these communities is identified in Figure 13. The case study follows a most different systems research design (MDS) (see Meckstroth, 1975; Przeworski & Teune, 1970). This is a research method originally designed for comparative political analysis. The goal is to identify sub-system factors that explain similar phenomena found in dissimilar system level settings (Meckstroth, 1975). In this case, the relevant sub-system factor is the SET decision-making model not a collection of variables. As Hoffman and Riley (2002, 314) argue, "in a dynamic, disequilibrium world processes are more central than attributes or variables for understanding outcomes."

Figure 13. Location of communities in sub-Saharan Africa for case study.

Each case highlights a particular combination of CAM variables. This ensures sufficient cross-case variation in key parameters to effectively validate the ABM and test the SET hypothesis. The three communities also share several conditions over the target timeframe. They are located in large cities in sub-Saharan Africa. They have a well-defined physical boundary. There is more than one authority actor providing a specific resource or service to the community, and the community authority structure changes states. A summary of community characteristics is shown in Table 1.

Table 1. Comparison of selected community parameters

Variable	Mushin '89-'04	Manenberg '89-'04	Kibera '86-'00
City [1] -neighborhood pop. (millions)	11.1 / 1.32 [2] (2005)	3.7 / 0.061 [4] (2011)	3.3 / 0.172 [3] (2009)
GDP (per capita 2009-2013) [5]	1555	7352	943
Political [6,7] Competitiveness	gradual liberalization	liberalization	factional, coercive
Dominant Non-state Actor	vigilantes, ethnic-based political movement	vigilantes, criminal gangs	ethnic militias
Non-state actor-Govt. relationship	conflict and cooperation	conflict, corrupt cooperation	conflict
Dominant Public Issue	criminals, ethnic gangs	criminal gangs	basic needs, crime
Infant Mortality/1000	(Lagos) 45 [8]	19 [9]	(Slums) 91 [10]
Country Corruption (TI) [11]	1.56	4.78	2.1
Ethnic/National Group Diversity	moderate	low	high

[1] World Bank (2014), [2] Lagos Government (2005), [3] KNBS (2010), [4] Government of South Africa(2012), [5] World Bank (2014), [6] Polity IV (2012), [7] Descriptions from Polity IV POLCOMP concept variable (Marshall, Gurr, & Jaggers, 2010), [8] UNICEF (2013), [9]City of Cape Town (2002) , [10] APHRC (2002), [11]Transparency International (2015).

An ABM scenario is created for each case. Each scenario is tested according to the behavioral validation procedures described in section 2.4. Appendix 3 provides the simulation parameter settings for each community.

2.6.1.1 Kibera

This scenario is based on the authority dynamics relevant to landlord-tenant dispute resolution in Gatwekera village, Kibera, Nairobi between 1991 and 2001. Over this timeframe, the relationship between the Luo residents and the Kamkunji militia strengthened while the relationship with government chiefs weakened. The Kibera case highlights the effects on authority structures of variations in identity membership degree

and access costs between authorities. Notable community characteristics include high population density, high in/out-flows of residents, high group segregation, and a single non-state actor.

Kibera is a large Nairobi slum with a population ranging between 175-500 thousand (Desgroppes & Taupin, 2011; KNBS, 2010; Mutisya & Yarime, 2011). In 2009, the population density of Gatwekera village was estimated at 73-94k residents per square km (Desgroppes & Taupin, 2011). The village is described as primarily Luo, segregated by ethnicity, but with representation from most major ethnic groups. According to one survey in 2009, 72-83% of households in Gatwekera village live on earnings below the poverty level (Desgroppes & Taupin, 2011). The reluctance of the government to sanction the provision of basic services forces residents to resolve most needs in informal markets.

The government officially owns all land in Kibera, but informally permits selected individuals to build structures for rental purposes (Amis, 1984; Dafe, 2009). This creates an uncertain situation where there is no formal mechanism for landlord-tenant dispute resolution (Joireman & Vanderpoel, 2010; Marx et al., 2013; Mutisya & Yarime, 2011). Landlords and tenants petition authorities that they feel will look after their needs, often pitting them against each other. Throughout the 1990's, government appointed Chiefs and ethnic gangs were the two dominant actors involved in these disputes.

These household level disputes and the authority structures that have emerged from them are tied directly to Kenya's national social-political conflict dynamics. Throughout the 1980's, a combination of sinking coffee prices, high population growth

rates, political violence, and land conflicts resulted in increased rural to urban migration and the growth of Nairobi's slums (Joireman & Vanderpoel, 2010; Kahl, 2006). The mass migration of Luo and other groups substantially changed the ethnic composition of Kibera. Primarily Nubian and Kikuyu structure owners decided to rent to newcomers and move to more affluent areas of Nairobi (Amis, 1984; De Smedt, 2009; Joireman & Vanderpoel, 2010).

At the end of the Cold War President Moi faced increasing pressure from the U.S., the U.K. and other donors unhappy with his authoritarian policies to open Kenya's political system to multi-party competition (Branch, 2011). Moi ultimately agreed to this transition. However, he also adopted a political strategy that marginalized potential challengers and suppressed opposition voters (Branch, 2011).

Violent voter suppression and mobilization of ethnic voting blocks characterized multi-party elections from 1992 to 2007 (Branch, 2011; Branch & Cheeseman, 2008; Diepeveen, 2010; Klopp, 2001). Some politicians enlisted the support of ethnic gangs with a presence in key communities to influence resident behavior (Anderson, 2002; International Crisis Group, 2008; LeBas, 2013). In Kibera violent riots directed against Kikuyu and Nubian structure owners and led by Luo gangs in 1991, 1995, 1997, and 2001 drove out potential Kikuyu voters and reinforced Luo residents' support for favored politicians (De Smedt, 2009).

The simulated community represents a random 500m square section of Gatwekera village. There are two social groups: Luo and other. Luo tenants comprise a third of the population (Desgroppes & Taupin, 2011; Marras, 2009). Segregation between the two

groups is high. The density of residents is very high compared to Mushin and Manenberg. The population growth rate and resident turnover is higher than the other two communities.

There are two authorities in the simulation: the government appointed Chiefs and the Kamkunji Luo militia (Joireman & Vanderpoel, 2010; Marx et al., 2013). Chiefs are the lowest level of the Kenyan governance structure. They have a degree of informal authority to manage community conflicts, and enforce their decisions using security forces (Joireman & Vanderpoel, 2010).

Non-state actors such as the Kamkunji resolve disputes as a way to maintain influence in the community and reduce government presence. The Kamkunji formed in 1992 as an outgrowth of existing Luo political organizations as a way to help meet the needs in the Luo community. Throughout the mid to late 1990's the militia solidified its power through a mixture of violence, criminal activity, and resolution of community issues (Anderson, 2002; Joireman & Vanderpoel, 2010; LeBas, 2013). Violent Kamkunji tactics on behalf of the Luo effectively ended rent collection in several areas of Kibera by 2002 (Anderson, 2002; De Smedt, 2009; Joireman & Vanderpoel, 2010).

The Kamkunji agent's identity membership degree for Luo residents is significantly higher than for non-Luo residents (Anderson, 2002; LeBas, 2013). Event membership degree is relevant approximately one year from the event. This reflects the increased in-group bias exhibited around elections (De Smedt, 2009). Events representing elections occur in 1992, 1997, and 2002. The Chief agent's identity membership degree

for Luo residents is slightly lower than for non-Luo residents (Joireman & Vanderpoel, 2010; Marx et al., 2013).

Both Chiefs and Kamkunji demand payment for services. Chiefs very often demand bribes from the parties and payment is anecdotally related to outcomes (Dafe, 2009). The Kamkunji claim to offer free services to constituents, but there are reports of taxes, and other demands for fees by members (Joireman & Vanderpoel, 2010). These demands appear to occur within the scope of broader relationship between the gang and residents rather than as a pre-requisite to take a particular case.

Tenants experience rent dispute resolution issues approximately every 3-4 months. Authority resources do not play a significant role in dispute resolution. The Kamkunji and Chiefs have the capacity to address any disputes that come to them provided they agree to do so.

The following is a description of how the Kibera system adapted between 1990 and 2000 used for model validation. The entry of the Kamkunji militia in 1990-1991 immediately began a transition in support by the Luo community away from the Chiefs. By 2000, this transition had taken place. This resulted in high instability in the Luo-Kamkunji relationship during this period. Overall satisfaction within the Luo community was relatively high on the issue of rent disputes. This was due to the aggressive tactics used by the militia against structure owners and the Chiefs. Members of other ethnic groups could not rely on Kamkunji support and were left to either indirectly benefit from the effects of their actions, or continue to patronize government institutions.

2.6.1.2. Manenberg

This scenario is based on the authority dynamics relevant to crime in Manenberg, Cape Town between 1994 and 2004. Over this timeframe, the relationship between the residents and street gangs strengthened at the expense of the relationship with the security services. The Manenberg case highlights the effects on authority structures of variations in community and spatial membership degree between authorities. Notable community characteristics include low group segregation and multiple non-state actors with exclusive territory.

The Group Areas acts of the 1950's moved the non-white population of Cape Town out of the city center and into ethnically homogenous communities in Cape Flats. These areas remain physically isolated from the urban core, its services, employment and social opportunities (Bennett et al., 2005; Robins, 2002; Samara, 2011). The absence of effective governance in Cape Flats offered an opportunity for street gangs to develop the informal economy that dominates these communities (Samara, 2011). Until 1994, the focus of the security services was on counter-insurgency not crime. This enabled gangs to develop extensive community ties. Cooperative, corrupt relationships between the police and gangs further isolated these communities.

As in many communities with street gangs, there is a persistent, contradictory tension between gangs, residents, and the police (Arias, 2004; Venkatesh, 2008). Over decades of local recruitment, street gangs became part of the social structure of Manenberg (Samara, 2011).The gangs provide employment and social status for under-

educated, under-employed young men. The resources earned through illicit activities make their way back into the community primarily through assistance to from gang members to relatives. The community often protects gang members from police. However, polling also reveals that residents prefer an end to gang activities, and a more visible, professional, effective police presence (Leggett, 2004a).

Despite a long history of gang activity, the conflict between the police, gangs and vigilante groups in Manenberg from 1994 to 1998 effectively ended the state's presence in the community. The opening of the South African economy in 1993 expanded the opportunities for gangs in the international narcotics trade (Leggett, 2004b). Manenberg gangs began a violent process of competition for territory. The security services responded with aggressive operations across Cape Flats. This campaign was intended to remove the gangs and provide the security required to implement community re-development plans. However, these operations often led to the arrest and death of innocent residents, and had little success limiting gang influence.

In 1996, the Muslim vigilante group People Against Gangsterism and Drugs (PAGAD) began operations in Manenberg. PAGAD assassinated several high-profile gang members at their houses and attacked the police as well (Lambrechts, 2012). However, by 1998, the security services had managed to end PAGAD's operational capacity in Manenberg.

The community response to the police and PAGAD was mixed. Initially, residents supported an end to gang activities. However, violent tactics and impacts to the informal

economy eventually led to a drop in community support. Ultimately, there was sufficient support for gang members due to their social and economic ties to the community.

During the late 1990's and early 2000's, as gangs replaced dead and arrested leaders and further consolidated territory, another round of inter-gang violence broke out (Samara, 2011). One significant impact was that gangs took over or reduced the operations of government institutions in Manenberg. The police had little influence over these conflicts due to very low community trust, limited resources, and high levels of corruption (Bennet, 2012).

The simulated Manenberg community represents a random 500m square section of Manenberg. There is one social group, 'colored', using the government classification system. In fact, the population distribution in 1996 was 91% colored, 9% other groups (City of Cape Town, 1996). However, for the purposes of this analysis, ethnicity does not play a significant role in the authority dynamics investigated. The density of residents, population growth rate, and turnover rate are relatively low compared to Mushin and Kibera. See Appendix 3 for details concerning social parameter settings.

The Manenberg simulation focuses on the development of the relationship between the community and two notional street gangs. The street gangs each own half the neighborhood territory with no overlap. As is often the case, gang territories only overlap until conflict resolves the boundary (Lambrechts, 2012; Venkatesh, 2008).There are also two additional authority agents representing the security services and PAGAD. These agents operate throughout Manenberg.

The key factor in community adaptation in Manenberg is differences in the community membership degree between the various authorities. In practice, this is a measure of responsiveness to needs, or willingness to engage the community. Class and ethnic identity are minor factors as the community is relatively homogeneous. Political events are also not a factor in authority strategies.

The street gangs' community membership degree for residents changes from low to high in the late 1990's due to the need for community support. The security services' community membership degree for residents drops from high to low in the late 1990's. This reflects the poor responsiveness to resident requests for assistance (Bennet, 2012; Leggett, 2004a).

Street gang and PAGAD access barriers are very low. In fact, PAGAD generally preferred to selected targets without input from the community and based on its own strategic goals. Individual members of street gangs may demand money from residents for services or resources. Residents identify police as corrupt, thus adding costs to community-police interactions (Leggett, 2004b; O'Regan & Pikoli, 2014). Finally, no single authority has sufficient capacity to resolve all resident security needs. All authority resources combined are insufficient to resolve resident security needs.

The following is a description of how the Manenberg system adapted from 1993 to 2002 for validation purposes. In 1993, there is a relatively strong relationship between the community and the government with respect to the gangs. By 1998, the community-government relationship is very low and the community-gang relationship is dominant. The gang response ratio first favors residents between 1998 and 2000. The community

request ratio transitions to favor the gangs between 1999 to 2001. The peak in structure instability occurs between 1996 and 2000 beginning with PAGAD's operations followed by the gangs asserting control. Community level satisfaction remains low following the decline in government presence. The gangs became dominant, but their inability to prevent crime leaves residents only moderately satisfied (Leggett, 2004a, 2004b).

2.6.1.3. Mushin

The Mushin scenario is based on the authority dynamics relevant to security issues including street crime and ethnic conflict between 1993 and 2003. Over this timeframe, the relationship between the Yoruba residents and the OPC militia strengthened while the relationship with the police and other vigilante groups weakened. The Mushin case highlights the effects on authority structures of variations in community and identity membership degree, access costs, and resources between authorities. Other notable community characteristics include high population density, high group segregation, rising issue rates, and multiple non-state actors with overlapping territory.

Mushin is a large district in Lagos, Nigeria with a population around 500,000 (National Population Commission of Nigeria, 2006). The district is mixed ethnicity, but the Yoruba are estimated to comprise around 70% of the population, based on their city wide distribution (Ayodele & Aderinto, 2014; Oduwaye, 2008).

Mushin began as a suburb of Lagos city. Over decades of growth it became integrated into Lagos' core. It is often described as a slum due to its poor services, low

income residents, substandard housing, and levels of crime (Alemika & Chukwuma, 2005). As with many slums, Mushin is often the first stop for migrants from other areas of Nigeria.

The combination of street crime and ethnic violence is the social issue considered in this analysis. The crime rate throughout Mushin is high. However, during the late 1990's it escalated for a combination of reasons including declining police resources, ethnic violence, political opposition clashes with the police, and the rising population (Alemika & Chukwuma, 2005; Enechojo, 2013; Ikelegbe, 2005; Salaam, 2011). The police were unable to meet community needs and had even sanctioned some degree of cooperation with neighborhood watch and other vigilante groups.

An older analysis of Mushin by Barnes (1986) presents a detailed picture of the relationship between individual residents and government authorities. The analysis covers the period until 1980. During this period, residents accessed services and resources through local patrons, usually landlords. These patrons interacted with the government, other patrons, and non-state actors on residents' behalf. This basic structure still exists, but more recent analyses indicate that individual residents or small groups are the focal point for local action on security needs (Alemika & Chukwuma, 2005; Enechojo, 2013).

The annulment of the first open elections in 1993 by the military led to a angry reaction by Yoruba political activists. The OPC established itself as the self-proclaimed defender of Yoruba interests in 1994 (Abdulazeez, 2013; Ikelegbe, 2005). Throughout the mid-1990's the group became the dominant Yoruba opposition movement in Nigeria. Its headquarters is in Mushin. From the late 1990's, as Presidential elections approached, the

OPC became increasingly violent. This prompted the government to outlaw membership and legalize the killing of OPC members on site (Ikelegbe, 2005). During this period, the OPC focused as much on defending Yoruba residents as policing crime within the Yoruba community (Ikelegbe, 2005).

Mushin residents have multiple options for meeting security needs. However, none of these options is able to reduce crime to acceptable levels. Businesses are attributed with starting the 'area boys' phenomenon of vigilante protection (Alemika & Chukwuma, 2005; LeBas, 2013). Residents often hire individuals or local youths to protect houses at night at a nominal cost. These efforts are seen as more effective than nothing, but generally inadequate (Enechojo, 2013). Finally, the police are viewed as corrupt, unhelpful, and unwilling to assist by large percentages of Mushin residents (Alemika & Chukwuma, 2005; Ayodele & Aderinto, 2014). Even the OPC has its detractors. One survey indicated that the violence and street justice that the OPC is known for is not fully accepted by many residents (Alemika & Chukwuma, 2005).

Based on the available information, the simulation describes a system composed of three authorities representing the police, vigilantes, and the OPC. The key differences between them are resources and membership degree. The police attribute low community membership degree to residents of all ethnicities. They have a high level of corruption. The OPC only deals with Yoruba residents. The OPC also has the highest resources. Vigilantes have the lowest resources, but they will help anyone that can afford their low costs.

The simulated community represents a random 500m square section of Mushin. There are two social groups: Yoruba and other. The Yoruba are 70% of the population. The community is moderately segregated, reflecting the level of inter-ethnic conflict during the late 1990's. However, the prevalence of Yoruba residents makes segregation less meaningful. The density of residents is also high compared to Manenberg, but lower than Kibera. The population growth rate is moderately high as is the turnover rate, though both are lower than Kibera.

The following describes how the simulated system adapts between 1993 and 2001 for validation purposes. The authority structure transitions slowly over this period. By 1999, the OPC is the dominant authority. However, system instability remains relatively high throughout. This is due to the underperformance of all authorities and the absence of a definitive 'lock-in' of support for the OPC to the exclusion of vigilantes or the police. Satisfaction is moderate due to the total resources flowing into the community and higher than it was prior to the entry of the OPC.

2.6.2 Research Question 2

Research question 2 provides evidence that authority structure resilience is, in part, a function of resident interactions, not simply individual experiences. This interdependence is an essential characteristic of complex social systems (Page, 2001; Scheffer et al., 2012; Schelling, 1978). There are two experiments. The parameter settings for both experiments are found in Appendix 2.

The first experiment compares the three case study scenarios with and without agent communication. The adaptation and stability variables are compared qualitatively to assess any differences. The adaptive behavior in each case should be different or communication is not an essential design feature of the ABM. The effect of resident interdependence should produce non-linear adaptation patterns in the scenarios with communication (Scheffer et al., 2012). These patterns should be weaker or non-existent when there is no communication.

The second experiment investigates the relationship between authority identity membership degree, group segregation, and structure resilience. It tests community adaptation at a range of segregation values. In each scenario, there are two social groups and two authorities. Each authority favors a different social group as indicated by the identity membership parameter values. Both authorities have sufficient resources to resolve all issues. Group territory is split evenly. Both authorities claim the entire area. In each scenario the relationship between the authority and the favored group will emerge. The question is how fast and how complete is the transition? How resilient is the system under varying segregation levels? System adaptation is measured using the 1-year moving average of the request ratio and stability variable for the relationship between an authority and its favored group.

There are two hypotheses. First, there is an inverse relationship between the segregation level and the time it takes a group to change its support to a more valuable alternative authority. This is measured as the time that it takes system instability to go below 0.01. There is no significance to this threshold. In general, it takes several years for

any scenario to go below this level. Thus, it is a good baseline for comparison of mature systems. This hypothesis is based on the idea that more homogeneous systems in terms of the actors will transition more rapidly than heterogeneous systems (Scheffer et al., 2012). Second, there is a direct relationship between the segregation level and the request ratio between the target social group and the authority that favors it. This is based on the idea of homophily in social networks (Kossinets, 2009; McPherson et al., 2001). The greater the reinforcement of shared identity, the stronger the relationship between the authority and members of the favored group. Spatial proximity and segregation increases the interactions between similar agents (Schaefer, 2012).

2.6.3. Research question 3

A series of three experiments illustrates how variations in membership, access, and capacity between authorities affect authority structure resilience. It tests the general hypothesis that barriers to exchange are inversely related to relative support. The resident request ratio is used to compare simulation runs. The request ratio provides the essential information concerning how residents adapt to authority behavior. The specific parameters used in each experiment are found in Appendix 4.

Experiment 1 illustrates the long-term value of temporary increases in membership degree for certain constituents even in situations when overall authority performance is poor.

In this experiment, two authorities implement an event-based membership strategy. Each authority supports a different group. The combined resources of the two authorities are insufficient to resolve all community issues. As an event nears, the event membership degree of the out-group is reduced. This increases the probability that resources are available for members of the favored group. The time between events varies from 1 to 7 years.

