A JOLT TO THE SYSTEM: MEASURING DISASTER-INDUCED SOCIAL DISRUPTION THROUGH WATER CONSUMPTION, SALES TAX REVENUE, AND CRIME DATA

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Major Field: FIRE AND EMERGENCY MANAGEMENT

This project examines the potential for quantifying the degree of social disruption and varying paths toward system restabilization by using data routinely collected by municipalities. Social disruption was measured by studying monthly patterns of water consumption, sales tax revenue, and crime data following the 2013 EF-5 Moore, Oklahoma tornado and the July and August 2012 wildfires in Stillwater, Oklahoma. Using two similar cities experiencing different disaster agents provided an opportunity to establish important similarities and differences in the level of social disruption created and how this disruption is manifested in the different "rhythms of life" within a city. This research was grounded on previous work related to social time, social routine, and disaster (Neal, 2004, 2013). This study documents how different components of both cities re-established the rhythm of life resulting in a similar but new normal.

Data collected on water consumption, sales tax revenue and crime patterns for four fiscal years for Moore and Stillwater, Oklahoma illustrate pre-impact, impact, and initial restabilization period social patterns. Following time series analysis, preliminary findings indicate these variables are valid measures of municipal social time and demonstrate disaster-induced disruption. Comparison among different variable patterns indicates that magnitude of impact and speed of restabilization appear to follow different patterns. This project suggests that social routine may be used to establish a Degree of Disaster Index to allow direct comparisons across multiple events and the study of long-term system restabilization.

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CHAPTER I

INTRODUCTION

It was a Monday morning in spring. Weekend schedules were filling up with baseball practices and "end of the school year" gatherings. As a result, Monday morning was a bit more hectic than mornings later in the week: backpacks and left shoes not easily found, breakfast a bit rushed, and traffic slow along major arteries and around the schools. Local meteorologists reported on the tornado that impacted the smaller towns in Cleveland County the night before. In the next breath, listeners were advised to prepare for a similar system later in the day and evening. Moore, Oklahoma had been through this before. People listened. Umbrellas were put into bags and back-up plans made for outdoor activities planned after school and work. Work progressed, the school children completed the day's classes and packed their backpacks. Umbrellas were not going to be sufficient for the storm that arrived that afternoon.

The initial tornado warning was issued at 2:40 PM in nearby Newcastle, OK and it looked frightening. The EF-5 tornado was headed to the city of Moore and picking up power. Radar indicated that the rotation would be on the ground in Moore at 2:52 PM and the first reports of the tornado on the ground in Moore came at 2:56 PM. The tornado hit two elementary schools as the children lined up for dismissal. When the tornado dissipated at 3:36 PM, it had left a path of destruction about 17 miles long and varying from 0.5 to 1. 3 miles wide. Twenty-four were dead including 7 3rd graders from one of the elementary schools. Another 337 people were injured and treated. The Moore Medical Center and one of the major water treatment plants for the city were heavily damaged. The damage estimate exceeded $2 billion with over 12,000 homes damaged and 61,500 left without power. Over 33,000 people were directly impacted by the storm and more than 22,000 insurance claims were filed.

Life didn't stop. Moore Medical Center staff set up a triage point near the damaged Warren Movie Theatre immediately. Volunteers and truckloads of relief supplies began arriving within 20 minutes of the tornado's dissipation. City churches and Oklahoma University (in nearby Norman, OK) opened as shelters. The first members of FEMA's response team arrive within minutes and help direct volunteers to shelter areas and away from damaged areas. The National Guard and local law enforcement set security perimeters by the next morning and residents are asked to adopt water conservation behaviors. By Wednesday, volunteer and resident cleanup was at full speed. Donations poured in including major contributions from the major local energy companies and professional basketball player, Kevin Durant. In fact, the Oklahoma City Thunder team and coaching staff tour the damaged area and visit with victims. The first funeral was held on Thursday.

The city worked to balance the demands created by the tornado with the desire to maintain a sense of continuity and "normalcy". While the school year was truncated a few days earlier than originally scheduled, all three public high schools proceed with commencement ceremonies at the Cox Center in downtown Oklahoma City as scheduled. Sunday church services were held in a modified manner to offer the opportunity for the greater community to worship communally. President Obama, accompanied by local and state politicians and FEMA Director Fugate, tours the city and meets privately with several survivors and the principal of the elementary school that suffered student deaths. Oklahoma-based celebrities Blake Shelton and Miranda Lambert host a nationally televised benefit concert on May 29, 2013. Slowly, the city cleans up and creates a new rhythm of life.

It was hot. Late July in Oklahoma was always hot; but this was convection oven hot. And dry. So dry. The entire state had been declared an extreme drought region. The Stillwater area still had water but getting it out of the tap was not an easy proposition. The red clay soil contracted with the heat and lack of rain. Old water system pipes that had been held in place by the pressure of the clay began to snap. City crews were playing cat and mouse with main breaks. Residents were urged to limit laundry and other water and energy dependent household tasks to early morning or late night hours. Weather reports included reminders of burn bans due to the potential of wildfire given the combination of heat, drought, and high winds. Other areas of the state had already experienced destructive wildfires. So far, Stillwater and Payne County had avoided anything larger than a small grassfire. That was about to change.

Payne County caught fire the last week of July and first week of August. Three separate fires ripped through the county destroying outbuildings, homes, agricultural equipment and endangering livestock. The last fire skirted the city limits. The smoke from the fires darkened the sky and made breathing difficult for those with asthma and other respiratory issues. Drivers were advised to avoid driving in smoke and some roads were completely closed. Emergency shelters were established for those evacuated from their homes and farms. Volunteer firefighters left other tasks as rural volunteer fire departments joined forces with professional departments to fight these fires. Other individuals also modified regular schedules to supply food, beverages and support services to victims and responders. Friends, family and the Red Cross provided support for families who lost their homes with temporary housing. By the end of the week, 59 homes had been destroyed.

Social life is made up of a series of routines (Black, 2015; Hall, 1983; Zerubavel, 1981.) As individuals and members of various social units, each of us establishes unique patterns or "rhythms" of life. We go to work, we drop off our children at school, and we attend movies or sporting events. We schedule events and activities in patterns that echo changes in our focus and demands on our time (Neal, 2013). Life becomes relatively predictable and manageable. Within our households, our schedules fit together with those of other household members while meeting the demands of outside influences. It is our predictable patterns of behavior that create space for social order and organization.

Such outside influences include our larger social units (employers, schools, places of worship, etc.), which also exhibit patterns that shape our activities and schedules. Major employers and school systems impact our personal rhythms by creating work and school routines requiring our involvement primarily Monday through Friday, 8:00 AM – 5:00 PM. Because our time is devoted to work or school expectations during the weekdays, we participate in most of our recreational activities outside of these time periods. Through the social processes of work and play, our daily routines and their locations reflect both individual and greater social unit patterns.

Our greater social systems, including organizations, cities, and regions, also establish unique patterns or rhythms. At the municipal level, the presence and activation of "school zones" with reduced speed allowances during typical start and release time periods are an example of how school schedules may impact all residents even if their household does not include a teacher or student. The region in which one lives may also exhibit a rhythm of life. Agricultural areas adopt routines based in the cycles of planting and harvesting. Transportation routes may be impacted for all residents, not just those involved in agriculture. Highway signs posted in rural areas in Oklahoma remind drivers to expect slow-moving farm equipment on the roads during harvest periods. Harvest festivals celebrating the end of harvest become annual events involving homecomings and family traditions. Similarly, some seasonal cycles are reflected in national patterns. The winter holiday season results in great changes in retail schedules and other business-related operational hours. In each of these cases, we adjust our individual and household routines to the changes created by the systems in which we operate.

Humans establish these routines to enhance predictability and make life more "livable" (Black, 2015.) Such routines create what sociologists refer to as "everyday" life (Neal and Murji, 2015.) Routine activities become so ingrained that they just seem to happen. We no longer consciously think much about these activities; they fly under our radar. We start our mornings with a cup of coffee in the red mug; we park in the same lot every day when we arrive at work; and we eat in with the same group of colleagues during the workdays. These routines help us pace our days and create a predictable rhythm to our lives. We incorporate the rhythms of the greater social system's seasonal or cyclical patterns. Our routines articulate not only with our family's individual patterns, but also with our neighbors', local business community, and the municipality as a whole. Back-to-school schedules and routines demonstrate this phenomenon well. For those households that include school-aged children or teachers, returning to school often means abandoning summertime patterns altogether. Alarm clocks are turned on, car pool or bus schedules determine morning routines, and leisure activities are moved to evening or weekend periods. The predictability of life returns as autumn schedules are set and new rhythms are established at the individual, household, and community level.

The opportunity to quantify social routines, the disruption caused by disaster, and the process associated with establishing a new normal is unique to this project. The examination of social routine at the municipal level through regularly collected data offers a chance to create a generalizable method for studying multiple events concurrently. This current examination facilitates the identification of key processes and sequences of the transition from impact to restabilization and a return to equilibrium. Increased understanding of the processes involved as a city transitions from impact should improve decisions regarding resource allocation and prioritization of intervention strategies for emergency management practitioners and policy makers. By examining two separate disasters and cities, this dissertation examines how disaster impacts the social routines at the municipal level. This project asks whether measurable disruption exists in all disaster settings. It also seeks to establish that regularly collected data may be used to measure the magnitude of the initial impact and duration of the disruption within a city.

Disaster, Disruption and Social Routine

Small, individual emergencies or crisis such as traffic accidents may cause us to alter our routines temporarily. We may sit in traffic waiting for damaged cars to be removed and the road reopened. This delay may cause us to start our scheduled tasks late and require us to shift our priorities slightly. These temporary “bumps in the road” typically impact few individuals (perhaps only us) and are resolved quickly. On the other hand, disasters disrupt our routines at multiple levels. The demands of the disaster situation force us to re-prioritize our lives. Even if the extreme event agent does not directly impact us, we may need to tend to the injured or assist family members or neighbors in cleanup or repair. Our homes may be damaged. We may not have access to electricity or water. We may need to find temporary shelter. Our place of employment may be damaged or unable to function due to infrastructure damage. Disasters may impact our regular transportation routes, forcing us to establish new routes with longer commute times. Interruption of our individual routines results in some level of discomfort but, it is only when larger community-level routines are impacted that true social disruption occurs (Neal, 2013.)

The social disruption created by an extreme event is inherent to our understanding of disaster. Beginning with some of the earliest disaster research, the definition of disaster involved the inability of the impacted community or region to provide services to community members (Fritz, 1961). The concept of time was often included in early attempts to define disaster. In his discussion regarding the creation of disaster phases, Carr (1932) stated chronological time was a poor measure of disaster impact and suggested defining impact in terms of the social processes and activities involved. Our understanding of time in the disaster context impacts how we define and consider disaster-related processes. Time as a social variable provides the foundation for this study and will be discussed in much greater detail later in this dissertation.

The daily routines each of us create and contribute to the larger social system form unique rhythms or patterns. These rhythms are disrupted following disaster impact.

According to Neal's Social Routine Theory (2013), these altered rhythms indicate social disruption. As I will demonstrate in Chapter II, disaster research has done a poor job of exploring the *processes* involved in the social transition between the point of extreme event impact and the creation of a "new normal".

This project attempts to quantify the processes involved in creating a post-disaster new normal by measuring several factors that may serve as proxies for restabilization in the built, economic, and social environments of a city. This dissertation examines the infrastructure variables of water consumption, sales tax revenue, and crime patterns (felony arrests, citizen-generated calls for service and traffic violations) from the perspective of social routine following two separate disaster events. The first disaster involved an EF-5 tornado that hit Moore, Oklahoma while the second involved multiple grassland wildfires during an extreme regional drought on the outskirts of Stillwater, Oklahoma.

Research Questions

By studying the impact of these extreme events on the municipal rhythms of water consumption, sales tax revenue, and crime patterns (felony arrests, citizen-generated calls for service and traffic violations), I have the opportunity to demonstrate and quantify disaster-induced social disruption and restabilization. Through the application the social routine theoretical framework, this project hopes to answer the following research questions:

1. Can social rhythms be quantified through the examination of water consumption, sales tax revenue, and crime patterns?
2. Are water consumption, sales tax revenue, and crime patterns valid proxies for social and economic rhythms?
3. Does each municipality have a unique "rhythm of life" prior to disaster?