The hypothesis is that there is a direct relationship between event frequency and the level of long-term support from the favored group. The basis for this hypothesis is found in the wide-spread strategies employed by authorities prior to political contests such as elections (Arias, 2010; Branch, 2011; Klopp, 2001). These strategies are designed to mobilize supporters and suppress opposition participation. In this case, the mobilization strategy is tested. Support is measured as the average of the last five years of the simulation request ratio.

Experiment 2 illustrates the effect of corruption on public support for authorities such as the police. There are two authorities and a single social group. Authority 0 has higher fixed costs. However, the addition of a bribe increases the Authority 1's total costs above Authority 0's. The total resources of all authorities are insufficient to meet resident needs. The simulation is run for a range of corruption levels.

The hypothesis is that if corruption is high enough, support will shift to the authority with the higher fixed costs and away from the corrupt authority. This hypothesis is supported by the research on corruption and its negative effects on support for government institutions. Opinion polls of residents in contested communities in

Manenberg, Kibera, and Mushin, for example, indicate decreased support for the police as a result of the costs of paying bribes (Alemika & Chukwuma, 2005; Leggett, 2004a; Marx et al., 2013). Support is measured as the average of request ratio for the last five years of the simulation.

Experiment 3 illustrates the relationship between issue related social stress, low authority capacity, and community adaptation. It demonstrates how repeated periods of social stress can reinforce community support for more effective authorities. Episodic spikes in issues represent events such as elections, natural and man-made disasters, or periods of social unrest.

The hypothesis is that support for the authority with the greatest resources is directly related to system stress. This hypothesis is one of the bases for understanding authority as an exchange of value over time between authorities and constituents (Ferguson & Mansbach, 1996; Migdal, 1988). The opportunity that social stress provides for well-resourced and effective authorities is significant. However, it can also reveal deficiencies in service delivery and capacity that encourage relationships with non-state actors and informal institutions (Bennet, 2012; Cioffi-Revilla & Rouleau, 2010; Sobel & Leeson, 2006). Stress is measured as the length of the stress period divided by the length of the steady state period in days. Support is measured as the average of the request ratio for the last two years of the simulation.

There are three scenarios. The scenarios investigate system response when the steady state issue rate is: greater than the total resources of A0 and A1; equal to A0 resources; and equal to A1 resources. For each scenario, A0 resources are 2.0 and 1.5

times A1's resources. In all scenarios, the issue rate alternates between peak and steady state values. The peak period is 30 days, and the issue rate is four times A0 resources. The steady state period is 1, 2, 4, 8, and 12 times the peak period. This illustrates how the relative resources of competing authorities affect adaptation under the three different stress patterns.

2.7. Summary

This chapter outlines the methods used to answer the three research questions. It describes the theoretical community adaptation model and its implementation in an ABM in sections 2.1-2.4. Next, the methods used to analyze the data produced by the ABM are described in section 2.5. This consists of comparing ABM results to expected results using four resilience variables: structure, adaptation, satisfaction, and stability. Section 2.6.1. summarizes the conditions found in each of the three community cases. This is followed by a description of the experiments for research questions 2 and 3 in sections 2.6.2 and 2.6.3 respectively. The methods used to set parameters for all experiments are found in Appendix 2. The case study parameters are found in Appendix 3. The parameters for the remaining experiments are found in Appendix 4.

CHAPTER THREE
RESULTS

This chapter presents the results of all experiments using the verified ABM described in the previous chapter. The results of research question 1 validate the ABM. The results of all experiments indicate that: (1) SET is a viable option for modeling individual authority-resident interactions with respect to needs satisfaction; (2) Communication between residents contributes to resilience of community authority structures; (3) the ABM is able adequately account for the effects of conditions such as group bias, corruption, and variable social stress patterns on structure resilience and adaptation.

This chapter is organized in three sections, each corresponding to a research question (RQ). To review:

- RQ1: Is SET a viable framework for modeling authority and resident decision-making with respect to partner selection in small communities? This question consists of the three community case study scenarios. It also serves as the behavioral validation of the ABM.

- RQ2: Is an authority structure a network phenomenon or an aggregation of independent exchange relationships between two actors? This question focuses on the contribution of agent communication to system adaptation.

- RQ3: Why and how do particular conditions such as corruption, actor resources, persistent in-group bias, event frequency, and issue/stress patterns affect the resilience of authority structures? This question is concerned with the effect of membership, access, and capacity factors on authority structure resilience.

3.1 Research Question 1

Is SET a viable framework for modeling authority dynamics in small communities?

This section provides experimental results that support the application of SET to modeling authority structure dynamics in small communities. These results also satisfy the requirement for behavioral validation of the ABM as described in section 2.4. Results for Kibera, Mushin, and Manenberg are presented individually. In all three cases, the ABM behavior qualitatively matches observed behavior. A summary of the ABM parameter settings is found in Tables 2 and 3. Table 4 provides a summary of expected results.

Table 2. Comparison of selected social and authority parameters for community scenarios

Community	Kibera	Mushin	Manenberg
Time Period			
Start/End	1987-2002	1989-2004	1988-2004
Start Collect Data	1991	1994	1993
Social Dynamics			
Population initial/final	1000/1840	800/930	300/412
g0	300 (30%)	560 (70%)	300 (100%)
g1	700 (70%)	240 (30%)	n/a
Population turnover	+60 = +72/-12	+9 = +12/-3	+8 = +9/-1
g0	30%	70%	100%
g1	70%	30%	n/a
Population segregation	0.90	0.80	0.00
Authorities			
Number	2	3	4
Type			
a0	chief	police	police
a1	ethnic militia	ethnic movement	street gang
a2	n/a	vigilantes	street gang
a3	n/a	n/a	vigilantes
Territory			
a0	100%	100%	100%
a1	100%	100%	50%
a2	n/a	100%	50%
a3	n/a		100%
Entry Timing			
a0	1986	1989	1989
a1	1991	1994	1989
a2	n/a	1989	1989
a3	n/a	n/a	1995

Table 3. Exchange parameters for community scenarios

Community	Kibera	Mushin	Manenberg
Capacity			
Issue description	housing disputes	crime	crime
Issue type	random	spatial	spatial
Issue rate	0.01	0.025 → 0.035	0.01 → 0.04 → 0.03
Authority resources	Total: sufficient	Total: insufficient	Total: insufficient
a0	0.01	0.01	0.01
a1	0.01	0.01	0.005 ('89), 0.01 ('96)
a2	n/a	0.002	0.002 ('89), 0.01 ('96)
a3	n/a	n/a	0.005
Access			
Population resources	mean 5, min 2, max 9		
Authority cost			
a0	0	2	1
a1	0	1	1
a2	n/a	1	1
a3	n/a	n/a	1
Authority corruption			
a0 only	0.88	0.90	0.65
Authority bribe			
a0 only	4	1	1
Membership			
Authority community			
a0	0.80	0.50	'89 0.50, '96 0.10
a1	0.80	0.75 ('94) - 0.95 ('96)	'89 0.30, '94 0.75
a2	n/a	0.99	'89 0.30, '94 0.75
a3	n/a	n/a	'96 0.25, '98 0.01
Authority identity			
a0	g0 0.75, g1 0.85	g0 0.99, g1 0.99	0.99
a1	g0 0.99, g1 0.005	g0 0.99, g1 0.005	0.99
a2	n/a	g0 0.99, g1 0.99	0.99
a3	n/a	n/a	0.99
Authority event			
a0	g0 1.00, g1 1.00	g0 1.00, g1 1.00	1.00
a1	g0 1.1, g1 0.50	g0 1.00, g1 0.50	1.00
a2	n/a	g0 1.00, g1 1.00	1.00
a3	n/a	n/a	1.00
Authority event days			
a0	0	0	0
a1	360	360	0
a2	n/a	0	0
a3	n/a	n/a	0
Event years	1992, 1997, 2002	1993, 1999, 2003	1994, 1999, 2004

Table 4. Expected resilience and adaptation responses for community scenarios

Community	Kibera	Mushin	Manenberg
Target Relationship	g0-a1	g0-a1	g0-(a1, a2)
Structure			
g0	a0 → a1	a2 → a1	a0 → a1, a2
g1	a0 → a0	a2 → a2	n/a
Adaptation			
Response Ratio	1993-1995	1997-1999	1996-1998
Request Ratio	1995-1997	1998-2000	1998-2000
Satisfaction			
g0	high increase	moderate increase	stable
g1	stable	stable	n/a
Instability			
g0	high	moderate	moderate
g1	stable	stable	n/a

3.1.1. Kibera

The results of 10 runs of the Kibera scenario and their assessment are found in Table 5. Based on the criteria described in section 2.4, the Kibera simulation results indicate satisfactory ABM performance. A detailed description of each variable follows.

Table 5. Summary of results for 10 Simulation Runs for the Kibera Case.

Case	Kibera, Nairobi						
Relationship	G0 (Luo), A1 (Kamkunji Militia)						
Structure	Transition occurs						
Adaptation	Expected	In Range	1-yr	> 1-yr	Mean	CI	STD
Responses	1993-1995	10	0	0	1994.22	0.17	0.27
Requests	1995-1997	10	0	0	1997.18	0.23	0.37
Stability	As expected						
Satisfaction	As expected						
Assessment	Satisfactory						

The simulated authority structure for the Kibera scenario changes as expected between 1992 and 2000. Figure 14 shows the ABM and observed authority structures for 1992 and 2000. The plots in Figure 14 are read as edge weight v. each possible authority-group edge. The exchange between Group 0 (G0: Luo residents) and Authority 0 (A0: Chiefs) decreases to around 33% of total G0 authority interactions (edges: G0-A0, A0-G0). Second, the exchange between Group 0 and Authority 1 (A1: Kamkunji Militia) increases to greater than 67% of G0 authority interactions (edges: G0-A1, A1-G0). The close relationship between G0 and A1 effectively polarizes the community into two authority systems. However, as observed, the transition is not complete as many G0 (Luo) residents still interact with chiefs (Joireman & Vanderpoel, 2010; Marx et al., 2013).

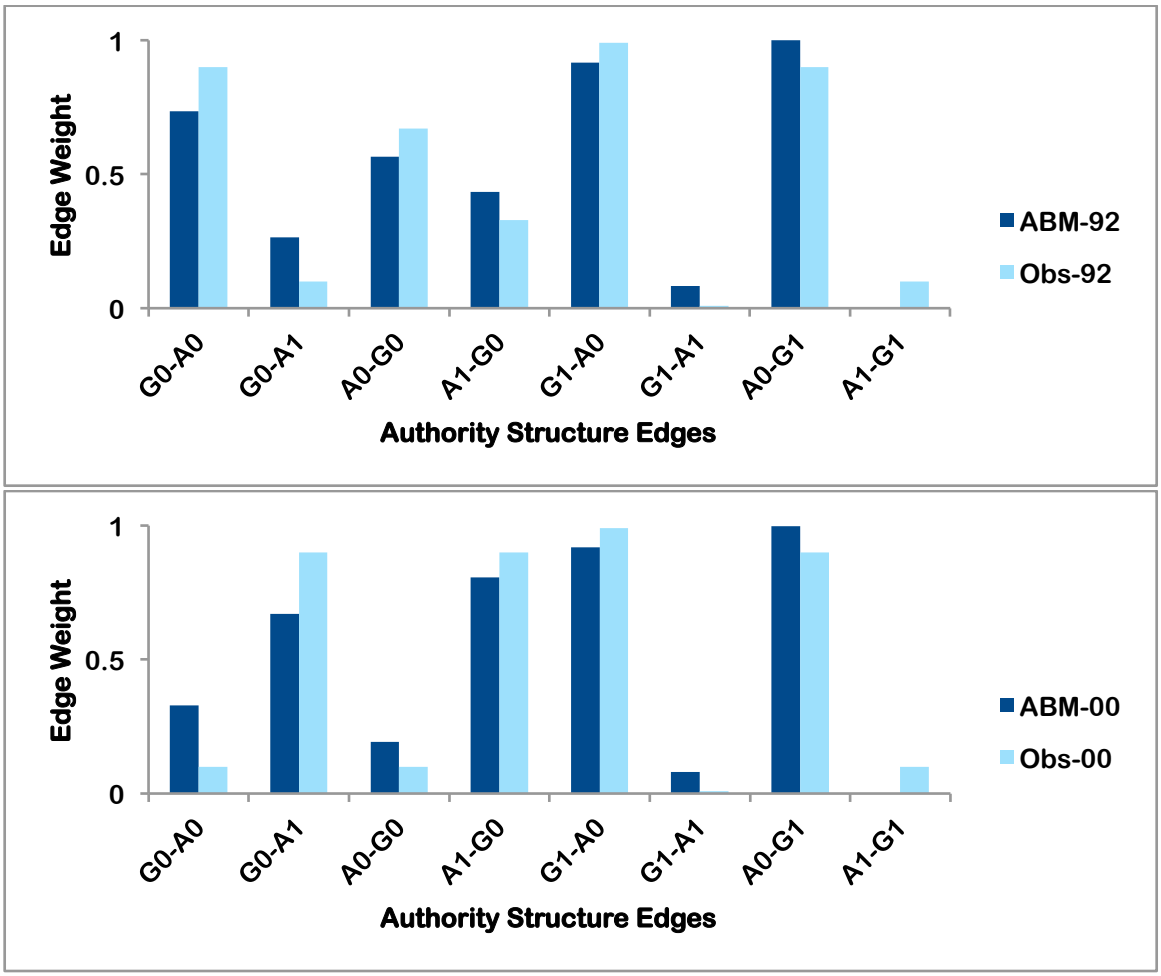

Figure 14. The 1992 (top) and 2000 (bottom) simulated (ABM) and observed (OBS) authority structures for the Kibera case study. Edge weights are the mean of 10 simulation runs.

The simulated adaptation of Group 0 to the entry of A1 is as expected based on the development of the relationship between the Luo population in Kibera and the Kamkunji militia by the late 1990's (Anderson, 2002; Klopp, 2001). A plot of the request v. response ratios for G0 for a representative simulation run is shown in Figure 15. The adaptation path begins in the bottom left quadrant indicating a strong relationship

between G0 and A0. By 2000, the system is in the upper right quadrant indicating a strong relationship between G0 and A1.

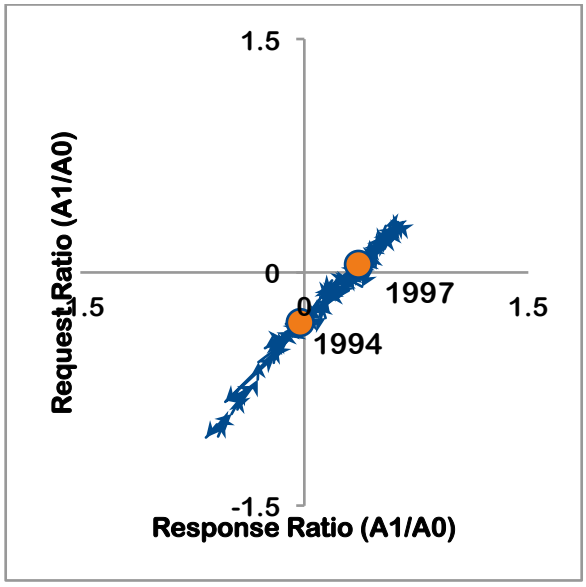

Figure 15. Adaptation plot (Request ratio v. Response ratio) for Group 0 (Luo residents) for a single run of the Kibera scenario. The ratios are Authority 1 (Kamkunji)/Authority 0 (Chiefs).

The simulated stability and satisfaction patterns for G0 qualitatively describe the observed trends in Kibera between 1991 and 2000. The plots of stability and satisfaction for 10 simulation runs are found in Figure 16, left and right panels respectively. As shown in the left panel of Figure 16, the majority of G0 agents switch from A0 to A1 between 1991 and 1995. This is consistent with observations of Luo militias effectively ending rent payments for many Luo residents by 1995 (De Smedt, 2009; Joireman & Vanderpoel, 2010). The relatively high simulated satisfaction level, around 8.0 by 2000, reflects the observed satisfaction levels.

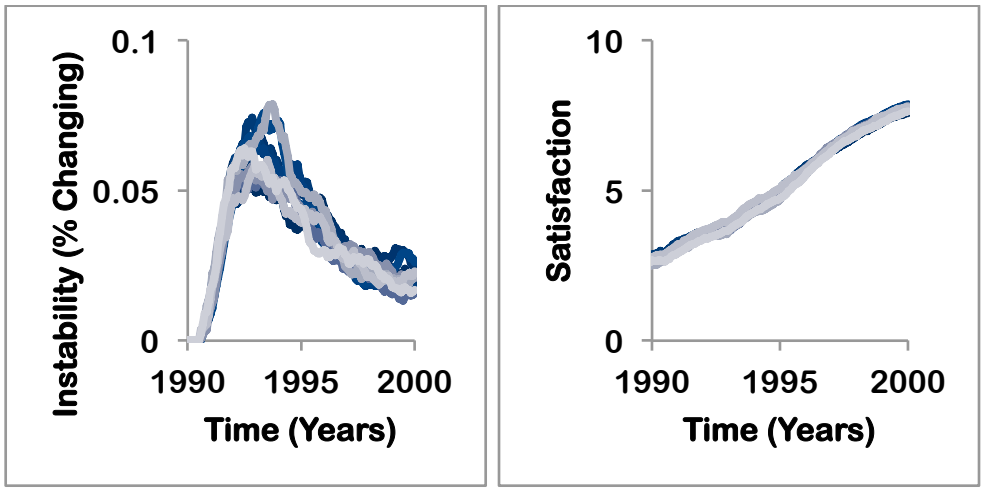

Figure 16. Group 0 instability *Left* and satisfaction *Right* from 1990-2000 for 10 ABM runs of the Kibera scenario.

3.1.2. Mushin

The results of 10 runs of the Mushin scenario and their assessment are found in Table 6. Overall, the Mushin simulation performance is satisfactory based on the criteria outlined in section 2.4. Notable variations in the adaptation request ratio and final satisfaction level occur. This behavior is discussed in greater detail in section 4.1.2.

Table 6. Summary of results for 10 simulation runs for the Mushin case

Case	Mushin, Lagos						
Relationship	G0 (Yoruba), A1 (OPC)						
Structure	Transition occurs						
Adaptation	Expected	In Range	1-yr	> 1-yr	Mean	CI	STD
Responses	1997-1999	10	0	0	1998.41	0.09	0.14
Requests	*1998-2000*	*0*	*7*	*3*	*2000.81*	*0.18*	*0.28*
Stability	As expected						
Satisfaction	*Stabilizes higher than expected*						
Assessment	Satisfactory						

As shown in Figure 17, the simulated authority structure changes as expected between 1992 and 2000. First, the exchange between Group 0 (G0: Yoruba residents) and the combination of Authority 0 (A0: Police) and Authority 2 (A1: Vigilantes) decreases to around 30% of total G0 authority interactions (see edges: G0-A0, G0-A2, A0-G0, A2-G0). Second, the exchange between Group 0 and Authority 1 (A1: OPC Militia) increases to 70% of G0 authority interactions (se edges: G0-A1, A1-G0). These changes are consistent with observations of Mushin (Enechojo, 2013; LeBas, 2013). By 2000, the OPC was a dominant force in the Yoruba community, though residents continued to interact with vigilantes and the police to address their security needs.

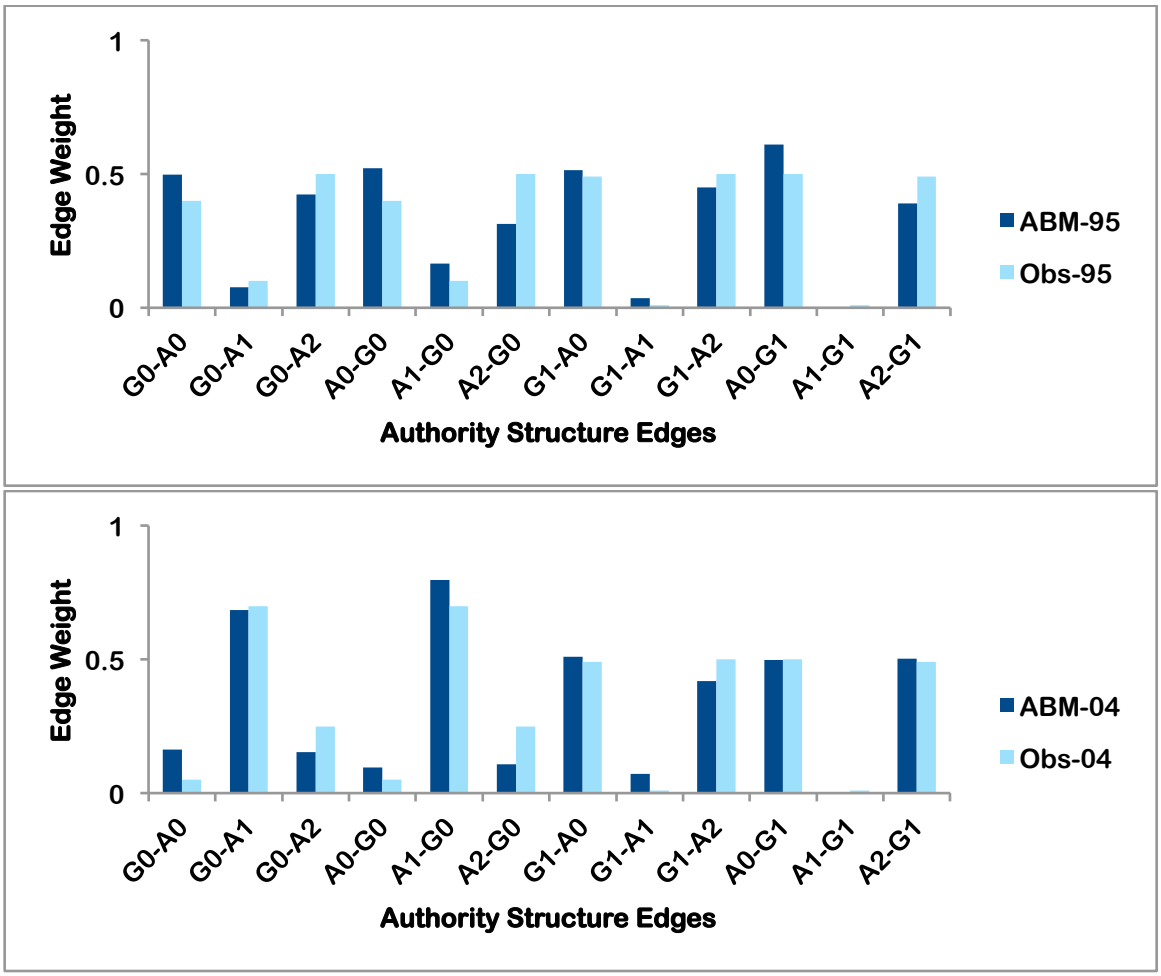

Figure 17. The 1995 (top) and 2004 (bottom) simulated (ABM) and observed (OBS) authority structures for the Mushin scenario. Edge weights are the mean of 10 simulation runs.

The simulated adaptation of G0 to the entry of A1 in 1994 is as expected. A plot of the request v. response ratios from 1993 to 2004 for G0 for a representative model run is found in Figure 18. The adaptation path begins in the bottom left quadrant indicating a strong relationship between G0 and the combination of A0 (police) and A2 (Vigilantes). By 2004, the system is in the upper right quadrant indicating a strong relationship between G0 and A1 (OPC) (see Guichaoua, 2009).

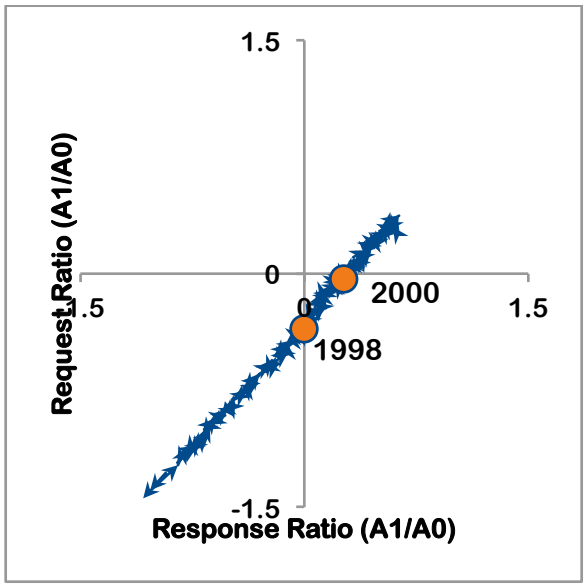

Figure 18. Adaptation plot (Request ratio v. Response ratio) for 1993 to 2005 for Group 0 (Yoruba residents) for a single run of the Mushin scenario. The ratios are Authority 1 (OPC)/(Authority 0 (Police), Authority 2 (Vigilantes)).

As shown in Table 6, the response ratios for all 10 runs transitioned as expected. However, the request ratios transitioned within the expected timeframe in seven of ten runs. In three of the ten runs, the request ratios transitioned within 1 year after the expected timeframe. The mean values of the response and request ratios fell within the expected timeframes.

The simulated stability pattern for G0 is as expected. The plots of system stability for all 10 model runs are found in Figure 19, left panel. The majority of G0 agents switch their primary partner to A1 over an extended period from 1994 to 2000. The gradual rise in instability is consistent with descriptions of this transition (Alemika & Chukwuma, 2005; Enechojo, 2013). Even after the entry of the OPC (A1), Yoruba (G0) support for vigilantes (A2) continued. After 2000, the simulated system begins to rapidly stabilize.

As shown in Figure 19, right panel, between 1995 and 1999, there is a rapid increase in simulated community satisfaction as exchange with A1 provides benefits to G0. After 2000, the satisfaction pattern for G0 stabilizes at a level higher than expected. The rise in satisfaction after 1994 is expected. However, relevant surveys indicate a persistent, high level of dissatisfaction with the overall performance of all authorities with respect to security (Alemika & Chukwuma, 2005; Enechojo, 2013).

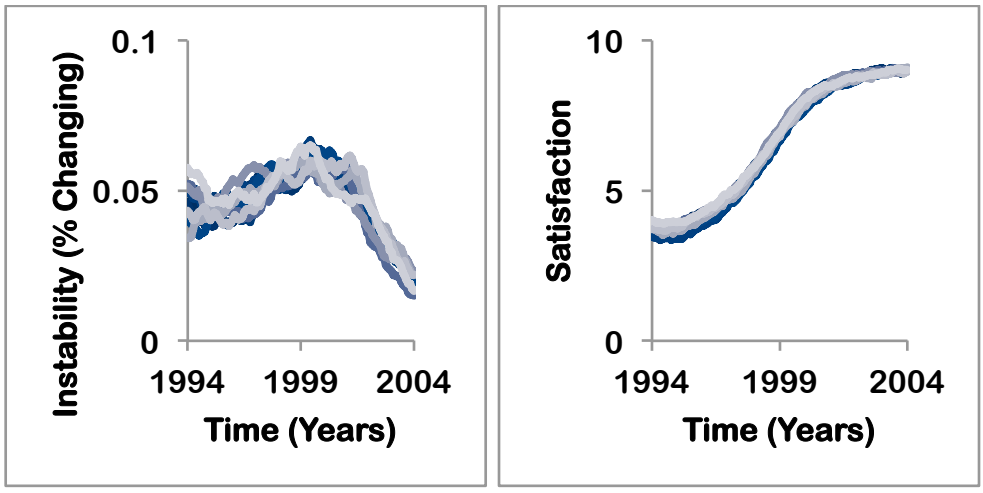

Figure 19. Group 0 instability *Left* and satisfaction *Right* from 1990-2000 for 10 ABM runs of the Mushin scenario.

3.1.3. Manenberg

The results of 10 runs of the Manenberg scenario are found in Table 7. The data concerns the adaptation of all residents. The response and request ratios for all 10 runs transitioned to A1 within the expected timeframe. The mean values of the request and

response ratios fell within the timeframe. In each run the system defined by G0 changed state as expected.

Table 7. Summary of results for 10 simulation runs for the Manenberg case.

Case	Manenberg, Cape Town						
Relationship	G0 (Community), A0/1 (Gangs)						
Structure	Transition as expected						
Adaptation	Expected	In Range	1-yr	> 1-yr	Mean	CI	STD
Responses	1996-1998	10	0	0	1996.05	0.04	0.06
Requests	1998-2000	10	0	0	1998.96	0.07	0.11
Stability	As expected						
Satisfaction	As expected						
Assessment	Satisfactory						

As shown in Figure 20, the simulated authority structure changes as expected between 1992 and 2004. First, the exchange between Group 0 (G0: all residents) and the combination of Authority 0 (A0: Police) and Authority 3 (A3: PAGAD/vigilantes) decreases to around 10% of total G0 authority interactions (see edges: G0-A0, G0-A3, A0-G0, A3-G0). Second, the exchange between Group 0 and Authorities 1 and 2 (A1, 2: gangs) increases to 90% of G0 authority interactions (see edges: G0-A1/2, A1/2-G0). Support is evenly split between A1 and A2 due to their similar characteristics and exclusive territory.

These structural changes are consistent with observations of Manenberg (Bennet, 2012; Lambrechts, 2012; Samara, 2011). By 1998, street gangs had firm control over Manenberg. The police had effectively withdrawn due to public opposition, lack of

resources, and low capacity to address their own security. The campaign against PAGAD ended its anti-gang operations in the community.

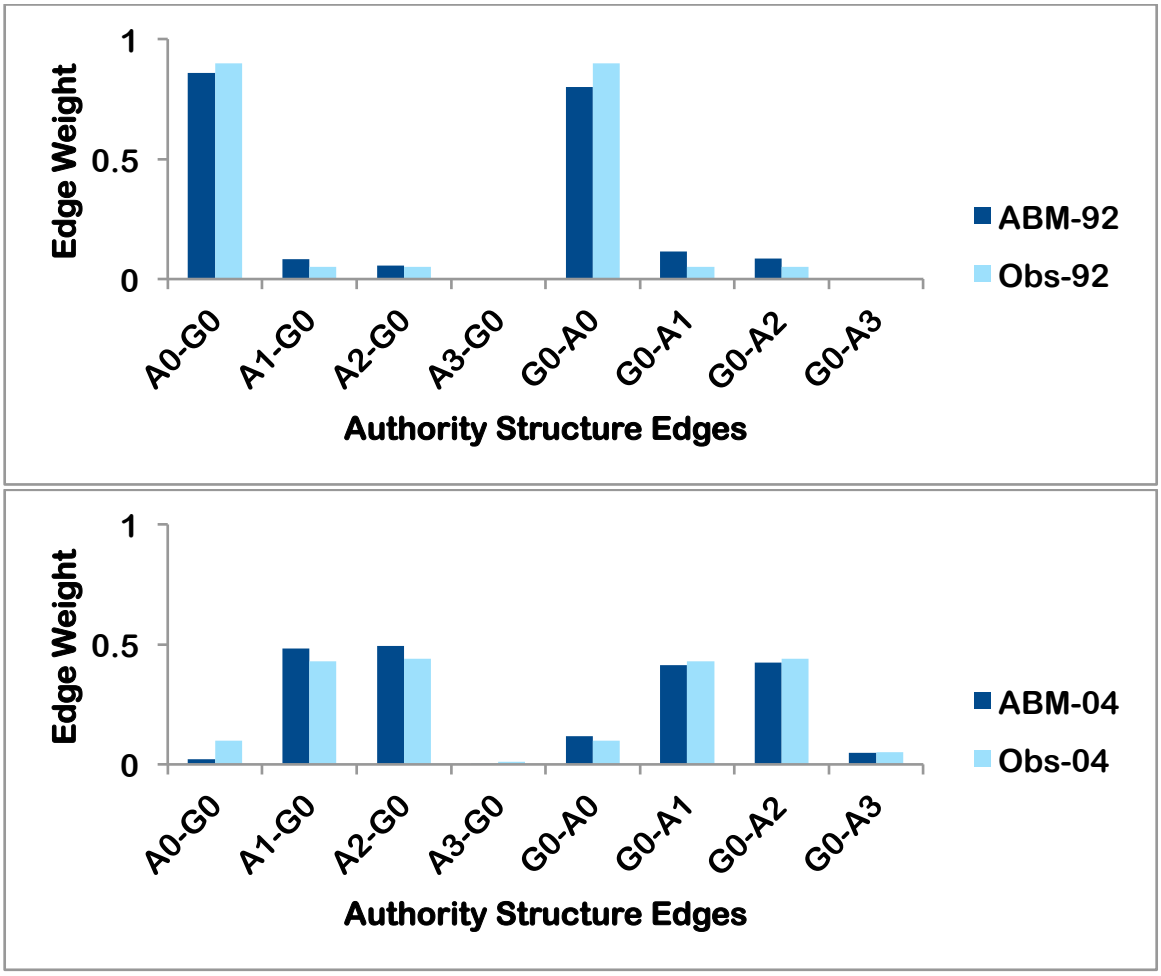

Figure 20. The 1992 (top) and 2004 (bottom) simulated (ABM) and observed (OBS) authority structures for the Manenberg scenario. Edge weights are the mean of 10 simulation runs.

The adaptation of Group 0 to the increased capacity and community membership of A1 and A2 in the mid-1990's is as expected. The adaptation plot for G0 for a representative ABM run is found in Figure 21. The adaptation path begins in the bottom

left quadrant indicating a strong relationship between G0 and the combination of A0 (police) and A2 (Vigilantes). An initial increase in the response ratio is followed by a matching increase in both the response and request ratios. By 2004, the system is in the upper right quadrant indicating a strong relationship between G0 and A1/A2, the street gangs (see Bennet, 2012; Lambrechts, 2012).

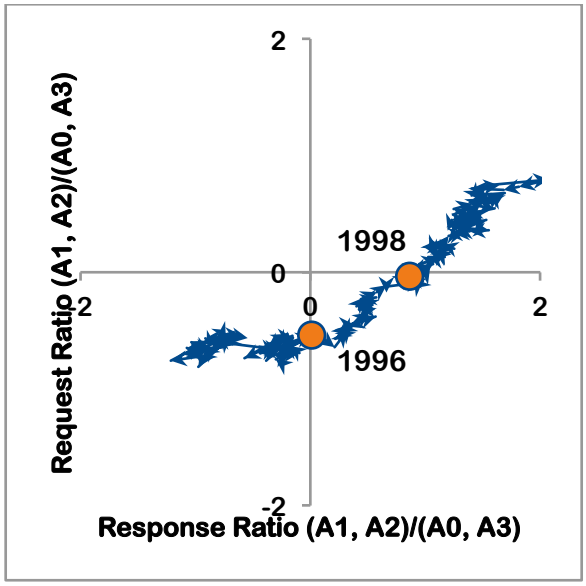

Figure 21. Adaptation plot (Request ratio v. Response ratio) for Group 0 (all residents) for a single run of the Manenberg scenario. The ratios are (Authority 1, Authority 2)/(Authority 0, Authority 3).

The simulated stability and satisfaction patterns for G0 are as expected. The plots for 10 runs of instability and satisfaction are shown in Figure 22. There is a relatively small increase in instability from 1996 to 1999 as G0 agent switch their primary exchange partner from to A1-A2. As shown in Figure 22, left panel, this increase in instability is followed by a large decrease from 1996 to 1999. This is consistent with

analyses of the dominance of gangs over the community after 1999 (Leggett, 2004b; Samara, 2011). The increase in the rate of G0 satisfaction after 1996 is expected due to the increase in gang engagement on security. The relatively low satisfaction value around 5.0 when satisfaction stabilizes is also expected as the gangs were generally ineffective at meeting community security needs (Leggett, 2004a; Samara, 2011).

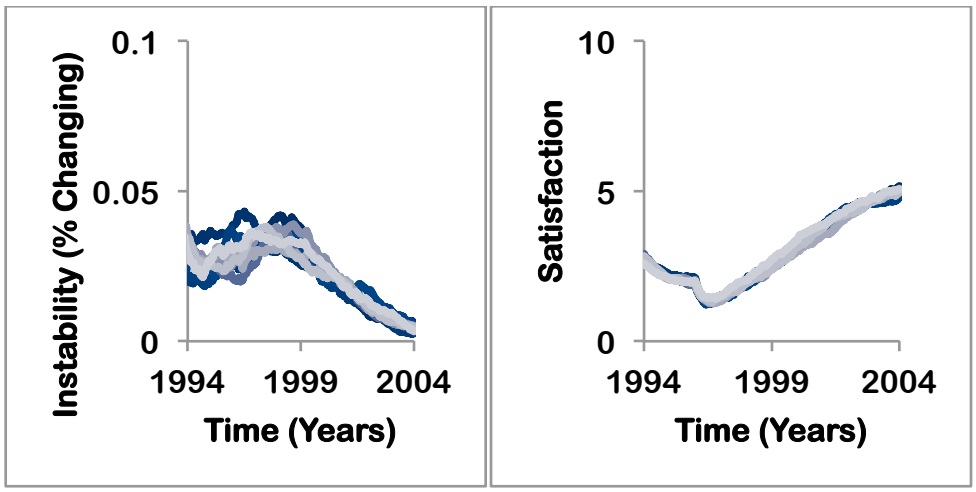

Figure 22. Group 0 instability *Left* and satisfaction *Right* from 1990-2000 for 10 ABM runs of the Manenberg scenario.

3.1.4. Summary of Results and Behavioral Validation Assessment

Based on the validation criteria outlined in section 2.4, the ABM produces satisfactory results in each of the three cases. All variables for the Kibera and Manenberg scenarios fell within the expected range for all 10 runs. In the Mushin scenario, in three of the ten simulation runs the values for the request ratio fell within 1 year of the expected timeframe. In addition, the satisfaction level for all 10 runs of the Mushin

scenario stabilized at a level higher than expected. Overall, the Mushin case is also accepted as satisfactory. A detailed explanation of the Mushin results is provided in the discussion section. Table 8 provides a summary of selected results for each case.

Table 8. Summary of ABM performance for the three case studies. Bold indicates deviation from expected results.

Case	Kibera	Mushin	Manenberg
Request Ratio			
Range	1995-1997	1998-2000	1998-2000
Mean (10-runs)	1997.18	***2001.81***	1999.96
Runs in range	10	***0***	10
Runs < 1yr of range	0	***7***	0
Runs > 1yr of range	0	***3***	0
Response Ratio			
Range	1993-1995	1997-1999	1996-1998
Mean (10-runs)	1994.22	1999.41	1997.05
Runs in range	10	0	0
Runs < 1yr of range	10	0	0
Runs > 1yr of range	10	0	0
Structure	As expected	As expected	As expected
Stability	As expected	As expected	As expected
Satisfaction	As expected	***> expected***	As expected
Overall	Satisfactory	Satisfactory	Satisfactory

These results accomplish two goals. First, they offer evidence that SET is a viable theoretical framework for modeling the resilience of authority structures in small communities. Second, they satisfy the behavioral validation criteria for the model as outlined in section 2.4. This allows further experimentation to take place with reasonable confidence that the results reflect actual social dynamics.

3.2. Research Question 2

Is an authority structure a network phenomenon or an aggregation of independent exchange relationships between two actors?

The purpose of the two experiments outlined in this section is to illustrate the effect of communication of exchange experiences between residents on authority structure resilience. It provides evidence that authority structures are not the simply the result of dyadic interactions between individual residents and authorities. The first experiment runs the three case study scenarios without agent communication. The second experiment investigates the relationship between constituency membership degree, group segregation, and adaptation patterns.

3.2.1. Communication

The three community scenarios are run without agent communication and compared to the adaptation and instability results from section 3.1 to identify any differences in model behavior. There are two expected results. First, the adaptive behavior should be different with and without communication. If it is not different, then agent communication is not an essential design feature. It is also less relevant to authority structure resilience, in general. Second, the effect of resident interdependence should produce non-linear adaptive behavior in the scenarios with communication. These patterns should be weaker or non-existent when there is no communication. The results of each community scenario are discussed independently.

3.2.1.1. Kibera

Overall, the Kibera case results illustrate how the range of adaptation is less when agents do not communicate experiences to one another. As shown in Figure 23, left panel, without communication, the system begins close the origin. This indicates near parity in the relationship between G0 and each of the authorities A0 and A1. This is not consistent with descriptions of the authority dynamics in Gatwekera village in the early 1990's when the Kamkunji was starting to establish itself in the community (Anderson, 2002; Joireman & Vanderpoel, 2010). As shown in Figure 23, left panel, blue plot, with communication, adaptation begins far from the origin in the lower left quadrant.

The instability plots with and without communication for Kibera shown in Figure 23, right panel, are identical for the initial year following the entry of A1. However, at that point the system without communication rapidly stabilizes. The system with communication stabilizes but to a lesser degree. The differences in these two profiles is attributable to the where the adaptation paths of the two scenarios begin.

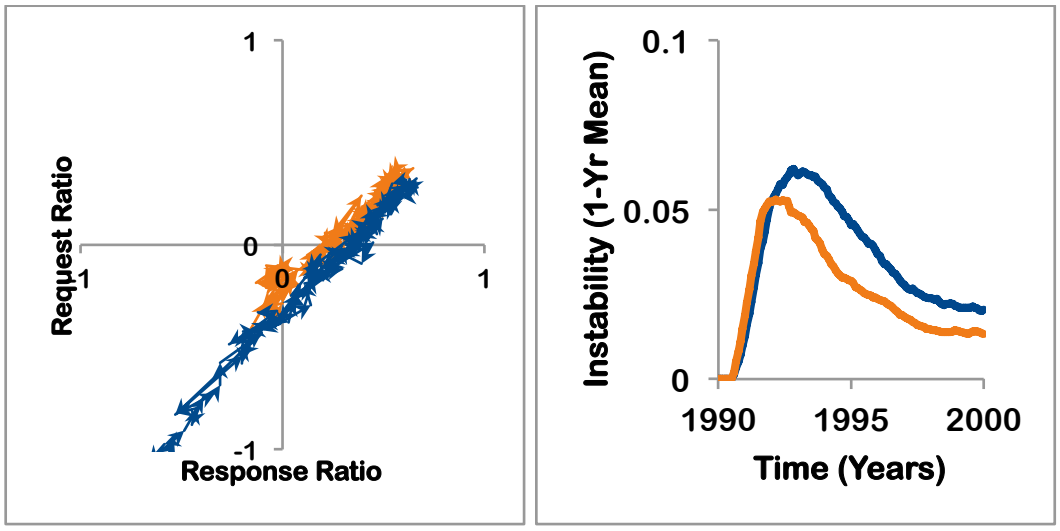

Figure 23. *Left*. Kibera request ratio v. response ratio adaptation plots with (blue) and without (orange) communication for Group 0 with respect to Authority 1. *Right*. The stability plots with (blue) and without (orange) communication. These are the mean values of the 1-year moving average for 10 runs.