4. If disaster induces measurable disruption, does it create the same disruptive patterns despite the different disaster agent?
5. Do changes in infrastructure rhythms create a quantified representation of the ***process*** involved in recovering from an extreme event?
6. Are disrupted infrastructure patterns demonstrated by quantifiable shifts in variance of water consumption, sales tax revenue and crime patterns? Can the establishment of a new "normal" or routine be measured by the re-stabilization of the variance within these variables?

Under non-disaster conditions, I expect the variables to reflect changes due to seasonal and/or citywide events. Water consumption should increase during the summer months and taper off during the cooler autumn and winter months. Similarly, sales tax revenue should reflect commercial patterns associated with events such as the start of the school year, holidays, tourism and the annual building and remodeling cycle. Crime patterns are likely to reflect the academic calendar as the summer months increase the activity of teens and young adults. These rhythmic patterns should be demonstrated by a relatively high correlation between annual cycles during which no extreme event occurred.

In my study, I will use data collected July 2011 through May 2013 to represent the pre-impact period in Moore, OK. In contrast to the pre-impact period, the period following impact (June 2013 – June 2015) is expected to reflect significantly different utilization patterns. Stillwater, OK will have different pre- and post-disaster periods. Data collected July 2011 – July 2012 will represent the pre-event period. Data collected for August 2012 – June 2015 will represent the post-disaster period. These differential patterns represent the social disruption that characterizes a disaster (Fritz, 1961; Barton, 1969; Quarantelli, 1995; Neal, 2013.)

Significance of the Project

Disaster researchers continue to struggle with establishing a definition of disaster (Quarantelli, 1985, 1998.) Social disruption has long been a common theme (Buckle, 2005; Fritz, 1961; Jigyasu, 2005; Smith, 2005.) Critics of disaster research often point to its tendency to focus on individual extreme events as a key limitation. The creation of a common assessment tool that could incorporate multiple aspects of disaster impact could provide a framework to enable multiple event and/or multiple agent comparison. This tool could take the form of a disaster index and the "score" would reflect the level of impact the event made in social processes within the impacted population.

Such an index would be similar to other indexes developed for specific aspects of the disaster situation. For example, Cutter, Boruff and Shirley (2003) developed the Social Vulnerability Index (SoVI), an indexed score incorporating built, natural, and social environmental factors to measure social vulnerability. This index expanded our ability to compare the impact of social vulnerability and its component characteristics on disaster impact across multiple events. Cutter, Burton and Emrich (2010) created a similar index for community resilience using their Disaster Resilience of Place (DROP) model.

Neal's Social Routine Theory (2013) offers a similar opportunity for the creation of such an index. Neal proposes that disaster intensity may be measured in terms of the magnitude of social disruption. Social disruption can be measured by examining the changes in pre-disaster rhythms within infrastructure patterns. He asserts that the length of time required to return to pre-disaster patterns is positively related to the intensity of the disaster event. The greater the negative impact of the disaster, the longer it will take for the infrastructure patterns to return to pre-impact rhythms.

Chang and Miles (2004) assert that recovery is complete when the rate of change in use patterns returns to pre-disaster levels. This assumption removes the need for an absolute return to pre-impact levels of production or consumption and focuses on the pattern and/or rate of change. The dynamic processes involved in disaster response and recovery are represented in the modification of infrastructure use trends. In the language of Sociopolitical Ecology Theory, the social system adapts to the post-disaster environment and a steady rhythm of life is re-established resulting in a new "dynamic homeostasis" (Bates and Pelanda, 1994). Peacock and Ragsdale (1997) apply Sociopolitical Ecology Theory to the Hurricane Andrew experience and emphasize that the interactions, both formal and informal, of multiple systems within the community are modified to accommodate and adapt to the new disaster environment. As these relationships change, conflict and competition re-emerge resulting in differential resource allocation and use patterns. This project examines the changes in use trends of infrastructure utilization and crime patterns pre- and post-disaster to study the processes associated with the creation of this new rhythm. Social Routine Theory (Neal, 2013) refers to this re-established rhythm as the "new normal."

Because the data used is regularly collected and reported, pre-disaster and post-disaster trends and rhythm can be compared. This dissertation will demonstrate how disaster changes pre-existing water consumption, sales tax revenue, and crime patterns at the municipal level. Instead of studying the return to pre-disaster use levels, I will be looking at the changes in variance for each variable (Chang, 2010.) Through the use of time series analysis, the level of variability can be examined as the city begins to adapt to the post-disaster environment, re-stabilize, and create its new "dynamic homeostasis" or new normal (Alesch, Arendt, & Holly, 2009). By identifying which variables exhibit the greatest magnitude of disruption and determining the pattern of restabilization for each, I can identify commonalities within the disaster context. These commonalities will provide the foundation for a generalizable Degree of Disaster Index.

The Municipality as the Community and Unit of Analysis

While one finds the term community applied differently within the body of disaster research, this project applies the term to represent the municipalities of Moore and Stillwater and all of their inhabitants. Because the data collected is administered by the central administration for the entire city, no attempt will be made to differentiate between neighborhoods or subpopulations that might represent different levels of social vulnerability. This approach reflects that of Alesch and Siembieda (2012), who argue that a municipality may be a reliable unit of analysis for the examination of infrastructure impacts following extreme events.

This project involves two cities, Moore and Stillwater, Oklahoma. While both cities are located in central Oklahoma, there are distinct differences. Moore, OK is located on the southwest edge of Oklahoma City, a major urban area. Stillwater is isolated and is approximately 70 miles from Oklahoma City or Tulsa (the other major urban center within the state.) Moore has a population of 58,414 while Stillwater's population is 47,186 (US Census, 2013.) Due to its more urban location, Moore's population density is higher than Stillwater as well. Stillwater's demographics reflect the presence of a large university. With a large population of traditional college students, the percentage of the population over the age of 65, median household income and home ownership rates are lower than Moore's. Educational levels are higher in Stillwater. Both cities are governed through the city council/city manager model and have maintained a stable leadership team over the past 15 years. The disaster experience of the leadership teams is quite different. The Moore team experienced three large tornado events between 1999 and 2013 including an F5 event in 1999 (the strongest categorization prior to the use of the EF scale.) The Stillwater group has not dealt with a major natural disaster of any sort for over 20 years with the exception of the extreme drought of 2012. The city has some experience with limited wind events but has not had a tornado, flood or severe winter storm.

The disaster agents also differ between these two cases. Moore experienced a large (EF5) tornado May 20, 2013. The impact of the tornado included the loss of over 20 lives, more than 12,000 homes, and impacted nearly 60% of the city's total population. Due to the magnitude of the damage and impact of the event, the city received a Presidential Disaster Declaration (PDD).

Stillwater experienced a series of wildfires during the last week of July and first week of August 2012. The fires did not impact the city itself but involved the surrounding rural area and required the commitment of city resources. The level of damage did not reach the level of a PDD. However, the area did lose 59 homes and over 11,000 acres of agriculturally productive land.

By examining two separate disasters and cities, this dissertation examines how disaster impacts the social routines at the municipal level. This project seeks to establish that regularly collected data may be used to measure the initial disruption within a city and asks whether measurable disruption exists in all disaster settings. A comprehensive literature review of social time, disaster impacts, social disruption, and the theoretical foundations from which I will study the processes of restabilization follows in Chapter II. Chapter III details this study's methodology in order to quantify social routine and measure disaster-induced social disruption. Chapter IV presents this study's analysis of data. In doing so, it demonstrates the processes involved in municipal restabilization following disaster. Finally, I present my conclusions, further discussion, and recommendations for future research and practical applications in Chapter V.

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CHAPTER II

LITERATURE REVIEW

Social disruption has long been considered the heart of disaster. People in households are displaced, business activity is interrupted, public services close, and the historical and cultural symbols of a community may be heavily damaged or missing altogether. The physical destruction caused by the extreme event fractures established social networks as well. Individuals may be separated from family, neighbors, and friends by the loss of homes, relocation, and emergency sheltering or temporary housing strategies. Routines associated with work, school, worship, and recreation may be replaced by the demands of debris clearance, caring for the injured, and reconstruction.

Defining Disaster

Social disruption is integral to defining an event as a disaster (Quarantelli, 1985). Fritz (1961) defined disaster as an "event, concentrated in time and space in which a society undergoes severe danger and incurs such losses to its members and physical appurtances that the social structure is disrupted and the fulfillment of all or some of the essential functions of the society is prevented (p. 655)." At the core of this definition is a sense of disorder, a departure from the expected patterns or rhythms of life. Fritz's definition assumes that the level of social and service disruption indicates the magnitude of the disaster. There are many possible methods to determine the level of disruption including the number of buildings destroyed, the number of people displaced and/or left without lifeline services, or the time it takes for a household or city to re-establish regular routines (Quarantelli, 1995). This study builds on the concept that the degree of disaster is related to the level of social disruption experienced as outlined by Neal (2013) and Chen, Neal, and Zhou (2013.) Determining the magnitude of disruption requires an understanding of the interconnectedness of the built, natural, economic, political, and social environments as presented in the Sociopolitical Ecology Theory of Bates and Pelanda (1994) as well as the dynamics of the human desire to create and sustain predictable routines.

Re-establishment of Social Order and Routine

The immediate aftermath of an extreme event is marked by uncertainty and disorder. Information relevant to normal behavioral patterns lacks meaning in the post-disaster environment (Peacock and Ragsdale, 1997.) However, humans and their institutions seek to re-create social order and struggle to maintain some vestigial pieces of the structure that existed prior to the disaster. For example, families do not simply scatter after impact but rather respond and seek safety as a unit (Bolin, 1994; Drabek, 1986; Morrow, 1997b.) Individuals function within pre-existing roles. For example, emergent search and rescue efforts reflect the non-disaster skillsets of the responders, i.e. off-duty medical professionals and those with leadership experience apply their skills in the field (Dynes & Quarantelli, 1968a; Rodriguez, Trainor & Quarantelli, 2006.)

One key task of people following disaster impact is re-establishing those patterns and rhythms that allow the fulfillment of the "essential functions" society members expect and require. Accessing the necessary knowledge, goods, and services requires parallel restoration processes among multiple systems throughout the social network. This requires that each unit, whether individual or organizational, re-create the bonds that tie it to the greater network (Peacock & Ragsdale, 1997.) Recreating pre-disaster social structure and order facilitates the re-establishment of daily routines. The process of establishing predictable routines and rhythms may be thought of as reaching a state of social homeostasis. The processes associated with reaching this new state of homeostasis and re-establishing predictable social order are dynamic because the task may change in focus and priority; the individuals and organizations involved in the task may change; and the time required or devoted to the task may ebb and flow.

The complex nature of the disaster environment is influenced by pre-impact activities and pre-disaster routines. Wenger and Smith (2007) emphasize this relationship between pre- and post-disaster action and processes in their discussion of recovery and the desire to "return to normal". They state that if a society prepares effectively through planning and mitigation prior to an extreme event, movement through the multiple processes required to reconstruct the physical, social, economic, and natural environments to reach a state of recovery occurs more quickly and follows a smoother trajectory. Other research has focused on the artificial temporal divisions of response and recovery phases to describe specific aspects of the post-disaster experience including emergent behaviors during response (Rodriguez, Trainor & Quarantelli, 2006) and neighborhood involvement in reconstruction and development (Pais & Elliott, 2008.)

The post-impact emergency phase, often viewed as the response phase, has been studied extensively (Barton, 1969; Drabek, 1986; Dynes, 1970; Tierney, 2003.) The post-response phases, often referred to as short- and long-term recovery phases, and the associated processes are the least examined aspects of the disaster cycle (Rubin, 2009). While this project does not employ the phasic disaster cycle, it is possible to apply several facets of previous research to the disorder that a disaster visits upon a society as well as the processes, patterns, and trends that emerge as the "new normal" is established. Pre-existing social structure undergoes significant changes as the disaster environment is managed through adaptation to changing relationships and demands between and among groups and individuals within the impacted community (Barton, 1969.) New norms appear, pre-existing organizations change their focus and/or structure, and entirely new systems of social organization and order may emerge (Dynes, 1970).