3.2.1.2. Mushin

The Mushin scenario illustrates how a system without communication can display a dampened instability profile behavior compared to a system with communication. The two adaptation paths shown in Figure 24, left panel, are nearly identical. The system without communication undergoes a less extreme transition than the system with communication. The most significant difference is at the beginning of the simulation.

The instability plots with and without communication shown in Figure 24, right panel, are significantly different. Without communication, the system undergoes a relatively minor rise in instability, followed by a gradual decline over the next five years. In contrast, with communication, instability rises gradually, then rapidly decreases. This is more consistent with observation. The OPC cultivated local Yoruba support throughout

the 1990's. Its peak period as a security provider took place around 1999 in response to a wave of ethnic violence (Abdulazeez, 2013; Enechojo, 2013).

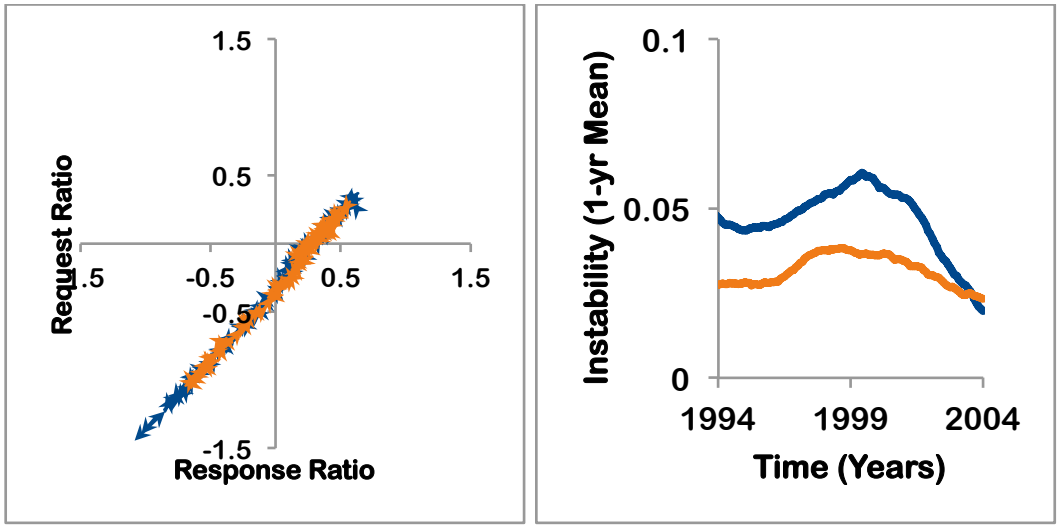

Figure 24. *Left*. Mushin adaptation plots with (blue) and without (orange) communication for Group 0 with respect to Authority 1. *Right*. The stability plots with (blue) and without (orange) communication. These are the mean values of the 1-year moving average for 10 runs.

3.2.1.3. Manenberg

The Manenberg scenario illustrates how a system with communication displays a wider adaptation range and a significantly different stability profile than a system without communication. In the Manenberg case, the two adaptation paths shown in Figure 25, left panel, are significantly different. As in the Kibera case, the greatest variation occurs at the beginning of the simulation. Once the request ratio favors A1 and A2 (street gangs), the two systems adapt along the same path. Prior to this, there is near parity of authorities in the system without communication. This is not the observed behavior. It was not until

street gangs became the only viable security option that the relationship with the community strengthened (see Samara, 2011).

The instability profiles for the Manenberg case are significantly different. As shown in Figure 25, right panel, without communication, the system begins with a high level of instability that decreases at a constant rate over 10 years. Consistent with observation, when there is communication, the system experiences a peak in instability from 1994 to 1998. During this period, gangs and vigilantes became more involved in community security while the relationship with the police deteriorated (Leggett, 2004a; Samara, 2010).

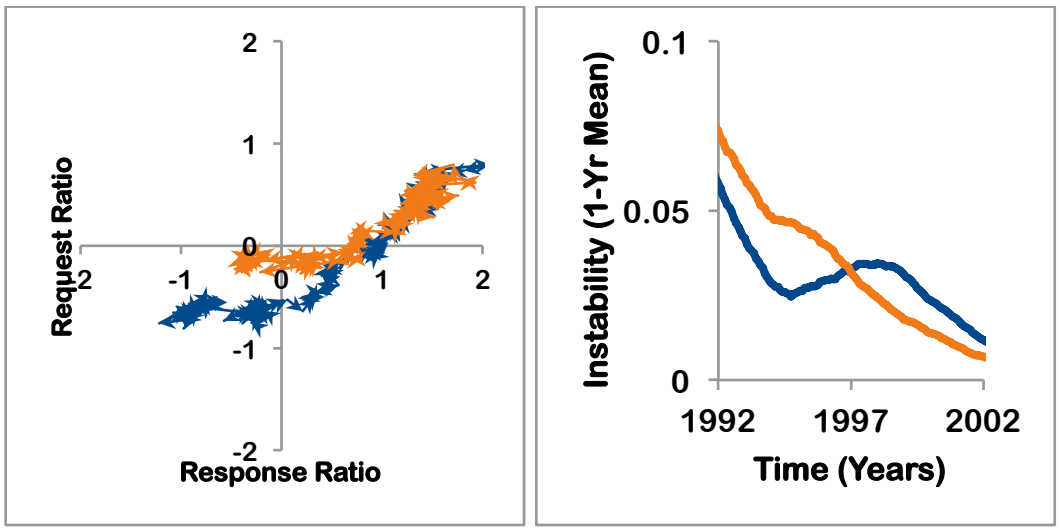

Figure 25. *Left*. Request v. response ratios for Manenberg with (blue) and without (orange) communication for Group 0 with respect to Authority 1. *Right*. The stability plots with (blue) and without (orange) communication. These are the mean values of the 1-year moving average for 10 runs.

3.2.2. Spatial Segregation

The purpose of this experiment is to illustrate how spatial homogeneity with respect to group identity can affect authority structure resilience. As described in section 2.6.2 and summarized in Table 9, the simulation parameters are set so that G1 will prefer A1. The strength of this relationship is indicated by the request ratio from G1 to A1. The relationship between spatial segregation and resilience of the authority structure is tested by varying the group segregation level between 1% and 99%. There are two hypotheses:

- There is an inverse relationship between the segregation level and the time it takes for exchange between the target groups and authority to stabilize. This is based on the basic behavior of complex systems with homogeneous actors (Scheffer et al., 2012).

- There is a direct relationship between the segregation level and the request ratio with respect to the favored authority. This is another perspective on social network homophily (Kossinets, 2009; McPherson et al., 2001; Schaefer, 2012)

Table 9. Summary of selected parameters for segregation experiment.

Parameter	Environment	A0	A1
years	15		
Population (g0, g1)	500, 500		
Population segregation	**1, 10, 25, 50, 75, 99%**		
Population territory	**g0: 50%, g1: 50%**		
Authority territory		100%	100%
Issue type	random		
Issue rate	1%		
Authority resources		1%	1%
Authority community		0.999	0.999
Authority identity year: g0, g1		0: 0.999, 0.999 2: 0.999, **0.50**	0: 0.999, 0.999 2: **0.50**, 0.999

The results confirm both hypotheses. The plots of the 1-year moving average of the request ratio are found in Figure 26. As shown in Figure 27, left panel, there is a direct relationship between the request ratio and segregation. The best fit to the data is: y = 0.41e ^ (0.01x) with $R^2 = 0.99$. Figure 27, right panel shows an inverse relationship between the time the system takes to stabilize and segregation. The best fit to the data is: y = 6.004 e (-0.003x) with $R^2 = 0.81$.

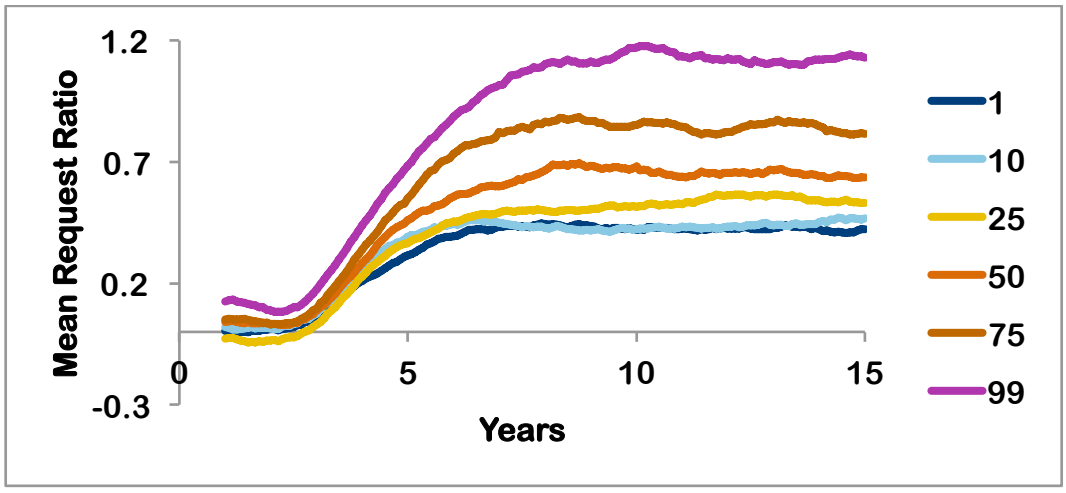

Figure 26. Mean request ratio for Group 1 (A1/A0) v. segregation probabilities ranging from 1% to 99%. Values greater than 0 indicate that G1 favors A1.

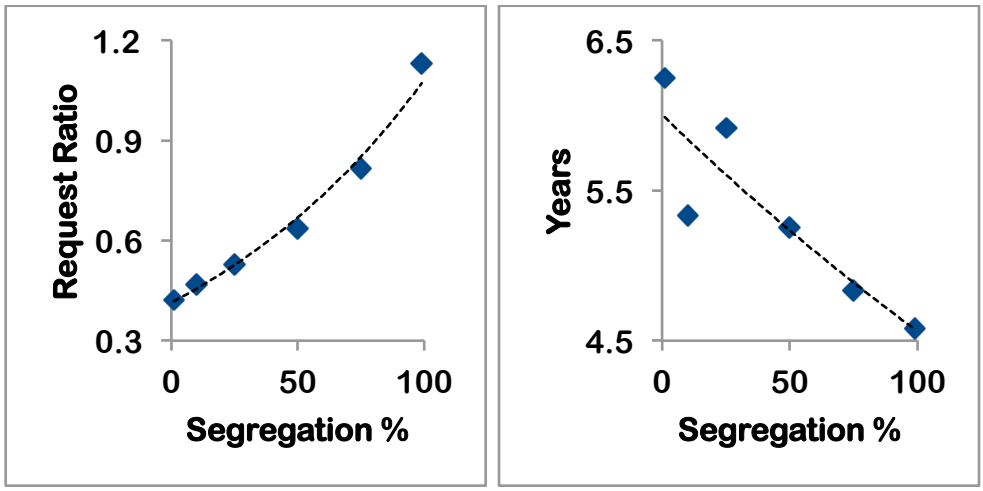

Figure 27. *Left*. Final value of the request ratio for group 1 v. degree of segregation. The best fit to the data is: y = 0.41e ^ (0.01x) with $R^2 = 0.99$. *Right*. The time for system instability to drop below 0.01 v. degree of segregation. The best fit to the data is: y = 6.0038 e (-0.003x) with $R^2 = 0.81$.

3.2.3. Summary of Results

The results from research question two indicate that communication between residents is an important factor in how authority structures adapt. The results with and without communication in the three community cases were significantly different verifying that communication is an essential design feature of the ABM. In addition, the results without communication were qualitatively different from observations of the real world cases.

The segregation experiment investigated the effect of agent homophily and spatial proximity on system adaptation. Both hypotheses were confirmed. There is an inverse relationship between stabilization and segregation. There is a direct relationship between group support for the favored authority and segregation.

3.3. Research Question 3

Why and how do particular conditions such as group preferences, corruption, actor resources, system level event frequency, and issue/stress patterns affect the resilience of authority structures?

This research question consists of three experiments. Each experiment is focused on one aspect of the exchange partner selection process described in the CAM: membership, access, and value/capacity considerations. The results illustrate how changes in a single decision-making factor can challenge the resilience of an authority structure. The experiments provide evidence that the CAM can explain the relationship between a wide range of social conditions and changes in authority structures.

3.3.1. Constituency Membership Reinforcement

The purpose of this experiment is to illustrate how episodic reinforcement of polity membership by an authority can increase the long-term support of a target community even when overall authority performance is poor. As described in section 2.6.3, and summarized in Table 10, each authority supports a different social group. As an event approaches, the authorities reduce the identity membership degree of the out-group. This increases the probability that members of the preferred group will get resources. The hypothesis is that there is a direct relationship between event frequency and the level of long-term support from the favored group (Arias, 2010; Branch, 2011; Klopp, 2001).

Table 10. Summary of selected parameters for membership experiment

Parameter	Environment	A0	A1
Years	15		
Population (g0, g1)	500, 500		
Population segregation	1,		
Population territory	50%, 50%		
Authority territory		100%	100%
Issue type	random		
Issue rate	5%		
Authority resources		1%	1%
Authority community		0.999	0.999
Authority identity		g0: 0.999, g1: 0.999	g0: 0.999, g1: 0.999
Authority event		**g0: 1.00, g1: 0.25**	**g0: 0.25, g1: 1.00**
Authority event concern (days)		360	360
Event years (years between events)	**1, 2, 3, 5, 7**		

The results of simulation runs with event frequencies varying from 1 to 7 years confirm the hypothesis. As shown in Figure 28, there is a direct relationship between the request ratio and the ratio of positive membership reinforcement. The best fit to the data in Figure 28, right panel, is a power function: $y = 0.324 x ^ (-0.892)$ with $R^2 = 0.989$.

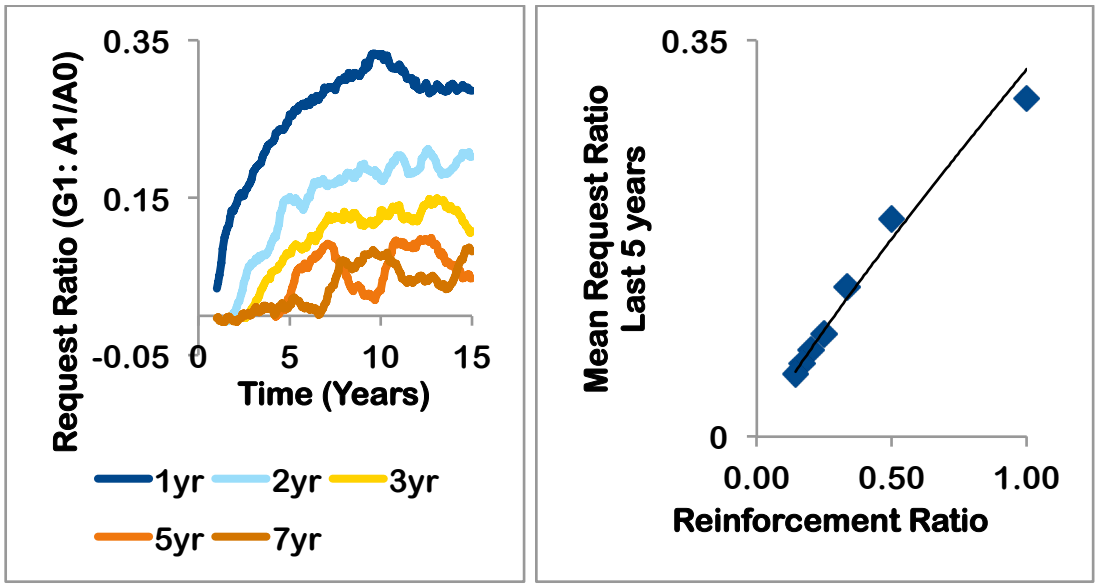

Figure 28. *Left*. Request ratios (A1/A0) for Group 1 for inter-event times ranging from 1 to 7 years. *Right*. Mean request ratio for last 5 years of simulation using 1-year moving average v. membership reinforcement ratio. Best fit: $y = 0.324\ x\ ^{\wedge}\ (-0.892)$ with $R^2 = 0.989$.

3.3.2. Access and Corruption

This set of experiments looks at the relationship between corruption, access costs and system resilience. The experiment parameters are described in section 2.6.3 and summarized in Table 11. One authority has higher fixed costs. The alternative authority is corrupt. When the alternative demands a bribe, its total cost is slightly higher than its competitor's is. To establish the baseline authority structure, each simulation runs for 5 years before the alternative authority begins to demand a bribe. The hypothesis is that there is an inverse relationship between corruption rates and community support if corruption is high enough (Alemika & Chukwuma, 2005; Leggett, 2004a; Marx et al., 2013).

Table 11. Summary of selected parameters for access experiment

Parameter	Environment	A0	A1
Years	15		
Population (g0)	1000		
Authority territory		100%	100%
Issue type	random		
Issue rate	5%		
Authority resources		1%	1%
Authority community		0.999	0.999
Population resources	mean 5, min 2, max 9		
Authority cost		2	1
Authority corruption (year: %)		0	**3: 10%, 25%, 50%, 75%, 85%, 95%**
Authority bribe		0	3

The results of the experiment shown in Figure 29 confirm the hypothesis. For corruption levels less than or equal to around 25%, the request ratio favors the corrupt authority. For levels greater than 25%, the request ratio favors the uncorrupt authority with higher fixed costs.

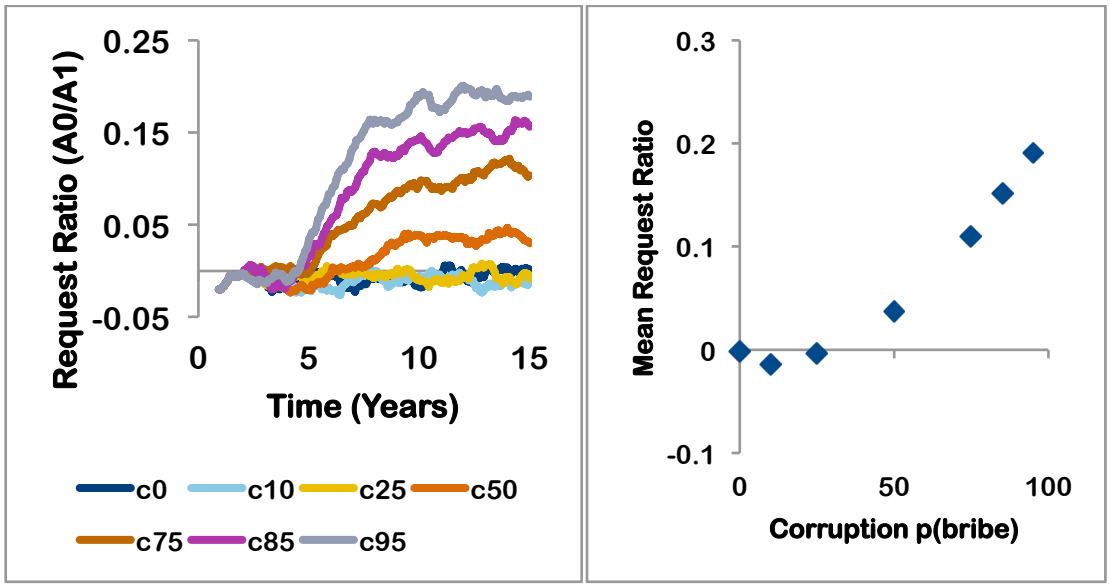

Figure 29. *Left*. Request ratio (A0/A1) for A1 corruption values ranging from 0 to 0.95. *Right*. Mean request ratio (A0/A1) for last 3 years of simulation run v. A1 corruption values ranging from 0 to 0.95.

3.3.3. Social Stress and Authority Capacity

This experiment illustrates the relationship between issue related social stress, low authority capacity, and community adaptation. It demonstrates how repeated periods of social stress can reinforce community support for more effective authorities (Bennet, 2012; Cioffi-Revilla & Rouleau, 2010; Ferguson & Mansbach, 1996; Migdal, 1988; Sobel & Leeson, 2006). The experiment is described in section 2.6.3 and a summary of selected parameters in found in Table 12.