This study attempts to take a more holistic view of the broader process of re-establishing a "new normal" instead of focusing on a single aspect such as housing (Comerio, 1998.) As a city re-creates municipal routine activities and provision of services, the patterns and trends of such action create a picture of the broader processes associated with establishing a "new normal". There is no need to define tasks as response or recovery phase activities. The chronological divisions of time are not how the story is interpreted. It is the experience of re-creating social routines and citywide rhythms that are reflected in the data. The lack of arbitrary divisions of the disaster cycle phases (preparedness, response, recovery and mitigation) makes this study unique. This work recognizes that tasks typically assigned to one phase may actually occur with tasks associated with a different phase as Neal (1997, 2004) demonstrates. As water service is restored, business districts re-open, insurance reimbursements are issued, and people return to a permanent home, new household routines are reflected in the greater citywide use patterns and municipal rhythms.

Social Order

The social construction underlying the causes and effects of a disaster is essential to understanding how a society and its organizations adapt and adjust as the demands of the pre-impact routine environment gives way to the uncertain and unstable post-impact social environment (Kreps, 1989). Social order provides a space within which society creates and supports norms and values. These norms and values dictate priorities and relationships among society members and their organizations. The structure offered through social order leads to predictable daily, weekly, and seasonal tasks and activities. This predictability allows us to create routines anchored in social time. Disasters interrupt the pre-existing social order and result in the loss of predictability and high levels of uncertainty. Tasks and time become less structured. Pre-impact norms are disrupted (Dynes & Quarantelli, 1968a, 1968b) and are replaced by behaviors and priorities determined by what must be and what can be accomplished.

Impacted individuals and organizations cope until their capacities are overwhelmed (Fritz, 1961). As more unique systems are stressed and their capacities overwhelmed, the level of disruption increases within the greater social system (Perry, 2005). This disruption spreads like ripples on the water after a rock is thrown into a pond. As disruptions increases, a greater level of adaptation is required of the larger social system. Social expectations are modified, community/municipal resources are diverted from regular activities, and the entire city adapts. As the city adapts and adopts emergency norms, the foundation of social structure is maintained. Over time, adaptations are either incorporated into the pre-existing social order or the social structure is modified to facilitate and support the new norm or value created in the disaster context. It is through adaptive adjustment that social order is maintained and stabilization (or recovery) occurs (Bates, 1997; Peacock & Ragsdale, 1997).

Building on the work of Dynes (1970) in which he describes the shifts in organizational structure and focus post-disaster impact, Bosworth and Kreps (1986) explain the shifts in structure, responsibility, and relationships organizations undergo within themselves and in relationship to other organizations following a disaster. Using their taxonomy regarding organizational domains, tasks, actions, and resources; the dynamics associated with the movement from impact to a "new normal" are illustrated at the organizational level. This project will move the examination of the dynamic processes of the re-creation of a stable social routine or "rhythm of life" from the organization to the municipality. Unlike the large body of research that focuses on the organizational response to disaster (Dynes, 1970; Dynes & Quarantelli, 1968a; King, 2007; Mendonca & Wallace, 2004; Tierney, 2003), this dissertation will examine the aggregate rhythmic patterns of water consumption, sales tax revenue, and crime patterns as the city moves from disaster impact to restabilization.

Moving Theory to Practice

By focusing on process and routine, this project supports the movement of disaster and emergency management research beyond theoretical discussion of what constitutes disruption and defines a disaster. This research applies the theoretical frameworks of social routine presented by Neal (2013) and Chen, Neal, and Zhou (2013) to describe the dynamic processes involved in the post-impact municipal environment.

The process of establishing the "new normal" is underway as a city repairs and/or develops social, political and economic processes, institutions and relationships that enable it to operate and cope in the new context created by disaster. These social systems interact through multiple linkages that facilitate the flow of information, membership, and resources. From this perspective, coordination of activities emerges from these interactions. When disruption interferes with one member or resource within the ecological network, the result is large-scale social disruption. This interactive environment provides the theoretical foundation for the Social Routine Theory (Neal, 2013.)

Many researchers have encouraged the shift from theoretical discussion to testing those theories in the actual field (Dynes & Quarantelli, 2008; Quarantelli, 1982, 1999; Tierney & Oliver-Smith, 2012). The need for theory testing in the post-emergency and recovery phases is especially noted (Smith & Wenger 2007; Rubin 2009). Although this research project is not a recovery phase study per se, the restabilization of the studied variables will represent a new dynamic homeostasis. Establishment of a new level of homeostasis may be used to define some level of "recovery". Bates and Pelanda's Sociopolitical Ecology Theory (1994) supports using pattern stability as an indicator of homeostasis as a social system evolves and adapts to the environmental changes that an extreme event creates. Chang (2010) also applies pattern stability as an indicator of the re-creation of the new normal. In both of these examples, the new normal reflects the adaptations of the multiple social systems to the post-disaster environment.

Most previous research has focused on experiential outcomes during temporally designated points post-impact. These researchers focused on chronological milestones or specific tasks (Rubin, Saperstein, &Barbee, 1985). For example, Kates and Pijawka (1977) divided the recovery period into a sequence of four phases based on task prioritization (emergency period, restoration period, replacement and reconstruction period, and commemorative, betterment, and developmental reconstruction period.) Other studies (Bolin, 1994; Comerio, 1998) attempted to define a state of recovery in terms of quantifiable goals linked to values existing pre-impact (ex. percentage of homes rebuilt or number of businesses re-opened) or a return to a pre-existing level of function (population levels or economic productivity). This latter method assumes that restoration of the pre-disaster environment is the ultimate goal of all post-disaster activities. The current study focuses on the holistic process of re-stabilization and the establishment of a new “normal”: a new “rhythm of life” instead of returning the pre-impact status quo.

Municipal Social Routine and Rhythms

My research focuses on social routine at the municipal level. Using the municipality as the unit of analysis also separates this project from earlier research. . This frame and unit of analysis provides a new approach to studying the post-disaster environment and the processes involved in re-establishing social order. The aggregate nature of my data will not allow me to consider some aspects of the post-disaster re-stabilization process. One facet that I will not address is social vulnerability. Other researchers have demonstrated that the processes associated with recovery are experienced differentially at the household level. This differential experience may be attributed to a variety of household characteristics. These factors include pre-disaster levels and forms of social capital (Aldrich, 2012), race and ethnicity (Bolin 1986; Bolin & Stanford, 1998), home ownership status (Comerio, 1998), gender (Phillips, 1993), socio-economic status (Nigg, 1995; Quarantelli, 1982), and overall social vulnerability (Wisner, Blaikie, Cannon & Davis 2004).

Similar factors have been considered at the neighborhood level as well. Structural racism and segregation (Bates & Peacock, 1989; Highfield, Peacock, & Van Zandt, 2014), along with high levels of overall social vulnerability (Finch, Emrich, & Cutter, 2010) impede the recovery process for large segments of the population. Other researchers have focused on economic recovery and individual business firms (Alesch, Arendt, & Holly, 2009; Webb, Tierney, & Dahlhammer, 2002). These works identified characteristics of the victims that contributed to increased exposure and the detrimental effects of a disaster. Studying differential impact and recovery experiences greatly expanded our understanding of social vulnerability and the unequal social distribution of risk (Tierney, 2014).

Recognition of the integral components of social vulnerability or factors that may contribute to differential disaster experiences is critical and represents a potential limitation of this current project. Data collected at the municipal level does not allow me to examine social vulnerability. The information gathered demonstrates an aggregate process and focuses on those services and activities supported by municipal administration. This study considers disaster at the municipal level; as such, aggregate information will include both vulnerable populations and the more advantaged. Both groups will impact the overall sequencing and the speed of return to routine stability, but the data will not allow delineation between different segments of the population.

The use of the municipality facilitates the collection of data, as well as the examination of both pre- and post-impact routine patterns and the identification of re-stabilization. These patterns and trends represent social routine prior to disaster impact and the dynamic processes required to reach a point of stability post-impact. The consideration of the dynamics associated with re-stabilization allows for the application of theoretical frameworks based in social time and social routine. Through the examination of overall trends in infrastructure use patterns, economic activity trends, and crime and law enforcement activities, post-disaster general pattern expectations will be identified. Further study can identify the impact of social vulnerability in subpopulations and develop strategies to address these concerns. Several aspects unique to Social Routine Theory and this study are outlined below.

Social time

Social Routine Theory (Neal 2013) presents several unique factors to consider as one studies how the transition from impact to the new normal occurs. The concept of social time is of fundamental importance to this study. Although the overall process of creating a "new normal" has yet to be studied sufficiently, the speed of recovery is one aspect of the recovery process that has received considerable consideration in previous research. Defined by Friesma et al. (1979) as the time a community requires to reconstruct the pre-impact built environment, the speed of recovery has been identified as a key to "successful recovery" (Rubin 1985.) Social Routine Theory departs from this traditional use of time to define phases or progress (Neal, 2013.) Neal asserts that impacted social units move from clock and calendar time (doing what is scheduled) to event time (doing what is needed now) following disaster. My research uses time to place the routine patterns into a temporal context that bridges chronological time with "social time" (or Neal's "event time.")

Social time differs significantly from the concept of chronological time. The Greeks used the term *chronos* to describe objective time. Chronological time assumes linearity and definite sequencing. For example, 2:00 PM represents a specific point that falls after 11:00 AM but prior to 3:00 PM. Morning precedes afternoon. Chronological time is clearly divisible and measurable by a clock and calendar. The Greek term *kairos* is used to describe processes that occur at the most opportune time. People perform tasks as they are required and also when the tasks can be accomplished. This form of time is not measurable by the clock. *Kairos* is subjective and derives its meaning from social constructs. The individual experiencing *kairos* time defines time through perceptions and expectations. This concept of *kairos* time is at the root of our understanding of social time. Social time acknowledges that time is experienced contextually and incorporates spatial and material aspects of a situation as well as overall tempo or timing of events. For example, we understand a weekday is to be devoted to work or school responsibilities while weekends offer opportunity for leisure activities.

Researchers from multiple disciplines have documented the social, cultural, and psychological tasks and activities of our lives as predictable rhythms and behavioral routines of daily life. Hall (1983) explored how humans have experienced time from pre-history through contemporary times. Pre-historic humans tracked moon phases and practiced death rituals to mark the passage of time both chronologically and experientially. Hall's work argued that humans need the security of ritual at the most basic biological, physiological, and psychological level. He asserts that routines and rituals are assigned symbolic meaning that allows us as individuals and social units to create our reality. We construct schedules and expectations that exemplify normality. Our collective sense of safety and security is rooted in the predictability social rhythms provide (Zerubavel, 1981.) Time is treated as the primary organizer for activities. It helps us create priorities and categorize experience. Through time, we integrate and evaluate how our lives and the social processes we create are progressing. Hall demonstrated that "individuals are dominated in their behavior by complex hierarchies of interlocking rhythms" which encompass nearly every facet of human behavior (p. 140.) He pointed out that as social beings, people strive to establish these routines to increase predictability and create a sense of social security.

Time Compression

The concept of socially constructed time is reflected in the condition of "time compression" (Fleischer, 2013). Outside of the disaster context, individuals experience time compression based on other situational factors. For example, time seems to fly when we are on a great date. On the other hand, time seems to stand still when we are on the treadmill. Individuals and organizations experience time compression during extreme events (Olshansky, Hopkins, & Johnson 2012). In the immediate aftermath of disaster impact, the ability to respond effectively is limited by the amount of time available to consider the situation and weigh options. Response and recovery priorities may shift dramatically in very, non-sequential ways. It is widely understood that response and recovery are not linear processes (Comerio, 1998; Quarantelli, 1982, 1998, 1999; Neal, 1997, 2004; Nigg, 1995; Phillips, 2009; Rubin, 1985.) Olshansky et al. (2012) pointed out that the recovery processes of physical reconstruction, financial transactions, social capital formation, and institution building compressed unequally in time. Their study examined how time compression in disaster changed recovery processes differentially resulting in great variability in recovery experiences. Differential application of time impacts helps to explain the negative impact of social vulnerability. Those with pre-existing networks providing access to limited resources experienced recovery at a quicker pace and more positively than those with weaker networks.

Social Disruption and Routine Pattern Shifts in the Disaster Context

In their qualitative content analysis of early disaster research, Thornburg, Knotterus, and Webb (2007) focused on the disruption of social routine that disaster brings to individuals and households. Individuals and groups participate in "ritualized activities and/or processes to create meaning, purpose, and a symbolic framework for actions and interactions". These rituals or *routines* represent the temporal structure on which Neal (2013) builds his Social Routine Theory framework. Disruption of these social rituals removes symbolic meaning from normal actions and interactions resulting in "deritualization". Thornburg et al. asserted that the victims of disaster defined their experiences through examples of aimless, confused, "deritualized" behavior. This study will examine disruption at the municipal level patterns of behavior. The emergent patterns of the examined quantifiable infrastructure variables will illustrate not only the disruption wrought by a disaster, but also the process of restoring social connections through rituals or routines.

Following rhythm interruptions, humans are driven to re-create patterns and routines (Hall, 1983.) These new patterns and routines are created with emphasis placed on event or activity defined time instead of chronological or clock time (Neal, 2013.) For example, prior to disaster a family may have designated Saturday morning as “laundry day” and all soiled clothes were expected to be in the laundry room by 8:00 AM Saturday morning. Post-disaster, laundry day would occur when a washing machine, water, and the person responsible for laundering were all available. For this study, our first task is the verification of the existence of social routine or “rhythm of life” prior to disaster impact as assumed by the FACSE model (Chen et al., 2013). Each city should have a distinct pattern or rhythm because of the unique combination of economic and social characteristics and activities present.

Social routine may be reflected in regular patterns or rhythmic fluctuations. Zerubavel (1981) referred to these patterns as “social cycles” in his discussion of human’s desire for temporal regularity. As individuals, households, and other social groups organize their activities, they establish relatively stable routines. As a simple example, standard work schedules result in higher traffic patterns in the morning and early evening. The school calendar (academic year versus summer break) and schedule (bus schedules/start and release times) contribute to these established travel patterns. Certain places are also important to the concept of social time. Most individuals perform work outside of the home requiring a change in location. The home may be the location for bathing, eating meals, and interacting with kin and neighbors. Other key social places may include recreational spaces like parks or gyms, places of worship, and shopping areas.

Under disaster conditions, the linear nature of chronological time is no longer relative as life takes on a task-driven aspect involving a cyclic series of events. In her discussion of time and crisis, Fleischer (2013) emphasized the shift to a socially constructed, subjective concept of time following disaster. As a subjective concept, time needs to be considered in terms of *how* it is experienced. Individuals, households, and larger communities may experience a disaster much differently from each other. This dynamic experience is what this study considers ***social time.*** Carr (1932) was the first to introduce the importance of social time into the study of disaster. He emphasized that disaster impact should be considered in terms of the social tasks required post-impact. Later researchers included the significant disruption of social processes as a component of the definition of disaster (Barton, 1970; Dynes, 1970; Dynes & Quarantelli, 2008; Fritz, 1961; Stallings, 2007). .

Disaster instantly removes most of the “anchor points” of daily life (Olshansky et al., 2012.) In their work following Hurricane Andrew, Peacock and Ragsdale (1997) and Morrow (1997 A) described the extreme changes disaster wreaks upon the social routine of those impacted. They noted that the individuals who survived Hurricane Andrew experienced no sense of a daily routine or a “normal life” for several weeks following the hurricane. Everyday tasks like getting a drink of water or taking a bath became “daunting tasks”. The foundation of the “routines” of daily life was no longer available. Electricity, water, gas, telephone, appliances, and houses were not available to survivors. Food, supplies, and services were not available in the same way or place as they were prior to the hurricane. Hurricane Andrew destroyed schools, hospitals, offices, and neighborhoods. Individuals were required to invest time and energy into gathering information and relocating resources. Morrow (1997 B) emphasized the loss of the ***home*** in terms of social routine loss versus the simple loss of the house as a physical structure.

She found that the survivors of Hurricane Andrews were unable to establish stable daily routines for extensive periods of time throughout response and recovery. In their 10 year follow-up research on a working-class community following Hurricane Andrew, Dash, Morrow, Mainster and Cunningham (1997) demonstrated that many survivors indicated that they were still attempting to re-establish daily routines resembling those that existed prior to the hurricane.

Re-creation of Social Routine and Rhythm of Life

To facilitate recovery, many researchers recognize that one of the primary needs is the re-establishment of pre-disaster social routines. In their consideration of community-level recovery both Schwab (1998) and Olshansky (2005) emphasized that the population's desire for a return to normal civic and economic activities may derail recovery and mitigation projects if not satisfied first. The return of routine is essential to the perception of recovery on the part of those impacted. It is here that the "speed" of recovery becomes critical (Friesma et al., 1979). The concept of time compression (Olshansky et al., 2012) reemerges as survivors perceived that more time is passing than actually did pass due to the lack of life routines. This can result in citizens becoming negative towards recovery efforts. Quarantelli (1995) defines the transitions among post-disaster housing (emergency shelter, temporary shelter, temporary housing, permanent housing) in terms of the survivors' ability to re-establish household routines. Hayashi (2007) referred to the creation of these new routines as "life recovery" and stated that "life recovery" is the ultimate goal of recovery.

In order to re-establish routine, post-disaster stabilization must encompass physical recovery of the built environment. However, such recovery cannot be defined as simple physical reconstruction (Dynes & Quarantelli, 2008.) The physical environment serves as a tool for economic development and recovery as well as the restoration of social infrastructure that allows the creation of new routines. The tasks associated with the restoration of the built, economic, and social environment are tightly connected to time in terms of the perception of recovery. Kates and Pijawka (1977) established that the pace of reconstruction was correlated closely with victims' sense of recovery success and completion. This concept of speed is key to understanding Rubin, Saperstein, and Barbee's (1985) assertion that speed was a key consideration in determining the success of recovery efforts.

This study makes no attempt to differentiate between the artificial phases of response and recovery. As demonstrated by King (2012), recovery begins immediately following impact, is triggered by response, and occurs concurrently with activities often associated with mitigation. This overlap supports the argument that disaster is not experienced in a linear manner (Neal, 1997, 2003.) Therefore, the phase-based approach of past research is insufficient for understanding the processes associated with the re-establishment of pre-disaster social routines. Assessing completion of "recovery" through the creation of stable, potentially "new" social routines distinguishes this research from other projects that focus on the value-laden questions of whether recovery should simply re-create the pre-disaster status quo or improve the resilience and/or reduce the vulnerability of those impacted by the event (Comfort, Boin, & Demchak, 2010).

Magnitude of Disruption as an Indicator of Degree of Disaster

The number of social systems disrupted, the degree to which social order is damaged, and the chronological time required to re-create predictability and routine suggest the degree of disaster experienced. While not attempting to distinguish specific phases or assign specific tasks and activities to such phases, this project asserts that it is the combination of the initial magnitude of pattern disruption and the time required to return to a stable rhythm that defines the Degree of Disaster that a system experiences. Again, the focus is not on the restoration of pre-disaster trends or patterns. Even the earliest disaster research demonstrates that the post-impact context differs greatly from pre-disaster conditions. Quarantelli (1985, 1999) and Neal (2013) pointed out that the number of pre-impact routines or rhythms affected, the degree to which these routines were altered, and the time required for routines to re-emerge reflect the overall degree of disaster experienced.

Systems Environment and the Ecological Framework.

Early disaster research acknowledges the differential impacts and experiences of the survivors as natural, built, and social environments interact. Fritz and Mathewson (1957), Bates et al. (1963) and Barton (1969) incorporated aspects of the relationship between social processes and physical damage into their work to argue that survivors respond in ways that reflect adaptation to the disaster context. Kates (1971) proposed the application of systems theory to the study of natural hazards explicitly. Kates' work clarified the essential interconnectedness of human (social) systems, natural systems, and technological systems. Friesma et al. (1979) adopted the systems approach and examined the interaction between economic impacts and social impacts on long-term community disaster recovery.

The interplay of social impact and the built environment is reflected in Quarantelli's (1982, 1995) post-disaster housing taxonomy. This work used the transitions between housing stages (emergency shelter, temporary shelter, temporary housing, and permanent housing) to demonstrate not only differential recovery experiences but also to reinforce the establishment of social "routines" to measure progress through his proposed stages of recovery. A disaster victim moves from the sheltering stages into housing only when household routines can be established and maintained.

The systems theory approach in the disaster context was further developed by Bates and Pelanda (1994) and expanded by Bates (1997) through the Sociopolitical Ecological Framework. The Sociopolitical Ecological Framework emphasizes the interconnectedness of multiple systems within the human ecological network that function within a larger ecological field. Humans construct social systems that include the built or technological environment, social environment, political environment, and economic environment. Society is viewed as a structural network, an ***ecological network,*** of independent social systems that are separate but linked through interaction and exchange. The ecological network functions within the greater ***ecological field***. The ecological field encompasses the natural environment (including biotic systems and non-living physical resources) and the associated set of physical conditions including climate, weather, sunlight, seasonal variation and other energy phenomena. As social systems interact with each other and the greater ecological field, competition emerges for finite resources. Additionally, changes in the ecological field may provide advantage to one social group over another. Key to understanding this theory is the concept of adaptation. Disadvantaged groups are more vulnerable to disruption within their network and field. This reflects our understanding of the concept of social vulnerability (Wisner et al., 2004.) Social systems adapt to changing conditions within ***both*** their ecological network and their ecological field. Systems with greater access to resources are likely to be more flexible and adapt more readily to changes in any part of their environment. Disaster disrupts the ecological network and ecological field. Restabilization represents the adaptation process to the post-disaster environment.

Using this framework, the disaster situation is considered holistically. Recognizing that social vulnerability is an inseparable component of an individual's, household's, and business firm's experience following a disaster; the system or ecological network approach allows for the study of the larger, more aggregate entity as our unit of analysis. Acknowledging the interaction and interdependencies among the built, natural, social, economic, and political environment is critical to understanding the creation and maintenance of social routines and the ability of a system to adapt and/or respond to an extreme event—a jolt to the system. The failure to incorporate the connectedness of these different aspects of the total environment is often cited as a weakness within disaster studies.

Neal (2013) compared the processes of regaining function and reconstructing relationships to the biologist's concept of "entrainment". He concluded that survivors essentially abandon clock time and move to event or social time in response to the availability of services and other members of the greater social network. McGrath and

Kelly (1986) described entrainment as the capture of an endogenous or innate body rhythm by an external cycle with a similar rhythm. While entrainment is most often considered from a biological or physiological perspective, it may also be experienced psychologically and socially. The perception of time passage is an example of psychological entrainment. When the amount of information processed and stored increases, so does subjective time perception. In a disaster situation, one could speculate that a person or social unit would need to assess a dramatically changed built, natural and social environment and make appropriate adaptations. These cognitive processes would force individuals to process and store levels of information greater than would be regularly encountered. As a result, individuals would subjectively assess extended time passage beyond what chronological time would indicate. Entire social units such as communities or in this case, a city, would collectively modify social rhythms to accommodate the altered post-disaster environment (McGrath & Kelly, 1986).

Many studies focus primarily or exclusively on the built environment and the level of damage created by the disaster agent. The rate of reconstruction or replacement of physical structures is often considered a key indicator of recovery (Comerio, 1998; Kates & Pijawka, 1977; Schwab et al. 1998) and very limited attention is given to other potential recovery factors. As Quarantelli's (1982, 1995) housing studies demonstrated, the reconstruction of the built environment is not sufficient to create community recovery. Instead, recovery needs to be considered in terms of the re-establishment of victims' social systems. Olshansky (2005) asserts that recovery is more about rebuilding lives and livelihoods (getting people back into their routines) than the rebuilding of buildings and infrastructure. ***The pace*** of reconstruction however is an indicator of the speed of overall social recovery. Because reconstruction always involves issues of equity, the pace of recovery is often slowed due to concerns regarding social vulnerability. A community is greater than its built environment. Recognizing that reconstruction is an essential component of overall community recovery, Dynes and Quarantelli (2008) concluded that longer reconstruction results in an equally delayed recovery. The importance of reconstruction was echoed in Morrow's (1997 B) assertion that housing loss should be interpreted as the loss of the ***home***. The social routines a home sustains represent the complex interplay between the built environment and the social rhythms of life.