Table 12. Summary of selected parameters for capacity experiment

Parameter	Environment		A0		A1	
Years	10					
Population (g0)	1000					
Authority territory			100%		100%	
Issue type (stress ratio)	steady state/stress (days): 30/30, 60/30, 120/30, 240/30, 360/30, no peak					
run each stress ratio for each of 6 experiments						
Experiment	1	2	3	4	5	6
Issue rate	2%/8%	2%/8%	3%/8%	3.5%/8%	1%/8%	1.5%/8%
Authority resources (A0/A1)	2/1	2/1.5	2/1	2/1.5	2/1	2/1.5

As shown in Figure 30, The results confirm the hypothesis that issue-based stress is directly related to support for the authority with the highest resources. In scenario 1, A0 has sufficient resources to address all resident needs during the steady state period. As shown in Figure 30, light and dark blue plots, the request ratio is highest when the difference between A0 and A1 resources are greatest. In scenario 1, the long-term request ratio favors A0 over A1 at each stress level.

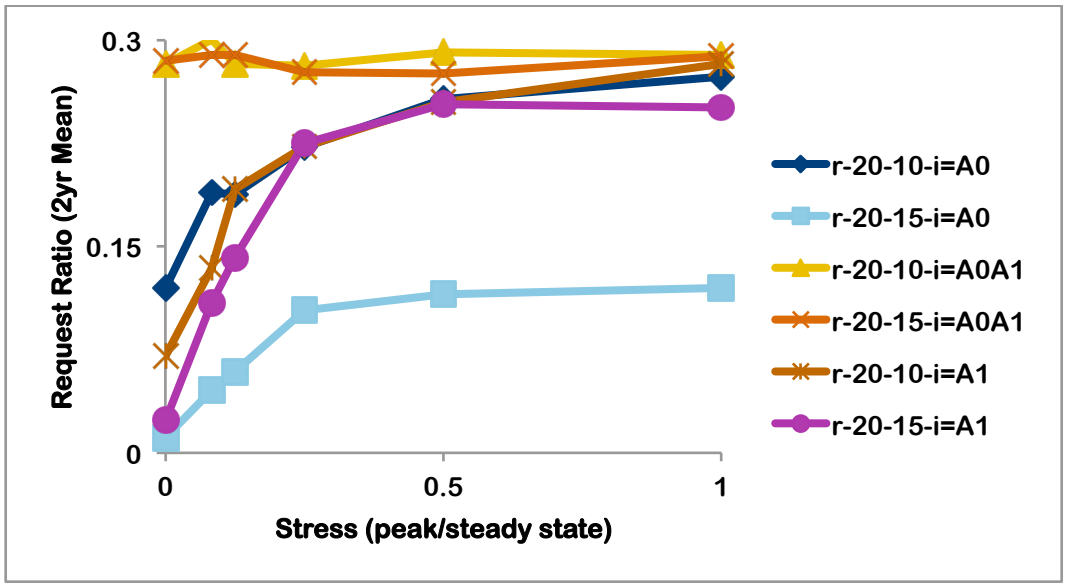

Figure 30. Mean log-request ratio (A0/A1) for last 2 years of scenario v. stress level. For each scenario A0 resources equal 20 and A1 is 10 or 15. Scenario 1 (dark blue, light blue) steady state issue rate is equal to highest resourced authority (A0). Scenario 2 (yellow, orange) steady state issue rate is equal to combined resources of A0 and A1. Scenario 3 (brown, purple) steady state issue rate is equal to lowest resourced authority (A1).

In scenario 2, the steady state issue rate is equal to A1's resources, thus both authorities are able to address all issues during this timeframe. The results of scenario 2 are similar to scenario 1, though the difference between the resource distribution plots shown in Figure 30, brown and purple, is much smaller than in scenario 1. In addition, both results for scenario 2 are nearly the same as the scenario 1 result where A0 resources are highest with respect to A1.

In scenario 3, the steady state issue rate is equal to the total of A0 and A1 resources, thus, neither authority is capable of addressing all issues alone. The results are inconclusive with respect to the hypothesis, but they do not reject it. The request ratio remains relatively constant independent of the stress level. This scenario also produces

the highest request ratios of the three scenarios. There is no discernable difference between the results with a high or low resource ratio between the authorities.

3.3.4. Summary of Results

In each of the three experiments, the hypotheses were confirmed. The following is a summary of the results:

- Membership: There is a direct relationship between event frequency and the level of long-term support from the favored group. The best fit to the data is $y = 0.324 x ^ (-0.892)$ with $R^2 = 0.989$.
- Access: There is an inverse relationship between corruption rates and community support if corruption is high enough. For corruption levels less than or equal to around 25%, the request ratio favors the corrupt authority. For levels greater than 25%, the request ratio favors the uncorrupt authority with higher fixed costs.
- Capacity/stress: There is a direct, non-linear, relationship between the issue-based stress level and support for the authority with the highest resources. The relevance of relative resources between the two authorities is greatest when the steady state issue level is equal to the resources of the highest resourced authority.

CHAPTER FOUR
DISCUSSION

This chapter assesses the performance of the ABM and establishes the relevance of the CAM as an analytic framework. The chapter consists of four sections. Section 4.1 discusses the results of each research question in detail. The contributions of the model and the results of the three research questions to computational social science, social exchange theory, understanding political authority, and public policy are found in section 4.2. The chapter concludes by proposing several model extensions and directions for further research in section 4.3.

The primary contribution of this analysis is the production of a validated ABM of community authority structure resilience based on SET principals. The model demonstrates how computational methods can advance the SET research program by overcoming some of the challenges of conducting multi-year experiments with large populations. As the results confirm, SET has great potential for explaining the dynamics of social structures in complex settings. However, the experimental emphasis in SET remains on small group interactions with limited complexity. This limits advancements in the field and the theory's application to more complex environments.

The results also demonstrate the utility of CSS and this ABM for political science. Specifically, this approach advances a more complex understanding of the concept of political authority. The model directly addresses the relationship between time, space,

and the development of authority structures. These elements are present throughout the literature on political authority, but they are difficult to study in real world settings. As discussed in sections 4.2 and 4.3, the model design also permits its straightforward extension to accommodate more sophisticated agent decision-making and more complex interactions between agents and their social and spatial environment. This is the foundation for applying the CAM framework to study larger scale authority structures across multiple communities.

4.1. Research Questions

4.1.1. Research Question 1

Research question 1 addressed the question: Is SET a viable framework for modeling authority dynamics in small communities? The findings of RQ1 are important for three reasons. First, the model produces the expected results in scenarios that vary across a wide range of authority and environmental parameters. This finding supports the viability hypothesis. It also strengthens the argument that SET has potential as the basis for modeling and studying a wide range of related phenomena associated authority structures. Second, it demonstrates the relevance of the four CAM resilience variables to analyzing authority structures. This set of variables provides a comprehensive picture of system behavior that can be used in a wide range of experiments. Third, the validated ABM design demonstrates that the basic concepts of relationship formation in SET are relatively straightforward to integrate into computational models.

The discussion of RQ1 consists of three sections addressing the four resilience variables: adaptation, structure and satisfaction, and stability respectively. Each section compares and contrasts the results of three cases, identifying any unexpected results. Throughout the discussion, agents in the ABM are referred to as groups (G_i) or authorities (A_i). Actors in the real world communities are referred to by name. A correlation is provided where appropriate.

The adaptation plot described in section 2.5.2 illustrates how exchange relationships develop over time. This is useful for correlating changes in system conditions with adaptive behavior. It indicates the system state and how exchange preferences change over time. In the Kibera and Manenberg cases, the state transition for the target group-authority relationship occurred within the expected timeframes in all simulation runs. In the Mushin case, the request ratio transition consistently took one year longer than expected. As shown in Table 8, in three of the ten Mushin simulation runs this transition fell outside the established limits.

The results in the Mushin scenario highlight the effect of memory on exchange relationships and how this is implemented in the ABM. A basic principle of SET is that the decision to engage with a particular partner is directly related to the history of positive interactions (Molm, 1997). Agent memory in the ABM is the set of recent positive exchange interactions from all partners. In the Mushin scenario, A2 was active for 5 years before A1, the target authority, entered the simulation. Despite the very limited capacity of A1, an exchange history between G0 and A2 developed that was

initially difficult for A1 to overcome. This dynamic is responsible for the consistently late transition of the request ratio.

The Mushin results illustrate how poorly performing groups can maintain support long after more capable actors become active. This is a common situation during authority structure transition periods. It is responsible for extended, multi-year periods where multiple authorities compete for dominance. This effect is exacerbated when all groups are near parity with respect to relative value as calculated by residents. In terms of SET, authorities find it difficult to distinguish themselves and achieve a degree of 'lock-in' with respect to a strong relationship with their constituencies. In terms of value exchange alone, residents have little incentive to select one authority over another.

Together, the structure and satisfaction variables provide a useful perspective on system resilience. The structure graphs indicate the relative strength of exchange relationships at a particular point in time. This also reflects the status of power-dependence relationships. The satisfaction variable is a 'resilience surrogate' (Bennett et al., 2005) that indirectly measures the strength of the authority structure itself. Analyses of real world cases indicate that the strength of a group-authority relationship is based on the relative rather than actual value of those options (Arias, 2006; Bennet, 2012; Enechojo, 2013). This creates situations where relationships may appear strong due to a relatively high interaction frequency, but are in fact, less resilient due to poor value exchange.

The Kibera and Manenberg cases illustrate two different combinations of structure and satisfaction. In the Kibera simulation, satisfaction stabilizes at a much

higher level than it does in the Manenberg case (see Figures 8, 14). However, the strength of the target relationship in Kibera is significantly lower than that in Manenberg (see Figures 6, 12).

The results of the simulations in both cases reflect observations of the actual dynamics in these communities. In Gatwekera village, the Kamkunji (A1) was very effective in resolving rent disputes in favor of Luo residents, even eliminating rent payments for many (De Smedt, 2009). There is also evidence that the Kamkunji, despite strong support in the Luo (G0) community, did not completely take over the rental dispute market (Marx et al., 2013). In contrast, Manenberg residents expressed low satisfaction with the gangs ability to resolve security issues (Leggett, 2004b). However, due to the low police responsiveness, residents had little option other than to engage the gangs or simply do nothing. Thus, satisfaction was lower in Manenberg.

As shown in Figure 19, right panel, the satisfaction level in the Mushin scenario stabilized at a much higher level than expected. This is due to a combination of two model dynamics. First, the resource levels of A1 should be higher than other authorities, but are likely set too high. The OPC (A1) was a successful organized political opposition movement with national level organization and in direct conflict with the state. As such it had substantially higher resources and capacity than other informal security providers composed of local residents or adolescent 'area boys' (Abdulazeez, 2013). However, despite the OPC's increased emphasis on Yoruba security needs in Mushin, reports indicate that its focus was more on ethnic conflicts than everyday security until the late 1990's (Ikelegbe, 2005).

The second reason for the high Mushin satisfaction rate is that G0 (Yoruba) residents exchange with all three authorities. This increases the rate of overall positive exchanges. Research on Mushin verifies that residents do address a wide variety of security providers (Enechojo, 2013). However, the simulation results exaggerate the positive effect of this relatively unstable system. Instead, the combination of all authority resources should be lower, though retain their relative strength.

Stability profiles offer another perspective on system adaptation. This variable indicates the level of consensus in the community concerning various authority relationships. High instability indicates the absence of a consensus. All three scenarios exhibit an expected spike in instability over the time frame when the request ratio first changes to favor the target authority (i.e. the Kamkunji, OPC, or gangs) (see Figures 8, 11, 14). Despite the overall similarity among the cases, each case scenario produces a distinctly different stability profile. These variations reflect differences in the underlying structural characteristics of the system throughout the state change.

The Kibera instability profile is indicative of a system where a new authority actor enters and mean population satisfaction is low. This illustrates the effect of accumulated potential for change in the population. The initial sharp increase in instability in Figure 16, left panel, reflects the rapid transition in G0 (Luo) support for A0 (Chiefs) to A1 (Kamkunji). High access costs due to corruption by A0 reduced the satisfaction level of G0 residents. In contrast, A1's access costs were lower, and reinforced by a strong preference for engaging G0 residents.

The Kibera simulated results reflect the observed dynamics. The Luo population was generally unsatisfied with available government dispute resolution processes due to their cost and perceptions of bias against them (Marx et al., 2013). The Kamkunji offered essentially free services to the Luo residents and used violence and intimidation to achieve positive outcomes for them.

The Manenberg stability profile exemplifies the behavior of a more resilient system due, paradoxically, to the unsatisfactory set of authority options available to the population. The simulated stability profile shown in Figure 22, left panel, consists of an extended peak in instability over 10 years. The infrequency of positive returns for resident interaction with all authorities prolongs the transition period.

Over the period from 1994 to 2004, conflict between the police, gangs, and vigilantes in Manenberg reduced the effectiveness of security services for the population. The substantial increase in the murder rate is one of many indicators of the situation at the time (Leggett, 2004a, 2004b). As the performance of the street gangs gradually improved relative to other options, structural instability decreased. However, this change in gang responsiveness was due as much to police withdrawal from Manenberg as any increased concern for residents by the gangs.

Finally, the Mushin stability profile shown in Figure 19, left panel, reflects a situation where resilience remains high in spite of the entry of a new authority actor. This extended period of slowly rising instability in the simulation is due to the relatively slow improvement in performance of A1 (OPC). Once G0 (Yoruba) residents established a sufficient exchange history with A1, there was a rapid decrease in instability.

As previously described, the OPC (A1) took several years before it became fully involved as an informal security provider. Initially, the organization was primarily concerned with its national ambitions and political opposition to the military government. However, from the late 1990's through the elections in 2002, the OPC was the dominant Yoruba political and social force in Mushin. This was in spite of its ongoing conflicts with the government and other ethnic gangs (Ikelegbe, 2005).

4.1.2. Research Question 2

Research question two investigated the effect of actor interdependence on authority structure resilience. It addressed the question: Is an authority structure a network phenomenon or an aggregation of independent exchange relationships between two actors? Communication of positive exchange interactions between agents serves as a simple mechanism for implementing interdependence.

The results of two experiments support the argument that interdependence is an essential element of system resilience. The finding of experiment 1 is that without communication, the model produces adaptation patterns that are significantly different from simulations with communication and from real world observations. The finding of experiment 2 is that the spatial density of agents with similar experiences is inversely related to the time it takes the system to transition, and directly related to the magnitude of that transition.

These findings are important for two reasons. First, the results confirm that communication and subsequent integration of indirect experiences in decision-making is an important ABM design feature. This finding supports the CAS perspective on modeling authority structures. It also undermines the idea that authority relationships are simply aggregations of individual relationships. Thus, computational models of exchange networks that reflect real world communities can benefit from including communication interactions (see Pujol et al., 2005). Second, communication of relevant information between members of an exchange network is implied in much of the theoretical social exchange literature, though it is not always integrated into experiments. Thus, the relationship between second-hand information and value-based exchange is not well understood (see Geller & Moss, 2008). The findings of this experiment indicate that this is a useful research direction.

4.1.2.1. Discussion of Results With and Without Agent Communication

Experiment 1 illustrates the effect of eliminating agent communication of experiences on the model's performance. The primary differences between the results with and without communication are in how the system adapts to the entry of new actors and the instability pattern throughout the request ratio transition period.

In all three cases, the request ratio for the target relationship begins at a lower level with communication than without communication (see Figures 14-16, Left images). Due to the way that resident agents use exchange histories, the probability of selecting a

poorly performing authority is nearly as likely as selecting a new authority. With communication, the effect of any positive experiences in the community is stronger due to feedback. Without communication, the effect of past exchanges is weaker. The request ratio starts closer to parity between authorities when the performance of older authorities is low.

The adaptation profiles without communication suggests a faster initial adoption of the alternative authority than typically observed. Secondary sources describe periods of several years where new authorities struggle to establish themselves even in sympathetic populations. It is rare for a new community actor to enjoy parity with existing actors from the beginning. This is the strongest argument against the behavior illustrated in the scenarios without communication.

However, while the ABM may better replicate real world observations when agents share experiences, there is an argument to be made that the exchange of value is not solely responsible for this in the real world. The ABM does not explicitly model the effect of conflict, violence, intimidation, or coercion by and between authorities. Instead, the various exchange parameters defining an authority at a given point in time reflect these effects. For example, the capacity parameter value of a non-state actor may go down if the police are effective in limiting its capacity over a particular time-period. In reality, in all three communities, the target authority (OPC, Kamkunji, or gangs) had difficulty establishing a relationship with the community in large part because of efforts by its competitors. The scenario parameters are set based on these conditions. However, interactions outside of value exchange are not part of agent decision-making or strategy.

The instability patterns for the three communities are also significantly different with and without communication. It is expected that in systems with a high degree of actor interdependence, state transitions accompany distinct peaks in system instability, or activity (Scheffer et al., 2012). The results of this experiment follow this pattern, though the extent to which the profiles in each case vary are different (see Figures 14-16, Right images). In the Kibera simulation, the initial system response to the entry of A1 is similar with and without communication. This is due to the poor performance of A0, as discussed earlier. Overall, the response without communication is lower over the five-year transition period than with communication, as illustrated in Figure 23, right panel. The Mushin and Manenberg scenarios, shown in Figures 24 and 25, respectively, also display a relatively slow decrease in instability after the peak. The system behavior observed in the three simulations without communication is due to the time that it takes resident agents to accrue sufficient positive feedback from the target authority to 'lock-in' the relationship.

4.1.2.2. Discussion of Results of Segregation Experiment

The principal finding of experiment 2 is that the intensity of feedback effects caused by agent communication with respect to structure resilience are directly related to the level of group segregation. This relationship is true when one or both authorities express lower membership degree towards one of the social groups. In both Mushin and Kibera, the dominant ethnic militias provided services almost exclusively to members of

their ethnic group (Abdulazeez, 2013; Anderson, 2002). In contrast, the government attributed far greater membership degree to residents of all groups.

Validating this finding with real world observations is difficult. However, group identity and spatial homogeneity are evident in the Kibera case, and to a lesser degree in the Mushin case. Luo residents in Gatwekera village, Kibera comprise a plurality, not a majority of the population. The ability of the Kamkunji militia to rapidly establish their presence in the village, and their initial selection of it are likely due to the segregation of Luo and other ethnic groups (Anderson, 2005; Joireman & Vanderpoel, 2010). This is evident in reports of Kamkunji taking over public spaces for open community meetings in contravention of national laws against public political organizing under President Moi (Joireman & Vanderpoel, 2010). This type of activity is possible when there is a strong degree of spatial and social control due to the physical distribution of supporters in an area. In Mushin, Yoruba residents are approximately 70% of the population. This high concentration and relatively high segregation levels supported the OPC's ethnically based engagement strategy (Guichaoua, 2009).

One shortfall in this particular experiment, and a feature of the ABM, is that segregation is a static parameter and not able to serve as the dependent variable in experiments. In reality, segregation is a dynamic property of communities. It is inter-related with exchange patterns, authority territory changes, and group relations on multiple time scales (Finney & Jivraj, 2013; York et al., 2010). The causal relationship between these variables is unclear. Thus, the relationship between segregation and

structural resilience should also include experiments where segregation is the dependent variable as well.

4.1.3. Research Question 3

Research question 3 investigated the relationship between authority attributes, external events and issues and structure resilience. It addressed the question: Why and how do particular conditions such as corruption, actor resources, persistent in-group bias, event frequency, and issue/stress patterns affect the resilience of authority structures? The results reinforce the CAM's usefulness in a wide range of likely scenarios of interest to policy makers and analysts.

The approach is valuable for three reasons. First, each experiment reflects an issue or dynamic that is found in multiple cases of contested communities. These phenomena are important factors undermining the resilience of government dominated authority structures. Second, the adaptation patterns unfold over periods of years. Differences between reinforcement schedules at these time scales and for populations of hundreds or thousands of subjects are outside the mainstream SET research. This is due primarily to the complications of conducting experiments at this scale. However, these effects are highly relevant to understanding the resilience of community social structures. This effort illustrates the usefulness of the model in contributing SET research involving situations that are more complex. Third, these experiments assist in model verification. Each experiment isolates an important authority attribute and studies its effect on system

behavior. Finally, these experiments illustrate how a single model can account for the effects of several different phenomena on authority structure dynamics.

4.1.3.1. Discussion of Membership Reinforcement Experiment

The simulation results support the hypothesis that the frequency of membership reinforcement is directly related to the strength of the relationship between an authority and its target constituency. Many authorities select episodic events such as festivals, anniversaries, memorials, and elections to reinforce their support for a constituency (Arias, 2006; De Smedt, 2009; Guichaoua, 2009; Klopp, 2001). These efforts often provide or promise resources and services and extend for limited periods. They may also reduce interactions with non-constituents. The results of this experiment offer an exchange perspective on why this may be an effective strategy. The effect of these strategies is also dependent on the level of reinforcement during non-critical periods. Authorities with poor engagement except for in proximity of an event are unlikely to benefit if the inter-event times are relatively long.

An unexpected finding from the simulated results is that the value of pursuing this strategy decreases non-linearly as the inter-event period increases. A likely reason is that any positive feedback caused by resident communication becomes less relevant as the time between implementing the strategy increases. The underlying reason for these results is that changes in membership considerations have a direct effect on capacity. If

an authority is less likely to provide resources to an out-group then there are more resources available for the in-group.