The Process of Rhythm Re-establishment and Dynamic Homeostasis

Human systems strive to return to routines, even if these routines are modified due to altered circumstances (Hall, 1986; Thornburg et al., 2007; Zerubavel, 1981.) However, it is this **process** of transitioning from impact to recovery as defined by the re-establishment of stable social routines that is of interest to this study. The key is the stability of these routines not the similarity or dissimilarity to pre-disaster routines.

Chang and Miles (2004) attempted to model the holistic recovery process by explicitly demonstrating the linkages between scales, sectors, and processes that encompassed political, economic, social, natural, and built environmental factors. This model presented recovery as a process including objective, functional, and dynamic models. Adding a temporal component to their model allows one to consider the dynamics of change over time and recognizes that recovery may result in a "new normal" characterized by pattern stability. Alesch, Arendt, and Holly (2009) referred to this new state as “**dynamic homeostasis**”. In the language of socio-political ecology, the attainment of this dynamic homeostasis is an evolutionary process of system adaptation to the new, disaster-produced condition in which the city functions. The new routines developed following impact are adopted as patterns of long-term everyday life. Alesch, Arendt and Holly (2009) point out that such adaptation requires time and is measured best with variables that include a temporal component (ex. gallons of water per month, dollars collected per month.)

Application of Alesch et al.’s “dynamic homeostasis” framework allows researchers to consider recovery in a non-linear, non-sequenced manner. Recovery is not declared complete at some designated fixed point. Recovery is considered relative to the pattern stability within the city and the function of its components encompassing the built, economic, and social environments. The process of establishing the “new normal” is underway as a city repairs and/or develops social, political, and economic processes, institutions, and relationships that enable it to operate and cope in the new context created by disaster.

The new stable state or dynamic homeostasis as the representation of the recovery process acknowledges that the post-disaster context is different from the pre-disaster context and the “new normal” reflects adaptation of the overall city system. This evolutionary adaptation supports the application of the holistic Sociopolitical Ecology Framework (Bates & Pelanda 1994). It is the **rate** of change within the statistical, temporal pattern that determines when stabilization (recovery) has occurred. Recovery should be conceptualized as a dynamic and endless process (Brown et al., 2008) with no concrete endpoint. Examining the patterns of infrastructure variables over time until the rate of change stabilizes addresses the dynamic and fluid aspects their work demonstrates as essential.

Examining recovery as a transitional process by considering trend or pattern stabilization over time prevents the tendency to compare progress in terms of the re-establishment of routines or patterns that existed pre-disaster. The pre-disaster context no longer exists and such comparison is based on false assumptions (Berke, Kartez, & Wenger, 1993; Mileti, 1999; Tierney & Oliver-Smith, 2012). For example, if water consumption the month before a disaster was 100,000 gallons; it would not represent restabilization if consumption reached 100,000 gallons per month again. It is quite possible that use patterns would not stabilize until post-disaster consumption reached 250,000 gallons per month. Addressing the reality of a completely new post-disaster context opens the door for the study of strategies intended to enhance sustainability and/or reduce vulnerability. The recognition of the interaction among several systems and functional units within a municipality supports the use of non-obtrusive measures to examine pattern disruption and the re-establishment of pattern stability. The temporal component of these patterns assists in the understanding of the discontinuity or disruption created by a disaster. The ability to create a theory of recovery based on both the degree of disruption to pre-existing routines and the time it takes to adapt and establish new, stabilized patterns or routines may lead to an overall Degree of Disaster Index (DDI) as proposed by Neal's (2013) Social Routine Theory and Chen, Neal and Zhou's FACSE framework (2013).

Such an index would provide a method to study and compare multiple communities and the impact of different disaster-agents. Such an index could be scalable to different units of analysis including household, neighborhood, city, and/or region. This study will examine the process of transition from impact to recovery at the municipal level. Alesch and Siembieda's (2012, pg. 198) definition of a city as an "urban settlement existing within a defined geographic area, operating as an open system, with **relatively persistent patterned interaction**, with significant differentiation among participating organizations and individuals but with the necessity of shared significant social commonalities or interests" allows examination of the restoration of social routine within a systems environment at the municipal level.

In accordance with the principles outlined previously, this study considers the impact that the built, economic, and social environments may have on community members' social routines. I have adopted the concept of the city as an *ecological network* of social systems nested within the biophysical ecological field (Bates & Pelanda 1994). This ecological framework allows us to consider both the social system interactions among various social systems and their relationship and/or interdependence with the physical environment that includes many of the infrastructure systems examined. With an emphasis on the principal of persistent patterned interactions, this study examines the re-establishment of social routine as illustrated through quantitative infrastructure variables: water consumption, sales tax revenue, and crime statistics.

Water Consumption as a Representation of Social Rhythm

Water consumption reflects both household and business use within the city. Because of the multiple impacts of water provision, it is considered a "metabolic" lifeline within the city (Mitchell 2008). Loss of the built environment and/or disruption of social activities will result in a change in use patterns (Chang & Miles, 2004; Karatani & Hayashi, 2007; Rose, Benavides, Chang, Szczesniak, & Lim, 1997.) Reconstruction may result in a different number and/or type of building replacing the damaged structures creating a different use pattern for the city. This study will focus on the process of re-establishing a stable use pattern instead of re-creating or attaining pre-impact levels.

Water consumption is closely linked to household residency and economic activity. Severely damaged dwellings would be uninhabitable and result in water service termination. Because water is required for cooking, bathing, and general household function, long-term water service disruption would prohibit habitation. Disruption of normal life routines may result in an abandonment of discretionary behaviors such as lawn care, gardening, and/or swimming pool maintenance. Water consumption plays a fundamental role in the re-establishment of household and municipal routines/rhythms. Lack of running water requires the household to establish new routines (rhythms) that likely also involve a change in social place. The destruction and/or demolition of residential and commercial property will be demonstrated by a disruption in the pattern of water use. Water access under post-tornado conditions may be restricted due to dwelling/building damage and not due to damage of the actual water delivery system. Normalization of use patterns as illustrated by the stabilization of the monthly rate of change, allows the pattern of recovery processes to be observed.

Sales Tax Revenue as a Representation of Social Rhythm

Sales tax revenue was selected to represent city-based economic activity. Previous research did not indicate long term economic changes following disaster (Haas, Kates, & Bowden1971; Friesma et. al 1979) but failed to consider different levels of recovery by simply examining Gross Domestic Product (GDP) of a larger region. Municipal sales tax revenue should reflect all economic activity performed at the municipal level. This would include purchases made with external aid, purchases not made due to external material donations and purchases made by local businesses and households using all forms of income including insurance payouts and aid. Within Mitchell's (2008) taxonomy, sales tax revenue would represent a material or economic function that sustains both the physical fabric of the built environment as well as the livelihoods associated with the city's population. Because it is the pattern of activity over time that is of interest, negative or positive changes are not the key. Rather, the stabilization of revenue patterns is critical.

Economic fluctuations are also linked to recovery. Previous research (Chang, 2010; Chang & Miles, 2004; Rose et al., 1997; Webb, Tierney, & Dahlhammer, 2002) has examined business recovery following natural disasters. Chang (2010) concluded that recovery could be defined by a return to pre-impact economic patterns instead of absolute values. Sales tax revenue is a direct measure of economic activity within the city. Sales tax reflects both essential and discretionary expenditures. Following an extreme event, disposable income may be negatively impacted by employment restrictions/loss or re-directed to the repair and/or replacement of housing. This project will not determine how spending may be modified or diverted. This study will look at overall economic activity. Reconstruction may result in an overall boost to economic activity. However, we expect to see disruption in the pattern of activity due to the impact of donations, insurance payments and the potential time lag between impact and reconstruction activities. City sales tax collections will reflect any municipal transaction and we are concerned with the patterns of overall local activity in this study.

Sales tax revenue is linked to overall community economic activity. The ability to produce services/products, fulfill employment roles and patterns of income disposal are reflected in sales tax revenue. Physical damage to businesses and/or redirection of residents' financial resources will be reflected in the economic activity of a community. Sales tax revenue provides a direct measurement of the economic impact of an extreme event.

Crime Patterns as a Representation of Social Rhythm

Crime patterns reflect social rhythms within a municipality effectively. Cohen and Felson (1979) addressed the occurrence of crime as a social process that occurs when time and place intersect. Their Routine Activity Theory provides a framework from which to evaluate disaster impact on several aspects of criminal behavior. In short, Routine Activity Theory proposes that crime is a routine activity through which time and place interact. The commission of crime is opportunistic. For crime to occur, three factors must intersect: an available target, the presence of a motivated offender, and the lack of guardianship that normally serves to reduce the likelihood of successful crime commission.

In his examination of patterns of criminalization and disaster impact in New Orleans following Hurricane Katrina, Berger (2009) concluded that crime and public safety practices were "symbolic manifestations of power relations" within a society (pg. 491.). The poor and marginalized were subjected to higher levels of both property and violent crime before and following Hurricane Katrina. The pre-disaster crime context influences the perception of post-disaster crime (Berger, 2009; Curtis & Mills, 2011.) Citizens who experienced high (or low) levels of victimization prior to an extreme event become acclimated to those conditions. The occurrence of crime and the response of law enforcement agencies became routine or expected. Following Hurricane Katrina, those unfamiliar with routine crime were shocked by what was perceived as exceptional criminal behavior and helped frame New Orleans as a violent, crime-ridden free-for-all (Brezina & Kaufman, 2008). Additionally, certain environmental characteristics such as empty or abandoned properties increased the likelihood of criminal activity. These properties are an indicator of social disorder and serve as a signal to potential criminals (Curtis & Mills, 2011). In the post-disaster setting, debris and damaged or abandoned buildings would indicate social disorder—especially when such damage results in the displacement of regular residents. This displacement forces residents to form new spatial relationships with blighted areas and former neighbors.

All of this suggests that crime rates would increase following disaster within the framework of routine activity. The post-impact environment provides conditions favoring fluctuations in crime patterns (Cromwell et al., 1995). Post-disaster, it is likely that potential targets are displaced and exposed in large numbers. Events that result in emergency sheltering and temporary housing disruptions of normal social connections (neighborhood and kin networks) create increased crime opportunities for potential offenders. An influx of outsiders during the cleanup and reconstruction phases would also increase the number of potential offenders. Finally, the guardianship structure is often impacted with formal law enforcement resources and attention diverted from routine activities. Curtis and Mills (2011) concluded that elevated crime rates and reduction in service levels led to delayed recovery for those in the heavily impacted areas. Some researchers determined that certain forms of crime might increase due to the social disorder and change of law enforcement practices following a disaster. These forms of crime include property crimes (Friesma et al., 1979), alcohol-related crimes (Siman, 1977), domestic violence (Zahran et al., 2009), rape (Siegel et al., 1999; Thornton and Voigt, 2007), and fraud crimes (Frailing, 2010; Quarantelli, 1994; Siman, 1977).

The third aspect of the Routine Activities Theory involves guardianship. Guardianship can involve formal guardianship by established law enforcement agencies practicing regular public safety behaviors and patterns. Informal guardianship includes the oversight and protection one's presence or the presence of others may provide. Formal guardianship structures are often impacted with formal law enforcement resources and attention diverted from routine activities. Family and neighborhood social networks may be disrupted due to displacement but informal guardianship is increased and strengthened in the form of the altruistic community that regularly forms following an extreme event (Barton, 1969). This altruistic community is created by the strengthened bonds among survivors and appears to counteract the loss of formal guardianship to some degree (Quarantelli, 1994; Quarantelli & Dynes, 1972.) Informal guardianship in the form of neighborhood patrols and voluntary traffic control efforts filled the gap created in formal guardianship following Hurricane Andrew (Cromwell et al., 1995) and resulted in a drop in crime rates. In their examination of victimization following the Northridge, CA Earthquake, Siegel et al. (1999) concluded that reduction in the rates of robbery indicated the rise of an altruistic community and social cohesion.

Another potential reason for the drop in crime rates involves the capacity of law enforcement to follow up on reports from impacted citizens. While not a true disaster situation, large events that impact an entire municipality may offer an opportunity to examine the effect of an influx of a large number of outsiders on a city and its citizens. Looking at the impact of the Olympic games on Salt Lake City, Utah, Decker et al. (2007) concluded that crime rate increase was limited not by citizen requests but rather by the capacity of law enforcement to follow up on calls to the dispatch center. Citizen-generated calls for service (CFS) actually increased during the Olympic games. This increase was attributed to the influx of outsiders (motivated offenders) into the city coupled with the increase in potential targets. Law enforcement resources were concentrated within the hosting area and did not have the capacity to respond to the increased demands outside of the actual Game and Village area.

Importance/Contribution of Current Research Project

Because disruption is at the heart of disaster (Stallings 2007), studying the re-creation of routines and social structures can provide insight into the processes involved in the movement from impact to re-stabilization. Previous research (King, 2012; Quarantelli, 1982; Smith & Wenger, 2007) discusses the difficulty in determining when recovery begins and ends. Households' disaster experiences differ due to a variety of factors including income (Peacock & Bates, 1997; Comerio, 1998), race and/or ethnicity (Bolin 1986, 2007; Bolin & Stanford, 1998; Highland, Peacock, and Van Zandt 2014;

Phillips 1993), gender (Morrow & Enarson 1997, 1998; Enarson and Fothergill 2001; Fordham, 1999) and age (Klinenberg, 2002). As a result, determining when "recovery" has been achieved is extremely problematic. Because of the likelihood of multiple vulnerability factors intersecting at the household level, examination on the re-stabilization of social routine at a larger unit of analysis should provide insight into the value of quantifiable variables as indicators of the transition from impact to recovery. Organizational mission and function, as well as governmental funding, may be phase-specific. Determining resource allocation priorities and overall disaster planning is inherently linked to response termination and/or recovery achievement.

Many researchers have suggested that disaster research could advance planning practice considerably if a multi-agent and multi-impact database could be created (Berke & Glvovic, 2012; Chang, McDaniels, & Beaubien, 2009; Mendonca & Wallace, 2006.) If a method for multiple case comparison was available, common trends could be identified and potential priority-based sequencing of resource allocation established. Divergent trends unique to specific agents or communities may also be identified for additional consideration.

Examining economic recovery following the Kobe Earthquake, Chang and Miles (2004) determined that recovery was achieved when the ***rate of change*** in their economic variables post-earthquake matched the pre-impact rate of change. Tying the establishment of a new equilibrium to Neal's (2013) Social Routine Theory involving social time and rhythms, this research explores the possibility of using quantitative infrastructure, economic and crime variables to measure recovery achievement through pattern stabilization. This model provides for the potential development of a Degree of

Disaster Index that may be applied to multiple events allowing for case comparisons. Such an index would create a method of "scaling" an assessment to multiple units of analysis (household, neighborhood, city, region, state, and nation.

Summary

This literature review supports the application of the Social Time Theory framework to the study of the social disruption caused by an extreme event. The use of my selected variables (water consumption, sales tax revenue, citizen-generated calls for service, felony arrest rates, and traffic citation rate) as proxies for multiple aspects of the social and economic systems within a municipality is also supported by previous research. The methods I will use to study the presence and magnitude of disruption and the non-linear processes a city experiences to reach a "new normal" are described in Chapter III.

CHAPTER III

METHODOLOGY

This dissertation uses the framework of social routine (Neal, 2013) to quantify the social disruption disaster creates at the municipal level. I collected monthly municipal use reports for water consumption, sales tax revenue, felony arrest rates, traffic violation citations, and citizen-generated calls for service prior to disaster and post disaster. Routine use rhythms for both pre- and post-disaster periods were established through univariate analysis. Time series analysis, the Chow Break Point test, and the cumulative sum of squares (CUSUM) test were applied to determine the significance of any disaster-related disruption and demonstrate the process of restabilization. Restabilization of the rate of change for each variable defined the establishment of a "new normal" or recovery (Chang, 2010). By examining both pre-disaster and post-disaster data and testing for the rate of change in the variance of each variable, any changes in pattern (routine) was considered from the pre-disaster context (Barsky, Trainor, and Torres, 2006.)

I selected the two central Oklahoma cities of Moore and Stillwater for demographic and geographic similarities; I use them to address the need to maintain a regional context as suggested by Chang (2010.) Although the cities are similar, they experienced very different disasters. A very large tornado struck Moore on May 20, 2013, resulting in a Presidential Disaster Declaration (PDD) while wildfires that did not meet PDD criteria burned in the Stillwater area.

The examination of the impact that these extreme events exerted on the municipal rhythms of water consumption, sales tax revenue, and crime patterns (felony arrests, citizen-generated calls for service, and traffic violations offers the opportunity to demonstrate and quantify disaster-induced social disruption and restabilization. The current study focuses on any change in the patterns of water consumption, sales tax revenue, and criminal and law enforcement behaviors and not an increase or decrease in crime levels. To counter the potential for law enforcement capacity limitations, I examined three different indicators: CFS (citizen-generated demand for assistance), Type A Felony arrests (police-generated activity in response to serious property and violent crime), and traffic citations (typically considered low-level, routine law infractions that would be of low concern during the post-impact period.)

Setting and Participants

The Community: Moore, Oklahoma

Moore, Oklahoma is a small city with 57,800 residents. Located on the southwest edge of Oklahoma City, Moore's economy is closely tied with the larger metropolitan area. Moore's population is younger (36.5% under 18, 13.5% over 65), slightly more White (+6.7%) and more likely to have graduated from high school (+3.7%) than the overall state population. Slightly wealthier than greater Oklahoma (+ $12,314 per year) and less poverty-stricken (- 6.2%), Moore boasts a home ownership rate of 75.2%, 7.4% higher than overall state average. The city of Moore covers an area of 21.82 miles resulting in a population density of 2524 people per mile (U.S. Census Bureau, 2015.)

Municipal governance is provided through an elected city commission/city manager model. Organizational stability has resulted in key city administrators holding their current positions since 1999. This length of tenure suggests that municipal leadership has extensive disaster response and recovery experience. Moore has withstood three significant tornadic events since 1999. These extreme tornadoes followed similar paths. The shared disaster experience creates a familiarity with the tasks associated with all phases of a tornado impact. Key response agencies (governmental and non-governmental), city administrative offices, and Moore community members demonstrate trust and comfort with each other due to experience working together through the response to and recovery from multiple disasters. The potential effect such an established disaster subculture (Wenger & Weller, 1973) is not the focus of this study but may influence the findings. Study of a similar community without significant disaster experience following an EF5 tornadic event may be warranted in the future.

The Event: Moore, OK tornado

May in Oklahoma is synonymous with tornado events. This is especially true for the city of Moore, OK. In just under 15 years, Moore has experienced three severe tornado events. Because of the frequency of tornadoes, Moore represents a consistent environment in which to field test the application of Social Routine Theory. The most recent tornado on May 20, 2013 cut a 17-mile long path through the city. The EF-5 (maximum strength rating issued by the National Weather Service/NOAA) tornado reached a maximum width of 1.3 miles and damaged much of the city's built environment. Forty minutes after it touched down, the tornado had caused 24 fatalities and caused injury to 337 individuals requiring medical treatment. The storm damaged over 12,000 homes, caused 61,500 power outages, and affected 33,000 people (58.9% of the city's population). The event resulted in 22,000 insurance claims and over $2 billion in damage. The tornado cut across neighborhoods and involved multiple citywide subsystems demonstrating critical interaction as assumed by the Sociopolitical Ecological Theory (Bates & Pelanda, 1994), the Social Routine Theory (Neal, 2013) and the FACSE model (Chen, Neal, & Zhou, 2013.)

The Community: Stillwater, OK

Stillwater, Oklahoma is more rural than Moore, Oklahoma and lies about 70 miles to the northeast. With a permanent population of 46,560, Stillwater experiences a "boom" of approximately 15,000 residents when Oklahoma State University is in session. Oklahoma State is the city's largest employer. As home to a major university, Stillwater's population is much younger (8.1% over the 65), more White (+7.3%), and more highly educated (94% hold high school diplomas, 48.7% hold at least a bachelor's degree) than the greater Oklahoma population. These trends hold for comparison between Moore and Stillwater. However, nearly twice as many Stillwater residents fall below the poverty rate (32.7%) than in greater Oklahoma (16.9%). Stillwater also has a much lower median household income (-$14,143) than the Oklahoma average. Home ownership rates are much lower (37.5%) than the Oklahoma average of 67.1%. Stillwater covers slightly more area (29.54 miles) than Moore, which results in a much lower population density of 1547 people per mile (U.S. Census Bureau, 2015.)

Similar to Moore, Stillwater is governed through the city council/city manager model. While not as stable as Moore's city administration, the majority of key city administrators have been in place for over 10 years. Unlike Moore, Stillwater had not experienced a major disaster in 20 years prior to the fires.

The Event: Stillwater, OK wildfires

The entire state of Oklahoma experienced extreme drought between 2008 and 2015. The summer of 2012 was not only dry; it was hot. Stillwater, OK experienced 38 days over 100 degrees Fahrenheit prior to the end of July, 2012. The grassland surrounding Stillwater was a tinderbox. Beginning on July 31, 2012, Stillwater experienced three wildfires; they burned through August 4, 2012. As the county seat of Payne County and relatively isolated halfway between the urban centers of Oklahoma City and Tulsa, Stillwater offered city resources to battle these fires before they endangered the greater city. At the end of that week, Payne County had lost 59 homes with 4 more severely damaged. The Oklahoma Department of Emergency Management reported that 59 of the damaged or destroyed homes had no insurance (Belser, September 1, 2012.) Economically, the agricultural center also experienced 11,571 acres of scorched earth that included the loss of outbuildings, crops, and livestock. Fortunately, no human lives were lost.

Variable Selection and Definition

Monthly use data was collected regarding total water consumption, sales tax revenue, Type A felony arrests, traffic violation citations, and citizen-generated calls for service (CFS) for each city. Information was taken from reports routinely filed. No special reports were generated for this research. By using reports that were regularly generated, the risk of any type of data manipulation was minimized. Pre-disaster and post-disaster collection and reporting processes were not modified for the benefit of this research.

While data for over 20 variables was collected from both Moore and Stillwater, total water consumption, sales tax revenue, and Type A felony arrests, traffic violation citations, and citizen-generated calls for service were selected for closer examination. Some variables were eliminated from consideration because only one city collected the requested information on a regular basis. Any variable that was collected by only one city was not considered. The selected variables were chosen because they represented multiple aspects of the municipal environment and were collected in the same units of measurement and in the same time increments in both municipalities. All of my variables met Alesch and Siembieda's (2012) requirement that flow variables (variables that are measured per unit of time) be employed for time series analysis when examining municipal recovery processes. Each variable is defined below.

Water Consumption

Water is considered an essential lifeline and is tightly linked with household and commercial routines and rhythms. Other researchers have identified water supply and livelihood indicators as two variables tightly correlated with recovery (Brown et al. 2008; Chang & Shinozuka 2004; Rose et al., 1997). Water consumption data was available for total consumption, by housing type, and use type in Moore but not in Stillwater. Because Stillwater could provide only total consumption, this was selected for study. Total consumption also captures the overall pattern of use throughout the entire city. Total water consumption also captured any regional drought-induced restriction or consumption increase not related directly to the disaster events examined.

Sales Tax Revenue

Restoration of a city's economic vitality is a key to overall re-stabilization. Employment and production are quantifiable factors that tend to be impacted only when large-scale disaster or catastrophe occurs due to collection issues. The state of Oklahoma maintains employment and production data instead of the municipal entities. Neither of the studied disasters involved a high level of industrial area damage. Major employers maintained full production. Work attendance may have been impacted as residents were kept from their jobs due to tasks associated with dislocation, relocation, and reconstruction. However, I could not capture shifts in actual employment through routinely collected municipal data. Business capacity was not inhibited due to the scale and geographical location of the tornado and wildfires at a municipal level.