4.1.3.2. Discussion of Access/Corruption Experiment

The principal finding is that the probability of demanding a bribe can replicate the effect of fixed costs under the right combination of bribe frequency and population resource levels. The role of corruption in undermining popular support for institutions is reported in all three communities studied here (Alemika & Chukwuma, 2005; Leggett, 2004a; Marx et al., 2013). The results of this simulation present one explanation of the dynamics at work. Corruption increases the cost of accessing authority resources. When bribes are demanded often enough and they raise costs above the threshold that residents can afford it negatively affects exchange histories.

However, these experimental findings only address the pragmatic or instrumental aspects of corruption. What the model does not address is how corruption often undermines a community's sense of fairness or justice (Tyler & Blader, 2003). This non-material or symbolic consideration also contributes to the willingness of residents to engage authorities (see Homans 1958). As discussed later in this chapter, these considerations are one area for expanding the application of SET principles within the model.

4.1.3.3. Discussion of Capacity/Stress Experiment

The simulated results confirm the general observation that social stress provides an opportunity for actors with higher resources to increase their share of constituent support. Conversely, low stress levels allow actors with relatively low resources to maintain a larger base of support in a community than they might otherwise be able to do.

This simulated adaptive behavior is based on the rules of exchange in the model. Once a positive relationship begins, it will tend to continue unless there is a compelling alternative. Another implication of this finding is that simply because an authority can resolve all issues, does not mean that all residents will eventually prefer it. If an alternative, even one that has low capacity exists it is likely to gain supporters, though these relationships are not very resilient.

As in the access experiment, the model only considers the instrumental aspects of decision-making with respect to authority performance. Agents do not have any additional performance related bias, either positive or negative. However, periods of social stress do create lasting impacts on the willingness of residents to engage with authorities in the future. This additional consideration, or even the long term effects on changing exchange environments is not addressed in the SET research. Instead, the current model is based entirely on the mainstream SET perspective that there is a consistent relationship between the frequency of relationship reinforcement and the strength of the relationship.

4.2. Contributions

The methods and results detailed in chapters 2 and 3 demonstrate the relevance of CSS and CAS approaches to studying political phenomena. They also provide specific benefits in the fields of social exchange theory, political authority, and public policy analysis related to urban communities. A description of the relevance of these results in each area follows in sections 4.2.1 – 4.2.4.

4.2.1. Computational Social Science and Complex Adaptive Systems

The CAM advances CSS and the study of socio-political systems within a CAS framework. The CAM extends the basic polity and contentious polity models by focusing entirely on the decisions that resident and authority agents make with respect to forming relationships. These relationships are the basic social structure through which authorities mobilize resources and support to accomplish goals. It is also the structure through which residents influence authorities to satisfy their needs. The implementation of the CAM as an ABM demonstrates that the inclusion of these basic authority-resident interactions are a viable addition to other models.

This research goes beyond previous models of polity dynamics, specifically, RebeLand (Cioffi-Revilla & Rouleau, 2010), described in more detail in section 1.2. The selection of SET as the theoretical basis for authority-society interactions is a significant extension of the dynamics in the RebeLand ABM. RebeLand was the first ABM to

implement an entire polity within a realistic socio-natural environment. However, RebeLand did not address how authority structures form. Instead, agents in the ABM communicate their evaluation of authority value through their satisfaction level. In contrast, the CAM models a participatory relationship between authorities and residents closer to that described by Migdal (1988). This has the effect of introducing a more realistic interaction dynamic into these relationships that can allow more complex social structures to emerge in larger scale models such as RebeLand.

Given the purpose of the CAM and its ABM implementation, this is the first model to directly address the emergence of authority structures in urban communities. It joins a collection of related ABM's used to investigate related phenomena such as the emergence of organized crime (Pint et al., 2010), informal power structures (Geller & Moss, 2008), social exchange networks (Pujol et al., 2005), ethnic conflict and resource scarcity (Bhavnani et al., 2008), and the growth of urban slums (Patel et al., 2012). While all of these ABM's address some relevant aspect of authority and the relationship between authority and social phenomena, they do not directly address the emergence and resilience of the community structures. However, all of these efforts could benefit from the addition of these dynamics. The CAM offers one approach making these extensions.

Finally, the computational methods used in this dissertation have significant potential for advancing research in the fields that were investigated here including public policy applications. These contributions are addressed in greater detail in sections 4.2.2 – 4.2.4

4.2.2. Social Exchange Theory

These results provide evidence that the SET research program should be expanded to include more complex applications and additional research questions. This research is most relevant to three areas: The size of the social structures that fall within the scope of SET research; explaining the relative resilience and stability of different social structures; and studying social structures consisting of multiple exchange types. The ABM developed for this dissertation demonstrates how CSS can contribute to research areas that are difficult, if not impossible, to investigate using traditional methods such as human subjects experimentation and field research.

One area for consideration is the size of the target social group. The CAM investigates social structures emerging from a population of hundreds to thousands of actors. However, the majority of experimental research in SET focuses on relationship pairs and small group structures. This is due primarily to the practical difficulties in conducting this type of research with larger groups. The result is that SET is primarily applied to organizational problems, and research takes place with these settings in mind. It is an open question whether there is an upper limit to the size of the network that is appropriate for analysis with SET concepts. The results of these experiments using a computational model indicate that there is merit in pursuing this question. However, in very large groups, there are likely to be additional dynamics at work that are not included in the SET framework.

SET research has also not adequately focused on the resilience and stability of the larger social structures that emerge from networks of exchange interactions. This is a critical shortfall considering that one of SET's original motivations was to explain the dynamics of social structures (Blau, 1964; Homans, 1958). Additionally, either as an independent or dependent variable, structure is central to SET research (Lawler, 2001; Molm, 1994; Pujol et al., 2005). Affect theory is one example of a research program that does tangentially address the idea of structure stability (Lawler, 2001; Lawler et al., 2008). The theory provides experimental evidence that certain types of exchange produce stronger commitment to group structures. POS and LMX also suggest a relationship between organizational level effectiveness and dyadic relationship strength (see Eisenberger et al., 1986; Lind & Tyler, 1992; Settoon et al., 1996). However, the direct relationship between individual exchange decisions and the resilience of an emergent social structure has not been adequately explored.

A third area for further research concerns complex social exchange networks that consist of multiple exchange types, or that transition between types based on conditions. This is directly related to the first two areas just described. Expanding the number of actors in the structure is likely to expand the diversity of exchange types, even on narrowly defined issues. Combinations of exchange types make it more difficult to identify the contributions to structural stability of each. However, this level of analysis is essential to understanding community level social dynamics.

It is unclear how to classify the exchange relationship between residents and authorities using the four generally accepted SET types: reciprocal, generalized,

instrumental, and negotiated (see Takahashi 2000; Molm, Collett, and Schaefer 2007; Molm 1994). Resident-authority interactions can be considered *reciprocal* exchange because the actors provide value without knowing if it will be returned by the partner. This is the approach used in this model. However, even the exchange rules in this research are not clearly reciprocal exchange.

In the real world, resident-authority interactions are very often conducted within a framework of *negotiated* exchange. Community members and authorities come to informal understandings over exchange terms through reciprocal exchange, thereby forming expectations and trust (Barnes, 1986; Singerman, 1995). When the government is involved, negotiated exchange may include formal legal obligations. Authority structures also involve a degree of *generalized* exchange. When an authority responds to a resident's request to arrest a criminal, the community benefits from reduced crime rates. Other people are also more likely to call the police when they experience an issue (Curtis, 1998; Leggett, 2004a). In another example, in the Kibera case, threats made by militias and gangs in individual landlord-tenant disputes correlated in lowering or eliminating rents for large blocks of residents (De Smedt, 2009).

Therefore, for practical public policy applications, there is a need to develop theory to include mixed exchange networks, large populations, and continue to refine understanding of structural resilience. There is research in SET that considers a progression of exchange types, but not a simultaneous mixture (Mitchell, Cropanzano, & Quisenberry, 2012). Mixed exchange structures add a significant level of complexity to any theoretical work, and soften the boundaries between the various SET perspectives.

However, the CAM, particularly its current simplicity illustrates the need to pursue this research direction. Otherwise, the study of complex social structures and authority, in particular, will be underserved.

4.2.3. Political Authority

This research performs a basic test of the concept of authority as an exchange relationship (Ferguson & Mansbach, 1996; Keehn, 1974; Migdal, 1988). This concept is so often applied as an explanation for political phenomena that it can almost be considered a first principle in the field. It is most often found in the literature in some variation of the assertion that the failure of one authority to address a public need provided an opportunity for another authority to establish itself as a viable alternative (Clunan & Trinkunas, 2010; Guichaoua, 2009; Lambrechts, 2012; Samara, 2011). The research conducted here offers a simple controlled test of this concept by implementing a relevant individual decision-making model in an ABM. It investigates, from the bottom up, how these transitions take place and why the structures that emerge persist. By modeling these dynamics, this concept of authority can be applied in a variety of related research efforts.

The results of this research contribute to a theoretical conception of authority structures that is more relevant to understanding regional and global patterns as an emergent feature of local dynamics. The current model does not prevent the expansion of the spatial boundary, the number of actors, or the number of social groups. Community,

in the context of the CAM is whatever physical area is relevant to the research goals. Though the structures described in the CAM are spatially bounded, the model itself can be extended to cover any area of interest. Taken to its extreme, there should be a way to investigate a global network of authority relationships, given sufficient information concerning authorities and residents.

This globally interconnected perspective on authority patterns is found in limited theoretical work (i.e. Rosenau, 1992). However, it is a central theme throughout much of the security studies literature on transnational non-state networks (Li & Schaub, 2004; Miklaucic & Brewer, 2013; UNODC, 2010). In these cases, groups maintain cross-border links with one another to support their business model and strategic goals. However, wherever they are physically present and conditions demand a degree of social control, these groups often attempt to maintain the support of the population. The expansion of organized crime and street gangs into the international narcotics trade and other areas since the 1990's is one example (Carter, 1994; Ketterer, 2001; Samara, 2011). These non-state actors are nodes in community authority structures as well as in international criminal networks.

This scalability of the CAM allows it to be used as a building block for larger multi-scale structures and models. The ABM integrates time, space, and actors in a single framework, but does not limit the scale at which the analysis is focused. This approach is not widely found in the existing literature on political authority. This is due primarily to the preference for limiting analyses to a single level of hierarchy, the state, a community,

or a region, for example. This focus has advantages for isolating causal relationships, but it fails to adequately reflect the multi-scale effects that are present in the real world.

One consideration is that the scalability of the CAM suggested by this analysis is not necessarily valid in practice. There may be behavioral changes at higher levels of hierarchy that the basic elements of this model do not address (see Blau, 1977). However, by applying computational methods and simple decision-making models, there is great potential to investigate this area further. Additionally, by maintaining the individual resident as the decision-making actor and investigating emergent structures in terms of groups, the effects of scaling should remain limited. The problems arise when scaling introduces conceptual social structures such as cities, districts, regions, and states as actors in the model. This is due to uncertainty as to how to model the behavior of these actors and the open question as to whether the SET model remains applicable.

4.2.4. Public Policy

With respect to public policy contributions, governance goals may require policies that either reinforcement or undermine community authority structures. The CAM offers an analytic orientation intended for this purpose. The three community cases illustrate how systems adapt to government weakness or ineffectiveness by strengthening the relationships between constituencies and non-state actors. However, the model is just as relevant to investigating how to return a system to government control.

The results of the experiments indicate that efforts to break the resilience of a structure should focus on the underlying conditions that sustain the membership, access, and capacity advantages or undesirable actors. Within this framework, there are two fundamental requirements for structural change. First, conditions must change sufficiently to undermine structural resilience. Second, conditions must influence the system to adapt in a desirable direction. Consequently, the analyst is concerned with the following questions. What actions would degrade the membership, access, and capacity of an undesirable authority? What actions would improve the membership, access, and capacity of a favored authority? How would the system adapt if these actions were effective?

In practice, it is difficult to both undermine the authority structure and positively influence its adaptation path. The results of this research offer insights into why certain widespread strategies, when applied in isolation are unsuccessful. The first strategy involves a heavy emphasis on security operations (see sections 2.6.1. and 3.1.3). The second strategy focuses on reducing the frequency of key social issues. There is nothing objectively wrong with either strategy, and in most cases, they need to be part of a comprehensive effort. However, an overemphasis on either can produce or reinforce undesirable results.

A widespread response to loss of government control over a community is to confront competitors using a combination of increased security operations and the legal system. These efforts can undermine structural resilience, but drive the system toward an undesired end state. Very often the results are counter-intuitive. The Manenberg case

study, section 2.6.1., clearly illustrates the paradox of aggressive security operations (Samara, 2010, 2011). The strategy adopted by the security services actually reinforced the relationship between the community and street gangs and vigilantes (see also Arias 2013; Venkatesh 2008). These operations often provide non-state actors the opportunity to reinforce membership and respond with their greater capacity to the increase in social stress (see section 3.3.3). They also place residents into confrontations with security forces that undermine the membership degree attributed by security forces to residents.

Addressing the issue rate directly is another common strategy. This has the potential to improve human security and institutional legitimacy, both important elements in developing a positive relationship with a community. This requires improvements to service and resource delivery.

However, as a collection of studies of Manenberg in the late 1990's found, simply doing things better is often insufficient to fundamentally change authority structures (Bennet, 2012; Lambrechts, 2012; Samara, 2011). This is particularly true in situations where alternative authorities are willing to use violence to reduce the willingness and opportunity for government, specifically, the police, to engage with the community. As the model demonstrates, reducing the issue rate does not necessarily reduce the effect of past exchange interactions (see also sections 3.1.2 and 3.3.3). What is important is that residents attribute the improvement in conditions to the desired authority. As demonstrated in the Mushin case, section 3.1.2, if an alternative authority is already embedded, then improved performance may take a long time to show a positive effect. In

fact, the transition time may be greater than the public policy or political decision-making cycle.

The ultimate value of CSS and agent-based models is that they can provide significant insights into the likely effects of a range of policies on both structure and adaptation. The computational simplicity of the current model allows investigation of a wide range of scenarios. Extensions of the current ABM outlined in section 4.4 will improve the relevance of the model for public policy analysis.

4.3. Future Research

This version of the community adaptation model is the basis for a more comprehensive research program on authority structure dynamics. The results indicate that the social exchange framework is a viable basis for developing theory and supporting public policy analysis.

However, the current version of the ABM is too rudimentary to effectively address the full range of complex conditions facing policy makers and analysts. First, the agent behaviors are very simple and do not include other relevant decision-making factors identified in sections 4.2.2-4.2.4. This is by design. The purpose of this dissertation is to define the theory and test its basic assumptions. This establishes its viability for more complex design extensions. Second, the model describes authority dynamics concerning a single issue in isolation from others. This significantly understates the actual complexity of real world communities. However, the necessity to test the

model's basic design before moving to more complex scenarios required the isolation of a single issue authority structure. This clarified the relationship between parameter changes and the adaptation of authority structures.

Several efforts will resolve these shortfalls and advance this research program. In each area, the basic principles and relationships of the CAM remain applicable. Each effort adds greater realism to the model and extends its explanatory power.

The current model describes an authority structure in terms of a single social issue. In fact, the degree of control an authority exercises in a community, and the dependent relationships between all actors are a function of exchanges concerning multiple issues (Molm, 1997; White, 2008). The degree of overlap between multiple structures varies with the situation. The effects of this overlap are poorly understood. Thus, the following questions are raised. How does the breadth and strength of the complete set of exchange issues alter the strength of the overall relationship between two social actors? How does the breadth and strength of the complete set of exchange issues impact the basic partner selection process modeled in the CAM? What are the implications of structural overlap for resilience in each of the relevant single-issue structures?

The interaction between multiple communities is another area for further research. Experiences in the CAM are completely contained within the target community. This is an overly restrictive condition. It is expected that communication effects should extend beyond the immediate community boundary (Clunan & Trinkunas, 2010; Miklaucic & Brewer, 2013). This is due, in part, to the combination of near ubiquitous access to global

communication and the connections between communities due to domestic and international migration. What is not well understood is how inter-community communication actually influences local (community) exchange structures. The reality is that in most cases residents have to resolve local issues using locally relevant relationships. However, within an urban area or sub-area, these effects are likely to have relevance to policy makers, and are worthy of further study.

The effect of exchange relationships between state and non-state actors on authority structure resilience is raised earlier with respect to public policy analysis. These relationships and their effects on communities are a long-standing research topic in many fields. However, they are not included in the current ABM. This does not undermine the experimental results. The effects of these relationships are integrated as best as possible into the relevant authority attribute settings. Including these dynamics in the current design would make it difficult to isolate the key dependent variables. That said, inter-authority dynamics must be included in a complete model.

The current model focuses on exchange of value without consideration of other relevant factors identified in the SET literature. The ABM applies a simple set of interaction rules based on the perspective that exchange relationships form and persist due to self-interest and mutual need. They strengthen over time due to repeated positive exchanges that reinforce confidence that the relationship will provide value. This approach associates the CAM with the instrumental and rationalist roots of SET. One critique is that this approach ignores the effects of social and emotional considerations in partner selection (Lawler, 2001; Mitchell et al., 2012). In the real world, residents may

eliminate or reduce interaction frequencies with authority choices for reasons beyond what this version of the model implements. This may be due to particular values, or actions it perceives as unjust (Masterson et al., 2000; Settoon et al., 1996). The research on group authority dynamics also indicates that justice and fairness considerations may play a greater role than performance in maintaining authority structures (Lind & Tyler, 1992; Tyler & Blader, 2003).

As the SET research program has progressed, the emphasis has shifted to explaining how self-interest can compete with other conceptions of value such as group solidarity, or not factor into decision-making at all. The current model does not include this additional level of decision-making complexity. This is primarily because the existing research on community authority dynamics heavily emphasizes instrumental and performance-based exchange considerations (i.e. Arias, 2013; Ayodele & Aderinto, 2014; Leggett, 2004a).

Another reason that more complex decision-making was not developed for this model is that a primary research goal was to identify the simplest decision-making model based on SET that would replicate real world observations. Given the very general qualitative data available for validation, it is unlikely that the additional social complexity required in the ABM to implement these features would have made a significant difference in the results. However, despite the rationalist simplicity of the current ABM, its design is readily expanded to include agents with greater decision-making complexity.

Indirect access to authority structures and group dynamics are other areas for further research and integration into the CAM. Indirect access includes patronage

networks and exchange mediators. Group loyalty describes the role of community norms and identity reinforcement.

Patronage networks introduce a layer of exchange between individual community members and authorities (see Eisenstadt and Roniger 1980). Patrons can mediate membership and access issues for residents. These networks are based on the delivery of value. However, trust, and relationship building processes are much more relevant in patron-client relationships than when institutions or organizations interact relatively anonymously with residents. Several community level analyses identify the role of patronage networks in enabling a form of indirect exchange between residents and various authorities (Barnes, 1986; Haenni, 2011; Singerman, 1995). What is not clear and demands further research is whether patronage networks reinforce or undermine resilience, how, and under what conditions?

Another area of research closely related to patronage is that of authorities mediating exchange for one another. A common example of this phenomenon is the relationships between non-state actors and political officials (Abdulazeez, 2013; Anderson, 2002; Arias, 2006; LeBas, 2013). Politicians seeking votes from a constituency may align themselves with locally influential groups, even criminal groups for political leverage (Patel et al., 2012). Kibera, and to a lesser extent, Mushin exemplifies this situation.

Relationships with members of state institutions can also provide legitimacy to non-state actors. This status may enter into resident decision-making due to group solidarity or fear of reprisals. However, the CAM does not include authority-authority

relationships and is limited to actors that can provide value directly to residents. Expanding the actor types to include politicians, NGO's, and other community leaders would expand the complexity and realism of authority structures.

Community norms and traditions also create social structures that may influence an individual's authority selection. This is particularly true where communities have existing traditional authorities or processes that compete with other state and non-state actors (Enechojo, 2013; Haenni, 2011; Joireman & Vanderpoel, 2010; Singerman, 1995). Loyalty to these authorities is not always based on the return of value. The CAM is thus, in a poor position to account for the appropriate exchange dynamic in these situations.

Finally, further field research is required to provide the insights required to expand and validate the current model. An important shortcoming of this research was the absence of relevant statistical and survey data that was directly relevant to model development and validation. The time and resources required to conduct original field research to resolve this shortfall were not available. Instead, the model was based on relevant secondary sources.

Case studies and surveys provide a wealth of information concerning resident preferences and authority strategies. However, there is a shortfall of information in two areas. First, there is a need for more detailed understanding of how individuals weigh various factors when selecting an authority. What information is important when considering a partner? Who do individuals consult prior to making a selection? How much influence do other people have over partner selection? Second, understanding how organizations or authorities select engagement strategies is narrowly focused on

particular actors. A more general understanding of several areas would help. When and why do authorities change strategy? What is the relationship between authority strategy and perceived support? What is the relationship between authority strategy and inter-authority competition? How do state and non-state actors assess support?