I elected to examine municipal sales tax revenue patterns for several reasons. First, sales tax revenue encompasses all sectors of economic activity within a city and can be expected to fluctuate within a regular rhythm. For example, Stillwater is host to a major state university. At the beginning of each school year, one would expect that the influx in new students would result in an increase in tax revenues. Sales tax revenue does not distinguish the source of the money being transacted. Whether the money spent comes from a household's personal savings, donations, or insurance payouts is not of concern. However, if households must divert resources and experience a disaster-induced reduction in disposable income, spending patterns may be altered significantly. Post-disaster tax revenue patterns may reflect the impact of donations (no need to buy supplies if they are being provided at no cost), the lag time between impact and insurance payouts, and periods of heavy spending associated with reconstruction. Citywide collections were tracked on a monthly basis. State sales tax revenue was not considered in this project. Municipal sales tax rates were constant for both cities during the research period so any fluctuation was not due to rate increases or decreases. (Note: The state of Oklahoma participates in a "sales tax free" back-to-school weekend every year in August. During this weekend, sales tax is not collected. In October, the state issues a credit to all municipalities. This credit is based on a statewide rate of reimbursement. The individual cities do not submit any form of request.)

Crime Data

As discussed previously in Chapter II, the research involving post-disaster crime patterns is mixed. The value of examining crime data is limited unless post-disaster trends are placed in the pre-disaster context (Barsky, Trainor, & Torres, 2006). By collecting and studying the same variables in both the pre-impact and post-impact period, this project ensures that pre-disaster trends are considered. In an attempt to examine three different aspects of social impacts that might be demonstrated through crime data, I chose to collect information regarding Type A felony arrests, the number of calls handled by the central dispatch service, and the number of traffic citations issued on a monthly basis.

Type A felony arrest rate. Felony arrests were tracked through the Uniform Crime Report (UCR) that is filed by every jurisdiction according to federal mandate. Type A felonies include forcible rape, sexual assault with an object, robbery, aggravated assault, simple assault, intimidation/threats/stalking, burglary/breaking and entering, all forms of felony larceny, motor vehicle theft, counterfeiting/forgery, fraud (false pretense / swindle / confidence game, credit or debit card, and impersonation), embezzlement, stolen property, vandalism / destruction / damage not due to arson, drug / narcotic / equipment violations, pornography/obscene materials, and weapon law violations. Type A felonies include those offenses that previous research suggests may become elevated post-disaster: gender-based offenses and fraud.

Traffic violation citations. Traffic citations reflect routine law enforcement. In times of disaster, law enforcement resources are diverted to disaster related tasks like perimeter creation and life safety concerns. Traffic violations become low priority. Consequently, I expected the number of citations to fall during the immediate post-disaster period.

Citizen-generated calls for service (CFS). Both felony arrests and traffic citations are a function of law enforcement. There will be no arrest or citation unless a law officer is involved. The ticketing, investigation, and arrest of violators are the responsibility of law enforcement personnel. Decker et al. (2007) noted that the number of arrests and citations is limited by law enforcement capacity. To avoid limiting my consideration of crime data to variables controlled by a municipal agency, I also included citizen-generated calls for service (CFS) in this study. The CFS data reflects the number of calls the central dispatch desk received for each city. These calls may initiate law enforcement action resulting in arrest and citation, but they may not. It is possible that the same event may result in multiple calls from concerned citizens. There is not a capacity limit to the number of calls the residents of a city may make to the dispatch center. Each call is electronically logged as it is received. If an event warrants increased citizen concern, this concern should be reflected in an increased number of citizen-generated calls for service. The changes in the environment as outlined by Cohen and Felson's (1979) Routine Activities Theory (increased number of potential victims, increased number of motivated offenders, reduced guardianship) should be reflected in changes in citizen-generated calls for assistance.

Use of Secondary Data

The transience of the post-disaster environment has long been an issue for researchers. Cisin and Clark (1962) noted that the difficulty begins immediately as the population of interest is completely disrupted resulting in a sampling strategy of nonrandom selection of subjects based on availability. Communication, transportation, and an ever-changing environment make the task even more difficult. These challenges are nearly universal in every form of disaster. Additionally, it is becoming increasingly difficult to access disaster sites immediately following impact (Michaels 2003; Tierney 2007). Because access to the field may be limited, the use of unobtrusive methods may be critical to study disaster impact and provide an opportunity for accurate assessment of the post-disaster environment (Stallings 2007).

For a longitudinal study, secondary data that is regularly collected and publicly accessible provides consistency and an opportunity to study trends and patterns as outlined previously (Webb et al. 1981). Chang (2010) asserted that statistical data and the application of time series analysis is "vastly underutilized." She continued, stating that this statistical data is not only accessible and inexpensive, most cities and countries collect the same or similar data, making it consistent and comparable across jurisdictions.

This routine collection and publication provides an opportunity for researchers to study patterns pre- and post-disaster. The availability of a pre-disaster data set is of great value in order to establish the pre-existing patterns and level of stability. The methods of collection and reporting should be consistent within the same city before and after disaster impact allowing for more reliable comparison. The use of secondary data also limits the impact of human emotion. Because the collection and reporting of such data is often automated, potential bias is limited. Use reports reflect actual behavior and not an individual's perception further minimizing bias.

In the development of a quantitative method to determine the magnitude of disaster, frameworks should facilitate comparisons across disasters and acknowledge the possibility of structural change where pre-disaster "normality" may differ from post-disaster "normality". Chang (2010) offered four principles for standardization and comparison for the development and application of statistical time series analysis addressed by this study. Because of the need of a temporal component, (a necessity supported by Alesch and Siembieda 2012), variables included in the analysis must be "flow" variables--those variables that are measured per unit of time. Flow variables are essential if one is to consider recovery as the creation of a new stable state. My analysis will examine the variables (water consumption, sales tax revenue, crime statistics) over time on a monthly basis.

Chang also asserted that the community studied needs to be placed in context of the greater region to account for exogenous variables such as general economic downturn or other broader social changes. Because both experimental cities in this study are located in central Oklahoma, any region-wide conditions would be reflected in both. For example, if the extreme drought created disrupted use patterns for Stillwater in 2012, the same disruption would be evident in the Moore patterns in 2012. If an economic downturn impacted the pattern of sales tax revenue in Moore during May 2013, the same pattern would be evident in Stillwater. Because I am examining use data from cities in the same general region, both municipal patterns will reflect any regional abnormalities (drought/water restrictions, wildfires, economic downturn, changes in regional demographics, etc.)

Shift in Research Design

Initially, I intended to conduct this research following a quasi-experimental design (Campbell & Stanley, 1963.) Stillwater and Moore are two cities with similar demographics located in central Oklahoma. The tornado of May 20, 2013 was the defining difference between the cities since Stillwater had not experienced a major disaster (defined by a Presidential Disaster Declaration.) Chang (2010) emphasized the need to place citywide research into a greater social context and supported the use of regional data as a source of statistical control. Regional data is not available for the variables I am considering. It simply is not collected at the regional level. Because Stillwater did not experience a tornado during the period of July 1, 2011 and June 30, 2015, I assumed Stillwater would serve as control to Moore. As a control city, Stillwater would provide verification that any infrastructure pattern disruption could be attributed to the tornado. In hindsight, choosing Stillwater as a control was an error that strengthened this project. Stillwater provided an opportunity to determine whether disruption occurs in smaller events and if the patterns of that disruption were similar to larger events.

As I outlined earlier, Stillwater is similar to Moore in population and located 72 miles northeast of Moore. Moore borders Oklahoma City to the south while Stillwater is not proximal to a major urban center. Both cities have similar socio-economic profiles but Stillwater does have a lower median household income and home value. Stillwater has not experienced a tornado or other major disaster for over 25 years while Moore has dealt with three F3 or greater tornadoes in the past 15 years (1999, 2003, 2013).

After I collected the data of interest and ran my initial analysis, it became clear that Stillwater had experienced its own form of disaster and disruption. This disruption occurred in August, 2012 and impacted every aspect of my data analysis. Further research into Stillwater's recent history identified the culprit. The entire state of Oklahoma experienced extreme drought from 2008 through May 2015. Stillwater was more fortunate than more southern and western cities and had adequate water resources to meet municipal demands without any form of municipal water use restrictions. (It should be noted that Moore was similarly fortunate. Neither city imposed water restrictions of any kind on its citizens.) In addition to extreme drought, the summer of 2012 brought 38 days with temperatures above 100 degrees Fahrenheit. Stillwater is more isolated and rural than Moore and is surrounded by farmland that had grown exceptionally dry under the drought and high heat conditions.

Between July 31, 2012 and August 4, 2012, Stillwater experienced three wildfires. By the end of the week, Payne County (the county in which Stillwater is located) had lost 59 homes to the fire and four additional homes were severely damaged. In addition to the homes that were lost, 11,571 acres of land were scorched. Fortunately, no lives were lost in any of the fires.

The fires did not damage the housing stock and built environment in terms of population displacement or service interruption as severely as the tornado in Moore, OK. Stillwater's economic production was also less impacted. However, these wildfires created disrupted infrastructure patterns indicating disaster experience. Instead of a control city, Stillwater provided an opportunity for a second disaster case study. I had the opportunity to compare similar cities experiencing different disaster agents to determine if disruption patterns, magnitude of disruption, and the variables demonstrating disruption in monthly water consumption, sales tax revenue, and crime patterns (felony arrests, citizen-generated calls for service, and traffic violations) were similar.

Data Collection

Because only secondary, publicly available information was collected, the Oklahoma State University Institutional Review Board granted me a waiver regarding human subject requirements and research limitations. Data regarding multiple infrastructure variables, many primarily associated with the biophysical environment, were identified and collected. These variables were selected because I predicted that they would impact the social interactions and organization within Moore, Oklahoma and Stillwater, Oklahoma, especially in the post-disaster context. I initially identified over 20 potential independent variables that were likely to provide insight into the rhythm of life within a city. While the original study design included daily data, the municipalities involved did not collect or track information at daily increments. Instead, data was collected at the lowest available time scale (monthly) from July 1, 2011 through June 30, 2015. Daily or weekly collection periods might have provided a more nuanced picture of the process of rhythm re-establishment and the unavailability of such information may limit the conclusions drawn from this study.

Telephone contact was made with key city administrators in both cities. Face-to-face meetings quickly followed this initial contact. In both cases, the city managers served as effective gatekeepers and facilitated access to all pertinent city officials. The Chief Financial Officer in both municipalities provided water consumption and sales tax revenue information. The Chief of Police in both cities facilitated access to the crime reports. All city office personnel agreed to provide requested data without hesitation and provided administrative staff support to pull the standard reports and ensure that the information provided was complete. I met with each staff member responsible for pulling the requested reports to verify that the provided data represented the function intended. Information was tracked on a monthly basis because the preferred daily/weekly time frames were unavailable as discussed previously. Data collection from private entities proved more problematic.

Unavailable or Incomplete Data

Despite multiple attempts to make personal contact with each private provider of electrical power and natural gas, they were not cooperative and would not provide the information I requested. I also attempted to collect school enrollment information. Due to pending litigation involving the deaths of seven elementary students and the injuries suffered by many other students, teachers and staff members, legal counsel for the Moore public school district advised school authorities not to provide any data. While it may have been possible to force the issue, in order to protect the positive relationship with school administration I did not pursue the data at this time. Subsequent research may involve this data as it becomes more readily available.

Stillwater did not track many of the potential variables in as much detail as Moore. Water consumption was not tracked by type of housing or intended use in Stillwater. Information regarding building permits also differed dramatically. Moore tracked permits very specifically according to specific trade (electrician, plumbing, general) or by specific structure (i.e. swimming pool, tornado shelter.). In Stillwater, permits were not tracked according to specific trade or by specific structure. I chose not to include those variables for which the reporting processes were not standard between the two cities.

Rhythm of Life Patterns

Using the pre-disaster data, routine patterns representing the "rhythm of life" in each city may be considered and compared. While similar demographically, Moore and Stillwater differ in terms of economic drivers and proximity to urban areas. For example, Stillwater is a university town. Routine rhythms in Stillwater should reflect the academic calendar: the influx of 25,000 students each fall and their mass departure in the summer. Without a university, Moore would have different patterns and routines. This study is not concerned with the re-establishment of pre-disaster values of the variables of interest. Rather, this project attempts to demonstrate the patterns associated with re-stabilization in terms of trends and time to re-stabilization.