Selecting communities for field research is also an important consideration. In most cases, communities are selected because they have already exhibited the target phenomenon. Research begins several years after critical transition periods take place. Security and resources are a common concern when research takes place in contested communities, particularly during periods of instability. Overcoming these challenges requires research methods such as performing less intensive monitoring and sampling for multiple likely cases over several years or around critical event periods. However, this requires dedicated teams of researchers with local expertise and long-term funding.

4.4. Summary

This chapter discusses the results of the various experiments for each research question in section 4.1. It provides context for the case study findings based on actual observations of adaptive behavior found in secondary sources. Based on the experimental results, the following claims are supported: (1) SET is a viable basis for modeling individual interactions between residents and authorities within the CAS framework; (2) Resident communication of authority experiences is a necessary element of authority structure resilience; (3) The model adequately represents the effects on resilience of

conditions influencing willingness, opportunity, and capacity for agents to interact such as corruption, identity group bias, and varying issue rates.

Section 4.2 provides a discussion of the contributions of these findings in several areas including public policy analysis, SET, the dynamic features of political authority, and computational models of political systems and phenomena. These contributions also set the stage for further research that expands on this effort as described in section 4.3. Valuable extensions include more complex decision-making, authority structures such as patronage networks, inter-community relationships and effects, and more computationally demanding simulations. With respect to the computational aspects of this research, adding more residents, more detailed physical features, and more complex non-exchange related social behaviors would provide more effective testing of the CAM than that performed here.

CHAPTER FIVE
CONCLUSION

This dissertation described a theoretical model based on social exchange theory that explains the resilience and adaptation of community authority structures. It tested this theory with a series of experiments using an agent-based model. These experiments include a comparative case study of three communities, Kibera, Manenberg, and Mushin in Nairobi, Kenya, Cape Town, South Africa, and Lagos, Nigeria, respectively. The goal was to answer three research questions that are central to developing this theory and implementing it in an ABM:

- Is social exchange theory a viable framework for modeling authority and resident decision-making with respect to partner selection in small communities?
- Is an authority structure a network phenomenon or an aggregation of independent exchange relationships between two actors?
- Why and how do particular conditions such as corruption, actor resources, persistent in-group bias, event frequency, and issue/stress patterns affect the resilience of authority structures?

There are three principle findings. First, a CAS framework is appropriate for modeling the dynamic properties of community authority structures. Within this framework, SET offers a viable decision-making model for individual agents. Second, actor interdependence, specifically, the communication of experiences, is a necessary condition in explaining authority structure resilience. Finally, this model offers a unified

framework for understanding the effect of a range of conditions including corruption, reinforcement of constituency membership, and authority responses to community issues on structure resilience. The complete set of results is found in sections 3.1 – 3.3 and a discussion in section 4.1.

Overall, these findings support a CAS perspective for understanding the resilience of community authority structures. An authority structure is defined as the network of instrumental exchange relationships between and among authorities and individual residents in a defined space, during a specified timeframe, and concerning a particular social issue. Authority structures are an emergent feature of resident and authority adaptation to community conditions. The resilience of these structures is a function of how individual actors calculate relationship value given their options, preferences, experiences, and goals. Community-authority relationships persist because they provide value to the actors. The willingness, opportunity, and capacity of two actors to provide value to one another is the basis for these relationships. Willingness emphasizes social and strategic preferences. Opportunity addresses access challenges associated with interacting. Capacity refers to resource availability to provide value to a partner. External conditions and secondary information from other actors experiences influence actor assessments of these three conditions.

This research makes significant contributions in several fields of research. The principle contribution is the development of a theoretical framework for analyzing how and why community authority structures form and change. This theory adopts previous approaches to studying socio-political systems based on complex adaptive systems theory

(Cioffi-Revilla, 2005, 2008, 2011). It extends these theories in two critical directions. First, it applies the polity framework to the sub-state level, to urban communities. This approach is consistent with the CAS/polity approach to political systems analysis, but to date this is the first example of its specification in a model of community level dynamics. Second, this model specifically addresses the question of why authority-society/community relationships form in the first place. The rich body of theory on authority addresses this relationship (see section 1.2). However, this is one of the first efforts to apply these principles to the analysis of urban community authority structures. Further, by conducting this research using an ABM, it is demonstrated that computational methods can play a central role in developing and testing political theories.

A second contribution is to the growing cluster of computational models of socio-political systems and related phenomena described in section 1.2.5 (i.e. Axelrod, 1995; Bhavnani et al., 2008; Carley et al., 2006; Cederman, 1997, 2001; Cioffi-Revilla & Rouleau, 2010; Louie & Carley, 2007). Despite this growth, there are very few agent-based models of polities that investigate how political structures emerge. The RebeLand ABM (Cioffi-Revilla & Rouleau, 2010) described in section 1.2.5 is the most relevant example as it is an implementation of the contentious polity model (Cioffi-Revilla, 2011), which is also the basis for this research (see also Geller & Moss, 2008). The ABM developed for this dissertation extends the authority-society relationship modeled in RebeLand in one critical way. By modeling the interactions between authorities and residents as exchange relationships that vary in importance and value over time, this ABM significantly advances how the issue of public support for a government or non-

state actor is implemented computationally. This ABM also demonstrates how issues of public support and influence, as specified in the contentious polity model and implemented in RebeLand, can be modeled using a dynamic, network-based approach.

The ABM also implements SET as the basic social dynamic driving agent relationships. As discussed, this makes significant contributions to other fields. However, it also illustrates how computational methods can be applied to expanding the SET research program itself. The ability to mix exchange structures and test the interactions of large communities of agents are interesting areas where SET research could go where human subjects experimentation cannot.

This research is also one of the first efforts to demonstrate a framework for conducting comparative analysis of urban communities (Pierre, 2005). It develops a theory that can be applied to study community authority dynamics is widely varying conditions. It also demonstrates how computational methods can be effectively used to support this analysis. This overcomes the significant resource, logistical, and security issues involved with conducting field research in multiple locations, over several years, in communities where conflict is likely.

Taken together with other relevant models of community phenomena such as the spatial expansion of slums (Patel et al., 2012) or participation in organized crime (Pint et al., 2010) it contributes to a growing understanding of the complex, dynamic properties of urban communities. This approach also complements and moves toward theoretical unification of the significant body of field research on community political dynamics.

Finally, this is one of the only models to directly address the issue of resilience and adaptation of community authority structures in a way that can be applied to support public policy analysis. Both the theory and ABM provide a baseline for understanding how efforts to undermine or support a particular authority structure are likely to change conditions in these communities. The CAM directly addresses the question: if actors leave or enter the community, or if conditions change, will the structure change, and if so, how? These questions are central to assessing policy impacts, but to date, the theoretical basis for these analyses has been absent. Further, there are few models that address the structural aspects of this challenge.

In conclusion, the research detailed in this dissertation makes significant contributions to computational social science, political science, urban studies, and public policy analysis. However, the model outlined here has much greater potential as the basis for future research into community authority structures. Because of its emphasis on implementing a model based on 'first principals' of authority-society interactions, it is readily expanded to research into more complex community social structures, the interactions between communities, and the interactions between higher levels of social hierarchy and communities. These relationships and structures are central to understanding a wide range of phenomena including crime, terrorism, human settlement and migration patterns, economic development and trade, among others. As demonstrated here, the use of computational methods is an essential element of this research program.

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APPENDIX 1
GLOSSARY

Agent "A computer program, or part of a program, that can be considered to act autonomously and that represents an individual, organization, nation-state, or other social actor (Gilbert, 2007, Glossary)."

Agent-based model "A social agent-based model (ABM) is an object-oriented computational model for analyzing a social system consisting of autonomous, interacting, goal-oriented, bounded-rational set of actors that use a given rule set and are situated in an environment (Cioffi-Revilla, 2014, Section 10.4)."

Authority An individual or group that can compel others to act in certain ways and within certain boundaries of behavior (Ferguson and Mansbach, 1996, p. 35).

Community "...a community is best described as an area of the metro region with at least one institution that is focused on local well-being... community studies provide evidence of specific links to sociospatial organizations in the area...(Gottdiener & Hutchison, 2011, Chapter 8)."

Complex polity "A complex polity is a political system composed of both official "vertical" state institutions defined by constitution, as well as one or more alternative "horizontal" institutions, such as religious, economic, paramilitary, or even criminal organizations. Both vertical and horizontal polities that compose a complex polity have policy-making capacity for the provision of public (and in some cases private) goods aimed at addressing various societal needs (security, welfare, identity, among others) (Cioffi-Revilla, 2011, p. 1)."

Constituency A group of actors bound by an interest in a particular outcome such as the solution of a particular social issue or maintaining a particular social norm (source: author).

Contentious politics Collective political struggle where at least one actor is the government (McAdam, Tarrow, & Tilly, 2001, Chapter 1).

Class "In object-oriented programming, a class is a specification of a type of object, showing what attributes and methods instances of that class would have (Gilbert, 2007, Glossary)."

Equilibrium "A steady-state condition of a dynamic system where the interactions among all the variables are such that all the forces are in balance, and no variables are changing (Walker & Salt, 2006, Glossary)."

Emergence Higher level patterns and structures created by the interaction of actors at lower levels of a system's hierarchy(Miller & Page, 2007, Chapter 4.1).

Model "A simplified representation of some social phenomenon. Executing or "running" the model yields a simulation whose behavior is intended to mirror some social process or processes (Gilbert, 2007, Glossary)."

Modeling environment "A computer program that allows the user to create, execute, and visualize the outputs of a simulation (Gilbert, 2007, Glossary)."

Network "The set of connections (number and pattern) between all the actors in a system (Walker and Salt, 2006, Glossary)."

Polycentric polity A system comprised of multiple authorities whose decision-making is independent of the others (Ostrom, Tiebout, and Warren, 1961, p. 831).

Power law "A relationship between two variables such that one is proportional to a power of the other. If one takes logarithms of each variable, the relationship between the logged variables is linear and can be represented as a straight line on a plot of the two logged variables. Many relationships between variables describing complex systems follow a power law (Gilbert, 2007, Glossary)."

Regime "A set of states that a system can exist in and still behave in the same way-still have the same identity (basic structure and function) (Walker and Salt 2006, Glossary)."

Resilience "The amount of change a system can undergo (its capacity to absorb disturbance) and remain within the same regime-essentially retaining the same function, structure, and feedbacks (Walker and Salt, 2006, Glossary)."

State of a system "The state of a system is defined by the values of the state variables that constitute the system (Walker and Salt, 2006, Glossary)."

System "The set of state variables (see State of a system) together with the interactions between them, and the processes and mechanisms that govern these interactions (Walker and Salt, 2006, Glossary)."

Simulate "To run a model and observe its behavior through time (Gilbert 2007, Glossary)."

Spatially explicit "A spatially explicit model is one in which geography is represented within the model, for example, by locating all simulated objects on a grid or other spatial representation (Gilbert, 2007, Glossary)."

Target "The social phenomenon or process that is represented by a model (Gilbert, 2007 Glossary)."

Validation "The process of checking that a model is a good representation of the target (Gilbert, 2007, Glossary)."

Verification "The process of checking that a model conforms to its specification, that is, that it does not include errors, or "bugs." (Gilbert, 2007, Glossary)."

APPENDIX 2
MODEL PARAMETER METHODS

This appendix reviews the methods used to set simulation parameter values. The list of model parameters is found in Table 13.

Table 13. List of ABM parameters

Parameter	Description
rand-seed	Random seed (int)
start-yr	Simulation start year (int)
end-yr	Simulation end year (int)
grid	The length and width of the community space (n-patches)
AUTHORITY PARAMETERS	
event-yrs	Simulation years that events take place [event years]
auths	A list of the authority identities [authority id's]
auth-init	Authorities present at the beginning of the simulation [authority id's]
auth-entry	Year each authority enters the simulation [year [authorities]...]
auth-exit	Year each authority exits the simulation [year [authorities]...]
auth-resources	Resources available to expend each day [[A [year resources]...]...]
auth-const-cmty	Constituency membership degree for each authority, for the community, for any relevant year. [[A [year value]]...]
auth-const-ident (yr: g0, g1)	Identity membership degree for each authority, for each group, for any relevant year. [A [group [year value][y v]] [group [y v][y v]]]
auth-const-event (yr: g0, g1)	Event membership degree for each authority, for relevant years, for each group. [A [year [group group ...]]]
auth-event-concern	Days from event there is 50% probability of event strategy. [A [year days]]
auth-cost	Fixed costs of accessing authority by a resident. [A [year cost]]
auth-corruption	Probability of demanding a bribe during an interaction. [A [year pr.]]
auth-bribe	Cost of bribe. [A [year cost]]
auth-territory	Spaces an authority operates in. [A [min-x max-x][min-y max-y]]
RESIDENT PARAMETERS	
issue (type)	How residents are selected to experience issues ["spatial", "group", "random"]
issue-data (yr, g0, g1)	Number of residents to select "random" [year number], "spatial" [year spaces number-per-space], "group" [year number-group0 number-group1]
segregation	The probability of settling in territory designated for the resident's identity group (float)

comms-scenario	Indicates if agents communicate with one another outside of exchange interactions. (bool)
groups	The list of group identities. [group id's]
population-init (g0, g1)	Initial population for each group. [Group0 Group1...]
population-update	Period to update simulation data in days (int).
population-inc (p(increase), n-increase, otherwise	The population increase every parameter update period. If U[0, 1] < probability, then increase by x-agents, otherwise increase by y-agents. [year [G0-prob., G0-x, G0-y]...]
population-inc (p(decrease), n-decrease, otherwise	The population decrease every parameter update period. If U[0, 1] < probability, then decrease by x-agents, otherwise decrease by y-agents. [year [G0-prob., G0-x, G0-y]...]
res-resources (poisson)	The number of resources for each resident agent (int) drawn from the following distribution with mean 5, min 2, max 9: [2 3 3 3 4 4 4 4 4 5 5 5 5 6 6 6 7 7 8 9]
res-territory (g0, g1)	Group territory (spaces). [group [min-x max-x][min-y max-y]]
norm-min	The number of other residents to ask for experiences drawn from U [2 2 2 3 4].
resource-risk	The amount of resources that must be kept as a buffer when considering access costs drawn from U [0, resources/2]
net-degree	The number of other residents in an agent's social network drawn from U [5 5 5 5 5 6 6 6 7 8 9]
ADAPTATION PARAMETERS	
tgt-auth-n	The id's of each authority in the numerator of the request and response ratios. [A0...]
tgt-auth-d	The id's of each authority in the denominator of the request and response ratios. [A0...]
tgt-gp	The identity of the target groups for consideration in the adaptation analysis.

1. Resident Parameters

Resident agent demographics are reflected in several parameters: the initial population (*population-init*), population growth (*population-inc*), population decrease (*population-dec*), segregation (*segregation*), and territory (*res-territory*).

The initial population is calculated as follows. The estimated linear growth for the community is determined from available sources. This provides a population estimate for the simulation start year. This estimate is reduced to the 500m x 500m community

boundary. It is reduced again to 10% of the total. This second reduction is done to ensure that small and very large communities can all be considered without excessive computational cost.

The population growth and decrease rates are set so that net growth over the simulation period results in an ending population that matches the original estimate. This approach reflects the effect of population turnover. This is an important dynamic because it is directly tied to the distribution of exchange histories in the population.

Segregation and territory determine where residents are located. Segregation is based on descriptions of conditions from available sources. Parameter values less than 20% reflect low segregation. Values greater than 80% reflect high segregation. Territory reflects group population distribution. If one group has 70% of the population, they have 70% of the territory.

The resident issue rate (*issue-data*) reflects trends over the scenario timeframe. The issue type (*issue*) is selected to allow differences in how different groups or locations experience an issue. There are three issue types: group, random, and spatial. These are described in detail in Chapter 2. The type is selected based on what is most relevant to the scenario needs or real world observations.

Existing case studies very often provide qualitative descriptions of the relationship between issue rates, impact on the community, and the relative capacity for authorities to adequately address these issues. Annual increases and decreases in the issue rate from a baseline reflect descriptions in available sources. The baseline is set based on very general estimates of how often a resident would experience the issue at the

beginning of the simulation. The magnitude of the issue rate considers qualitative descriptions and the parameter values relative to authority resources. It answers the questions, was the issue rate greater than the capacity of some authorities, or the total of all their resources? The timing of changes to the initial baseline is based on the existing literature.

Resident resources are held constant for all experiments. Other relevant parameters such as authority costs are set based on the resident resource distribution. This makes the model significantly easier to use in comparing cases with widely varying economic conditions. It also reduces the reliance on statistical data that may be difficult to obtain. Finally, this approach highlights the effect of relative ability to access authority resources.

Resident resources (*res-resources*) are randomly selected from a Poisson-like distribution with a mean of 5, minimum of 2, and maximum of 9. This reflects the distributions found in census data from the three communities studied here. Resource risk (*resource-risk*) is randomly selected from a uniform distribution ranging from 0 to 50% of the agent's resources.

Resident social interactions are controlled by two parameters. The size of a resident's network ranges from 5 to 9 other agents (*net-degree*). This distribution is roughly exponential. Resident's ask about the authority experiences of a set number of agents in the network (*norm-min*). The norm-min parameter is randomly selected from the following distribution: [2, 2, 2, 3, 4]. The combination of these factors means that

most agents have a network composed of 5 members, and they ask 2 of them for their experiences when they have an issue.

2. Resident Exchange Partner Selection

Residents select an authority partner based on the process outlined in section 2.1.2. Figures 31 and 32 illustrate the effects of this approach on the probability of selecting any particular authority under several conditions. The probability of selecting an authority increases as the number of positive direct experiences relevant to other authorities increases. As illustrated in Figure 31, left panel, if more residents also recommend that authority, the probability curve is higher than if only a few residents make that recommendation. When the number of authorities in the system increases from 2 to 5, the overall effect of positive direct experiences and network recommendations on the overall probability of selecting a particular authority is less than in systems with fewer authorities.

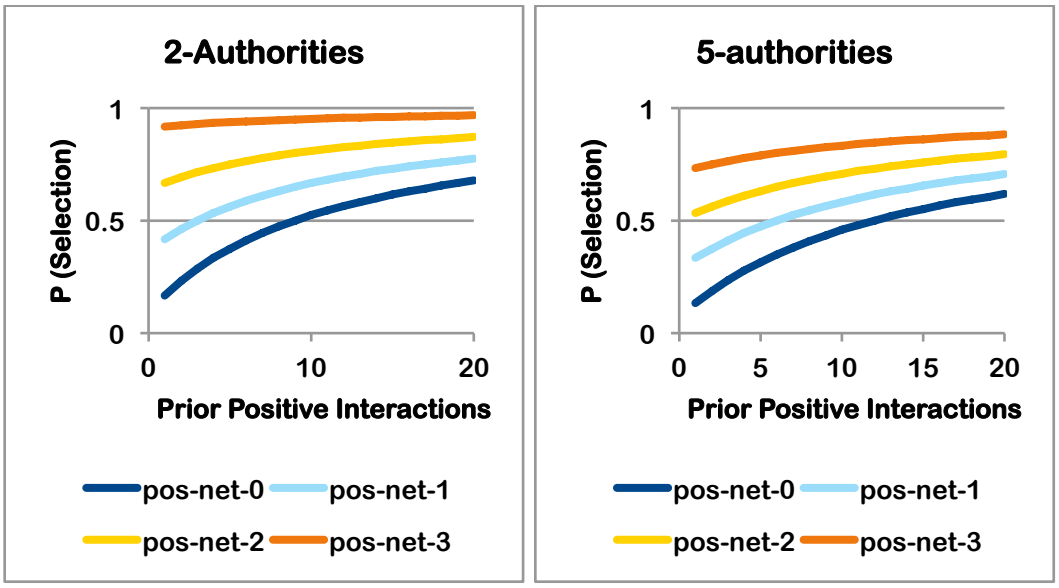

Figure 31. Probability of selecting an authority v. number of prior positive interactions when 0 to 3 other residents have a positive experience with that authority for a community with 2 *Left* and 5 *Right* authorities.

As shown in Figure 32, the overall contribution of network recommendations on selecting a particular partner also varies with the number of authorities in the system and the number of network members recommending that authority. When there are only 2 authorities, the influence of network recommendations is higher than when there are 5 authorities.

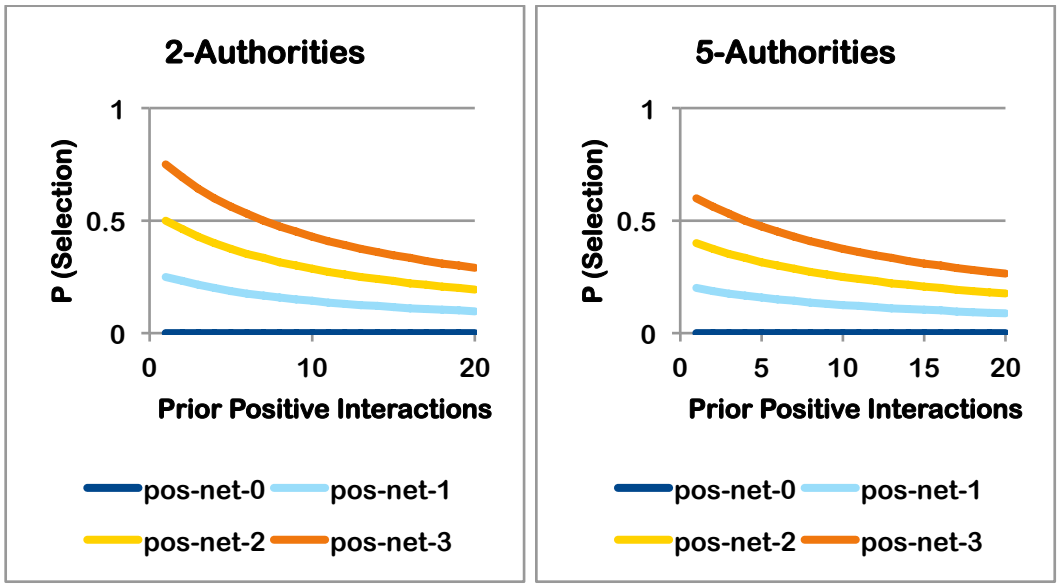

Figure 32. Influence of network experiences on selecting an authority v. number of prior positive interactions when 0 to 3 other residents have a positive experience with that authority for a community with 2 *Left* and 5 *Right* authorities.

2. Authority Parameters

Authority parameters are based on narrative descriptions form available sources. There are very few situations where actual values exist, and even fewer where they exist for multiple cases in a comparative study. The year that an authority enters a simulation (*auth-entry*) and exits (*auth-exit*) are found in the existing research (i.e. Guichaoua, 2009; Joireman & Vanderpoel, 2010; Lambrechts, 2012). The list of authorities in the simulation when it begins is *auth-init*. The total number of authorities is *auths*.

Authority resources (*auth-resources*) are assigned based on narrative information and their value relative to issue rates and other authorities. Resource values below the issue rate indicate insufficient capacity. Values below other authorities indicate relatively

lower capacity. The total resources across all authorities is also considered. Often research provides general indications that the resources of all authorities are insufficient to meet demand.

The process for determining membership parameters is also based on narrative accounts. The community and identity parameters are *auth-const-cmty* and *auth-const-ident* respectively. There are three ranges. Rejection of a community or group results in values between 0.005 and 0.01. Generally apathetic or unengaged relationships range between 0.50 and 0.60. Positive relationships range from 0.90 to 0.999. Intermediate values are used when there is a improvement or degradation of the membership degree of a group. The intermediate values increase or decrease to values in one of the three general ranges over one to several years, as appropriate.

An event strategy reduces or increases the membership degree of a particular social group by *auth-const-event*. The *auth-event-concern* parameter indicates the number of days from an event (*event-yrs*) when there is a 50% likelihood that an authority will implement an event strategy.

The concern parameter is based on research into event strategies for each authority. Events in this dissertation refer to elections. The concern parameter for highly politically engaged authorities ranges from 720 days to 360 days. The 720 day value indicates nearly constant political engagement with respect to elections and supporter mobilization. The event membership factor can range from 0.0 to 2.0. Values greater than 1.0 increase the overall membership assessment. Generally, apolitical authorities have an

event concern parameter of 0 combined with an event membership value of 1.0 indicating no change.

Authorities evaluate their concern over events based on an event concern function. The function is:

$$p(auth - const - event) = 1 - \left(\frac{1}{(1 + e^{-10*(event-0.50)})}\right)$$

The event value in the event concern function above, provides the ratio of days to an event to the days where there is 50% concern about that event:

$$event = \frac{(event\ date - current\ date)}{auth - event - concern}$$

If U [0, 1] is less than *p(auth-const-event)*, then the *auth-const-event* parameter will differ from 1.0 based on the settings for that authority agent. The probability of selecting an event-based strategy for various values of *auth-event-concern* are illustrated in Figure 33.

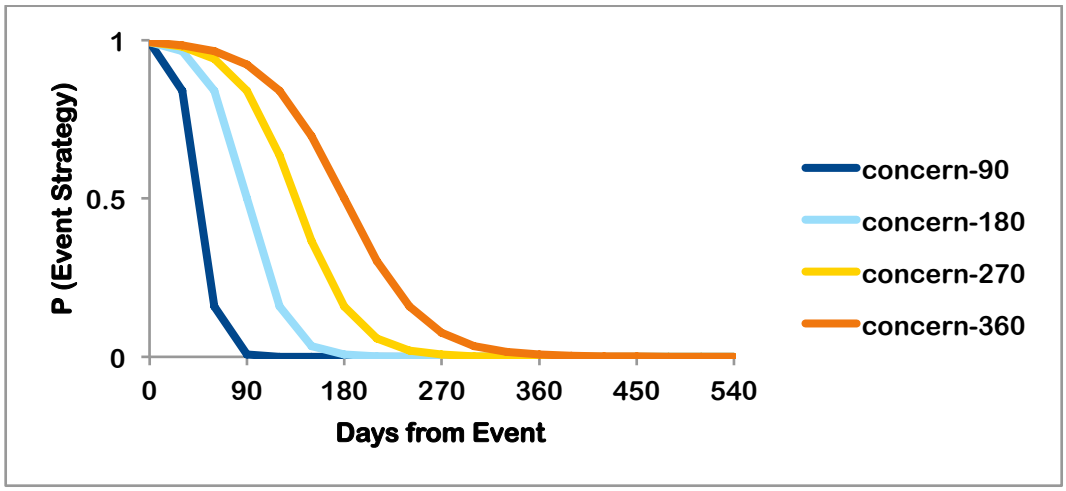

Figure 33. Probability of selecting an event-based strategy v. days from event for selected concern levels.

Authority access costs are indicated by three parameters. Fixed costs (*auth-cost*) and bribes (*auth-bribe*) are set relative to the resident income distribution. If fixed costs are described as prohibitive for most residents, then a value greater than 5 is selected. If costs are not a factor, then 0 or 1 is assigned. Bribe costs are assigned in the same manner. The probability that a government authority will demand a bribe is the *corruption* parameter. This corruption parameter is calculated using the Transparency International corruption rating (TI) for the relevant simulation year (Transparency International, 2015). The conversion is shown in equation 3 and illustrated in Figure 34.

$$corruption = 1 - \left(\frac{1}{\left(1 + e^{-10 * \left(\frac{TI}{10.0} - 0.60\right)}\right)} \right). \quad (3)$$

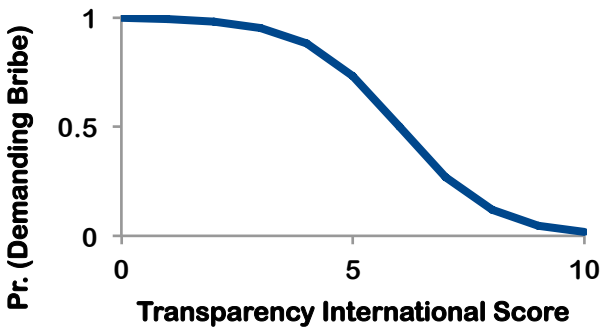

Figure 34. Probability of Government agent demanding a bribe during an interaction with a resident v. Transparency International score (Transparency International, 2015).

Finally, each authority is assigned to operate in a set territory. This does not reflect actual territorial control, only where the authority claims a right to operate. In general, the government claims 100% of the community territory. Some non-state actors such as street gangs have exclusive territory in a sub-section of a community. In these cases, territory can be assigned to conform to social group distributions, relative power, or any other relevant consideration. Most important is to ensure that residents in a particular location have access only to those authorities that are known to be available to them.

APPENDIX 3
RESEARCH QUESTION 1 (CASE STUDY) MODEL PARAMETERS

This appendix provides a list of all parameters for each of the three community cases. The parameters are derived using methods outlined in Appendix 2. These parameters settings were used to produce the results in Chapter 3.

Neighborhood condition parameters are based on various sources. Population dynamics are drawn from several statistical databases (United Nations 2011; The World Bank 2014; KNBS 2010; Lehohla 2013). Inter-communal relationships, local conditions and government capacity are set based on a review of primary and secondary sources as appropriate to the variable (Hendriks 2010; Shaw 2002; Enechojo 2013; Barnes 1986; LeBas 2013; Anderson 2002; Bennet 2012; Lambrechts 2012; Robins 2002). Political system and election years are found in the Polity IV dataset (Marshall, Gurr, and Jaggers 2010). Tables 14 – 16 provide the parameter settings for the scenario runs in each of the community cases.

Table 14. Mushin simulation parameters

Parameter	Environment, Group	A0 (police)	A1 (OPC)	A2 (vigilante)
rand-seed	100-1000			
start-yr	1989			
end-yr	2004			
grid	10 x 10			
AUTHORITY PARAMETERS				
event-yrs	1993, 1999, 2003			
auths	3			
auth-init		1989	n/a	1989
auth-entry		1989	1994	1989
auth-exit		n/a	n/a	n/a
auth-resources		1989, 1%	1994, 1%	1989, 0.2%
auth-const-cmty		1989, 0.50	1994, 0.75; 1996, 0.95	1989, 0.99
auth-const-ident (yr: g0, g1)		1989, G0: 0.99, G1: 0.99	1994, G0: 0.99, G1: 0.005	1989, G0: 0.99, G1: 0.99
auth-const-event (yr: g0, g1)		1989, G0: 0.99, G1: 1.00	1994, G0: 1.00, G1: 0.50	1989, G0: 1.00, G1: 1.00
auth-event-concern		0	360	0
auth-cost		2	1	1
auth-corruption		0.9	0	0
auth-bribe		1	0	0
auth-territory		100%	100%	100%
RESIDENT PARAMETERS				
issue (type)	"random"			
issue-data (yr, g0, g1)	1989: 2.5%, 1994 3%, 1999 3.5%, 2001 3%			
segregation	0.8			
comms-scenario	on			
groups	2			
population-init (g0, g1)	560, 240			
population-update	30			
population-inc (p(increase), n-increase, otherwise	G0: 50% 2, 0; G1: 50% 1, 0			
population-inc (p(decrease), n-decrease, otherwise	G0: 25% 1, 0; G1: 25% 1, 0			
res-resources (poisson)	mean 5, min 2, max 9			
res-territory (g0, g1)	70%, 30%			
norm-min	U [2 2 2 3 4]			
resource-risk	U [0, resources/2]			
net-degree	U [5 5 5 5 5 6 6 6 7 8 9]			
ADAPTATION PARAMETERS				
tgt-auth-n	1			
tgt-auth-d	0, 2			
tgt-gp	0			

Table 15. Manenberg simulation parameters

Parameters	Environment, Group	A0 (police)	A1 (gang)	A2 (gang)	A3 (PAGAD)
rand-seed	100-1000				
start-yr	1989				
end-yr	2004				
grid	10 x 10				
AUTHORITY PARAMETERS					
event-yrs	1994, 1999, 2004				
auths	4				
auth-init		1989	1989	1989	n/a
auth-entry		1989	1989	1989	1996
auth-exit		n/a	n/a	n/a	n/a
auth-resources		1994, 1%	1994, 0.5% 1996, 1%	1994, 0.5% 1996, 1%	1996, 0.5%
auth-const-cmty		1989: 0.50 1994: 0.25 1996: 0.10	1989: 0.30 1994: 0.75	1989: 0.30 1994: 0.75	1996: 0.25 1998: 0.01
auth-const-ident (yr: g0, g1)		0.99	0.99	0.99	0.99
auth-const-event (yr: g0, g1)		1	1	1	1
auth-event-concern		0	0	0	0
auth-cost		1	1	1	1
auth-corruption		0.65	0	0	0
auth-bribe		1	0	0	0
auth-territory		100%	50%	50%	100%
RESIDENT PARAMETERS					
issue (type)	"spatial"				
issue-data (yr, g0, g1)	1989: 3, 50%; 1996: 10, 50%; 1997: 12, 50%; 1998: 8, 50%				
segregation	0				
comms-scenario	on				
groups	1				
population-init (g0, g1)	300				
population-update	30				
population-inc (p(increase), n-increase, otherwise	50% 2, 0				
population-dec (p(decrease), n-decrease, otherwise	25% 1 0				
res-resources (poisson)	mean 5, min 2, max 9				
res-territory (g0, g1)	100%				
norm-min	U [2 2 2 3 4]				
resource-risk	U [0, resources/2]				
net-degree	U [5 5 5 5 5 6 6 6 7 8 9]				
ADAPTATION PARAMETERS					
tgt-auth-n	1, 2				

tgt-auth-d	0, 3
tgt-gp	0

Table 16. Kibera simulation parameters

Parameter	Environment, Group	A0 (chiefs)	A1 (Kamkunji)
rand-seed	100-1000		
start-yr	1987		
end-yr	2002		
grid	10 x 10		
AUTHORITY PARAMETERS			
event-yrs	1992, 1997, 2002		
auths	2		
auth-init		1987	n/a
auth-entry		1987	1991
auth-exit		n/a	n/a
auth-resources		1987, 1%	1991: 1%
auth-const-cmty		0.99	0.99
auth-const-ident (yr: g0, g1)		1987: 0.80, 0.99	1991: 0.99, 0.005
auth-const-event (yr: g0, g1)		1987: 1.00, 1.00	1991: 1.1, 0.50
auth-event-concern		1	360
auth-cost		0	0
auth-corruption		0.88	0
auth-bribe		4	0
auth-territory		100%	100%
RESIDENT PARAMETERS			
issue (type)	"random"		
issue-data (yr, g0, g1)	1986: 1%		
segregation	0.9		
comms-scenario	on		
groups	2		
population-init (g0, g1)	300, 700		
population-update	30		
population-inc (p(increase), n-increase, otherwise	50% 3, 2 100% 4, 1		
population-dec (p(decrease), n-decrease, otherwise	25% 1, 0 70% 1, 0		
res-resources (poisson)	mean 5, min 2, max 9		
res-territory (g0, g1)	30%, 70%		
norm-min	U [2 2 2 3 4]		
resource-risk	U [0, resources/2]		
net-degree	U [5 5 5 5 5 6 6 6 7 8 9]		
ADAPTATION PARAMETERS			
tgt-auth-n	1		
tgt-auth-d	0		
tgt-gp	0		

APPENDIX 4
RESEARCH QUESTIONS 2 AND 3 MODEL PARAMETERS

This appendix lists the parameter values for each experiment performed in research questions 2 and 3 in Tables 17 - 20. Note that the parameter settings for experiment 1, research question 2, concerning the effect of communication on adaptation are the same as those in Appendix 3. Each case is re-run without agent communication, but all other parameters including the random seeds are the same.

Table 17. Research question 2 segregation experiment parameters

Parameters	Environment, Group	A0	A1
rand-seed	100		
start-yr	0		
end-yr	15		
grid	10 x 10		
AUTHORITY PARAMETERS			
event-yrs	n/a		
auths	2		
auth-init	0, 1		
auth-entry	n/a		
auth-exit	n/a		
auth-resources		1%	1%
auth-const-cmty		0.999	0.999
auth-const-ident (yr: g0, g1)		0: 0.999, 0.999 2: 0.999, 0.50	0: 0.999 0.999 2: 0.50, 0.999
auth-const-event (yr: g0, g1)		0: 1.00, 1.00	0: 1.00, 1.00
auth-event-concern		0	0
auth-cost		0	0
auth-corruption		0	0
auth-bribe		0	0
auth-territory		100%	100%
RESIDENT PARAMETERS			
issue (type)	"random"		
issue-data (yr, g0, g1)	1%		
segregation	vary: 1%, 10%, 25%, 50%, 75%, 99%		
comms-scenario	yes		
groups	2		
population-init (g0, g1)	500, 500		
population-update	30		
population-inc (p(increase), n-increase, otherwise (g0, g1)	100%: 1, 1; 100%: 1, 1		
population-inc (p(decrease), n-decrease, otherwise	100%: 1, 1; 100%: 1, 1		
res-resources (poisson)	mean 5, min 2, max 9		
res-territory (g0, g1)	50%, 50%		
norm-min	U [2 2 2 3 4]		
resource-risk	U [0, resources/2]		
net-degree	U [5 5 5 5 5 6 6 6 7 8 9]		
ADAPTATION PARAMETERS			
tgt-auth-n	1		
tgt-auth-d	0		
tgt-gp	1		

Table 18. Research question 3 membership experiment parameters

Parameter	Environment, Group	A0	A1
rand-seed	100		
start-yr	0		
end-yr	15		
grid	10 x 10		
AUTHORITY PARAMETERS			
event-yrs	1yr: 1 - 14 2yr: 2, 4, 6, 8, 10, 12, 14 3yr: 3, 6, 9, 12, 15 5yr: 5, 10, 15 7yr: 7, 14		
auths	2		
auth-init		0	0
auth-entry		0	0
auth-exit		n/a	n/a
auth-resources		1%	1%
auth-const-cmty		0.999	0.999
auth-const-ident (yr: g0, g1)		0: 0.999, 0.999	0: 0.999, 0.999
auth-const-event (yr: g0, g1)		0: 1.00, 0.25	0: 0.25, 1.00
auth-event-concern		360	360
auth-cost		0	0
auth-corruption		0	0
auth-bribe		0	0
auth-territory		100%	100%
RESIDENT PARAMETERS			
issue (type)	"random"		
issue-data (yr, g0, g1)	5%		
segregation	0		
comms-scenario	yes		
groups	2		
population-init (g0, g1)	500, 500		
population-update	30		
population-inc (p(increase), n-increase, otherwise	100%: 1, 1; 100%: 1, 1		
population-inc (p(decrease), n-decrease, otherwise	100%: 1, 1; 100%: 1, 1		
res-resources (poisson)	mean 5, min 2, max 9		
res-territory (g0, g1)	100%, 100%		
norm-min	U [2 2 2 3 4]		
resource-risk	U [0, resources/2]		
net-degree	U [5 5 5 5 5 6 6 6 7 8 9]		
ADAPTATION PARAMETERS			
tgt-auth-n	1		
tgt-auth-d	0		
tgt-gp	1		

Table 19. Research question 3 access experiment parameters

Parameter	Environment, group	A0	A1
rand-seed	100		
start-yr	0		
end-yr	15		
grid	10 x 10		
AUTHORITY PARAMETERS			
event-yrs	n/a		
auths	2		
auth-init		0	0
auth-entry		0	0
auth-exit		n/a	n/a
auth-resources		1%	1%
auth-const-cmty		0.999	0.999
auth-const-ident (yr: g0, g1)		0.999	0.999
auth-const-event (yr: g0, g1)		1	1
auth-event-concern		1	1
auth-cost		2	1
auth-corruption		0	0: 0% 3: 10%, 25%, 50%, 75%, 85%, 95%
auth-bribe		0	3
auth-territory		100%	100%
RESIDENT PARAMETERS			
issue (type)	"random"		
issue-data (yr, g0, g1)	5%		
segregation	0		
comms-scenario	yes		
groups	1		
population-init (g0, g1)	1000		
population-update	30		
population-inc (p(increase), n-increase, otherwise	100%: 1, 1		
population-inc (p(decrease), n-decrease, otherwise	100%: 1, 1		
res-resources (poisson)	mean 5, min 2, max 9		
res-territory (g0, g1)	100%, 100%		
norm-min	U [2 2 2 3 4]		
resource-risk	U [0, resources/2]		
net-degree	U [5 5 5 5 5 6 6 6 7 8 9]		
ADAPTATION PARAMETERS			
tgt-auth-n	0		
tgt-auth-d	1		
tgt-gp	0		

Table 20. Research question 3 capacity-stress experiment parameters

Parameters-capacity	environment	A0	A1
rand-seed	100		
start-yr	0		
end-yr	10		
grid	10 x 10		
AUTHORITY PARAMETERS			
event-yrs	n/a		
auths	2		
auth-init		0	0
auth-entry		0	0
auth-exit		n/a	n/a
auth-resources		2%	exp 1, 3, 5: 1% exp 2, 4, 6: 1.5%
auth-const-cmty		0.999	0.999
auth-const-ident (yr: g0, g1)		0.999	0.999
auth-const-event (yr: g0, g1)		1	1
auth-event-concern		1	1
auth-cost		0	0
auth-corruption		0	0
auth-bribe		0	0
auth-territory		100%	100%
RESIDENT PARAMETERS			
issue (type)	"custom" steady state days: 30, 60, 120, 240, 360 peak days: 30		
issue-data (yr, g0, g1)	steady state rate: exp1&2: 2%, exp3: 3%, exp4: 3.5%, exp5: 1%, exp6: 1.5% peak rate: 8%		
segregation	0		
comms-scenario	yes		
groups	1		
population-init (g0, g1)	1000		
population-update	30		
population-inc (p(increase), n-increase, otherwise	100%: 1, 1		
population-inc (p(decrease), n-decrease, otherwise	100%: 1, 1		
res-resources (poisson)	mean 5, min 2, max 9		
res-territory (g0, g1)	100%, 100%		
norm-min	U [2 2 2 3 4]		
resource-risk	U [0, resources/2]		
net-degree	U [5 5 5 5 5 6 6 6 7 8 9]		
ADAPTATION PARAMETERS			
tgt-auth-n	0		
tgt-auth-d	1		
tgt-gp	0		

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