Descriptive Statistics and Spearman's Correlation

I expect that standard descriptive measures will not provide much useful information. Because the disasters in each case are expected to produce a significant change in the value of each variable, the minimum and maximum values and mean will not provide much insight. However, a large standard deviation may indicate something unusual happened. I will use Spearman's Correlation to determine if the rhythm of life in each city is impacted by an extreme event. For the Moore tornado, I will compare the correlation that existed prior to the event with the correlation that exists following the tornado. In Moore, the fiscal years prior to the tornado (FY 2012 and FY 2013) will be correlated and compared with the correlation between fiscal year 2012 and the year following the tornado (FY 2014). Because the Stillwater wildfires occur so early in my collection period, I will compare the fiscal years most distant from the event (FY 2012 and FY 2015) with the fiscal years containing the fires and immediately following the fires (FY 2013 and FY 2015). If disruption occurs within the municipal system, I will expect to see a greater degree of correlation in the periods with no event compared to the periods that contain the event.

Time Series Analysis

In their attempt to create a recovery index using time series analysis involving electricity consumption and Gross Regional Product (GRP), Karatini and Hayashi (2007) discussed the need to remove seasonal trends and address incidental variation (“noise”.) I will follow the same general approach using time series analysis as developed by Box, Jenkins, and Reinsel (2004.) My analysis will apply the CUSUM of squares test as developed by Brown, Durbin, and Evans (1975) and validated by McCabe and Harrison (1980.) The CUSUM of squares test is based on the cumulative sum of the recursive residuals of each data point. The test demonstrates parameter instability if the cumulative sum goes outside of the confidence interval (CI). Time series data may be expressed using the following equations:

$$X(t) = T(t) + S(t) + I(t) \text{............}$$

X(t): time series data at time t

T(t): trend (overall trend)

S(t): seasonal variation

I(t): random variation

I(t), S(t) and *T(t)* are calculated by the following equations:

$$I(t) = x(t) - MA(3)\{x(t)\}$$

$$= x(t) - 1/3 \,.\, (x(t\text{-}1) + x(t) + x(t+1)$$

where *MA(p)* represents a moving average of *x(t)* over *p* terms (months)

$$S(t) = x(t) - MA(12)\{x(t)\}$$

$$= x(t) - 1/12\ (\ ½\ .\ x(t\text{-}6) + x(t\text{-}5) + ...x(t) + … + x(t+5) + ½.\ x(t+6)$$

$T(t)$ is determined by subtracting $S(t)$ and $I(t)$ from the time series data.

Seasonal trend identification and removal. Because this study focuses on patterns associated with the recovery process beginning at the time of impact, it is important to remove any trends associated with non-disaster factors such as seasonal demands. These seasonal trends represent the routine or "rhythms" of life discussed previously. I used Karatini and Hayashi's definition of trend as a "certain systematic change in relation to the level and slope of time series data." I adopted Miles and Chang's (2006) assertion of restabilization of the rate of variation around the pre-disaster slope as the establishment of dynamic recovery. The magnitude of the initial fluctuation created by disaster impact and the time required to re-establish the pre-disaster pattern (or slope) will indicate the degree of disaster as suggested by Chen, Neal, and Zhou (2013.)

Using E-Views software, the data was analyzed to establish the overall expected slope, seasonal variations and residual variance. E-Views allows the Moving Average model to be applied directly to the series data. This produces a univariate model specifying the conditional mean of the series as a constant and measuring the residuals as differences of the series from the mean. Points that fall outside a 95% Confidence

Interval indicate disruption that cannot be explained by routine variation (Hendershot, 2010).

In order to establish the overall trend for each variable, seasonal trends must be identified and controlled. Seasonal trends interfere with the ability of the selected statistical tests to identify variation-or disruption-due solely to the disaster impact. My first hypothesis is therefore that my variables demonstrate distinct seasonal trends. To test this hypothesis, I used the Augmented Dickey-Fuller unit root test. The E-Views Correlogram function provides a visual illustration of the presence of such trends. If seasonal or regular trend behavior is identified, the data must be regressed to establish stationary control through the use of lag variables. Each variable was considered independently of the others.

Preliminary data review indicated that in addition to the lag variable to measure the rate of change month to month, water consumption requires a 4-month lag variable to account for seasonal variations. Sales tax revenue appears to require a 2-month lag variable in addition to the 1-month comparative lag variable to account for periodic (expected) variation.

The crime data required different lag variables depending on which variable was being considered and the city. Moore's citizen-generated Calls For Service (CFS) data became stationary using only a 1-month lag variable. Stillwater's CFS data required the single month and a 3-month lag variable to remove the unit root trend. Traffic citation data required the same differential treatment: a single month lag for Moore and both a 1-

month and 3-month lag for Stillwater. The UCR data required only the 1-month lag for both cities.

Chow Break Point Test. Following the application of the lag variables listed above, stationary series were created for each variable and city. The Chow break point test was applied to the stationary data series to determine whether there was a significant break in the expected pattern for each variable. Because Stillwater experienced wildfires in August 2012 and the Moore tornado occurred in May 2013, variables exhibiting disaster-related disruption should yield a significant Chow break point test for those periods. However, Stillwater did not experience the May 2013 tornado and should not show disruption for that time period. In the same way, Moore should not demonstrate disruption for the August 2012 wildfires. It is possible that due to municipal billing cycles the actual break may be evident during the 2 months following the actual event.

Cumulative Sum Test. The Cumulative sum test (CUSUM) provides a visual representation of the break point identified by the Chow break point test. Inclan and Tiao (1994) verified its usefulness in identifying the change in expected pattern during time series analysis and Lee, Ha, and Na (2003) confirmed its application to moving average models. While the CUSUM test introduces the idea that the variance somehow changes at the break point, it does not indicate the direction of the change nor does it determine the significance of the break.

Cumulative Sum of Squares Test. Once the data was regressed to establish stability and the Chow break point test confirmed that a significant point of disruption occurred, the CUSUM of Squares test was run to establish points of overall trend disruption as indicated by points that fall outside of the 95% CI slope lines section. The CUSUM of Squares test is similar to the CUSUM test in that it examines parameter stability and illustrates the duration of disruption through the return to system equilibrium. I expect the Moore data to demonstrate significant disruption associated with tornado impact with subsequent variation patterns illustrating the recovery process as the rate of change within the variable stabilizes. Data from Stillwater should indicate similar disruption and variation patterns for the period following the wildfires but should consistently remain in near proximity to the overall trend slope during the time of the Moore tornado. The pattern of each city's disruption and re-stabilization or return to equilibrium should be unique. It is important to remember that the trend slope represents the rate of change (standard deviation) within the data across time, not absolute values. I looked for stability within the use and/or collection patterns, not a return to pre-disaster levels of the variable of interest.

Limitations

My collection methods and the use of secondary data introduce a variety of limitations to the current study. First, the use of secondary data limits the ability to "scale" the data. Both cities studied collected and released their information on a monthly basis. It is possible that hourly, daily, or weekly data would have revealed patterns that monthly information disguised or masked. It is possible that a different pattern may have become apparent altogether. Collecting data for three years pre- and post-impact may have also increased my ability to verify that the return to equilibrium was a true return. However, the timing of the Moore tornado did not allow for more data collection.

While the availability of municipal data supports using the city as the unit of analysis, the scale of the city may similarly mask differential patterns or trends. Brown et al. (2008) encourage the creation of a temporal assessment tool that may be scaled for household, individual, business or neighborhood analysis. However, they assert that the initial analysis should be conducted collectively within the context of the greater community. The aggregation at the municipal level disallowed the possibility of examining impacts at the individual, household, neighborhood, or other sub-community level. The potential impact of social vulnerability is an aspect that the current research design cannot consider. Instead, the municipality or city serves as the unit of analysis. (The term "community" is also used to represent the city as an aggregate and not a sub-population or neighborhood within a municipality.) The understanding of the city as a self-organizing system is critical to the application of the social routine framework to the experience of Moore, Oklahoma and Stillwater, Oklahoma. The city is viewed as a complex and self-organizing system as outlined by Alesch and Siembieda (2012.) The various component systems that make up the greater municipal system (economic environment, built environment, natural environment, social structures, social institutions, etc.) are interconnected and interdependent. In the disaster situation, one or more of these systems are rendered non-functional, resulting in the disruption of important relationships. Within the city system, recovery is a process by which components regain function and reconstruct relationships based on the ***new*** conditions created by the disaster agent or the city's response to the agent. In this manner, the city's progress is adaptive and dynamic as outlined in Bates' Sociopolitical Ecological framework (1997). As discussed previously, the scale of the available data was a function of the collecting agencies and could not be influenced. However, the advantages of consistency and availability outweigh these potential issues.

The data I collected should be free of post-disaster emotions and potential distortion or bias. The methods used by each city for monitoring, reporting, and billing for all examined data categories remain consistent. These cities have similar municipal governance models and are located in the same state less than 100 miles apart. Future research involving multiple cities or cities located within different states or countries may encounter issues with identifying comparable data between municipalities. The secondary data used in this study is recorded and maintained for long periods of time. If comparable variables can be identified, the longevity of such information, as opposed to the ephemeral nature of much post-disaster data, increases the likelihood for extended longitudinal study of these cities and disasters as well as consistent multi-event comparisons in the future.

LIST AND DEFINITIONS OF EXAMINED VARIABLES

WATER CONSUMPTION (H20)	Total number of gallons of water provided by municipal utility	Reported monthly
SALES TAX REVENUE (TAX)	Total number of dollars collected by municipality, (includes all taxable transactions)	Reported monthly
UNIFORM CRIME REPORTS-CLASS A (UCR)	Number of arrests reported to federal government, Class A felonies	Reported monthly
CITIZEN-GENERATED CALLS FOR SERVICE (CFS)	Number of calls received at central dispatch, law enforcement only, citizen-generated	Reported monthly
TRAFFIC VIOLATIONS (TRAFFIC)	Number of traffic citations issued within municipal jurisdiction	Reported monthly

CHAPTER IV

RESULTS

Every disaster is unique to the context in which occurs. One should expect that different disaster agents to impact different cities in a distinctive manner. In this light, I expected that the combination of disaster agent and impacted city would yield slightly different patterns and trends within my selected variables. However, the same variable could exhibit some shared characteristics. Should my analysis yield similar trends, it should be possible to create a more generalized and predictive model associated with my selected variables. In this chapter, I will discuss each of the findings for every variable measured for each extreme event and city. Once each variable is presented and discussed, Chapter 5 will present a broader overview and conclusions.

Data Analysis

Descriptive statistics, Spearman correlations, and time series analysis were used to determine the presence and magnitude of disruption that disaster created in each of my selected variables. Trends and patterns illustrating the processes associated with disruption and restabilization were also demonstrated in each municipality. Statistical significance was determined throughout the study at $p \geq 0.05$ for each stage of analysis.

Descriptive Statistics

Moore, Oklahoma

All of the variables studied demonstrated the same type of pattern: the maximum and minimum values were inconsistent and presented a great deal of fluctuation. This was not unexpected. I anticipated that a disaster event would create a "jolt" of some type and increase or decrease the variable values considerably. Of greatest interest is the large standard deviations demonstrated by every variables that reflected the presence of fluctuation within the period of study. This initial analysis suggested that something had occurred within the city to create a "jolt" and change the use or occurrence pattern (Table 4.1, Appendix A.) With the exception of the large standard deviations, the descriptive measurements such as mean provided little insight into the change in the city's rhythms due to the sudden change in the pattern induced by the disaster impact.

Stillwater, Oklahoma

The descriptive statistical analysis for Stillwater, Oklahoma mirrored the results from Moore but with a reduced magnitude (Table 4.2, Appendix B.) The standard deviation for each variable was large and indicated that something unusual had happened to introduce a high level of variability. Again, descriptive statistics such as the mean provided little, if any, insight into the municipal patterns or rhythms pre- or post-disaster.

Spearman Correlation and Time Series Analysis

In order to answer my third research question, I needed to discover if each of my examined cities had an established "rhythm" for each variable prior to the disaster. Spearman correlations were run on each variable to determine how tightly correlated use and occurrence patterns were with no disaster activity and between no-disaster and post-disaster periods. Time series analysis was then conducted to address the other research questions.

In time series analysis, seasonal and other regular trends must be removed by using a moving average operation that includes identifying lag variables. Each variable will have unique lags and the same variable may exhibit different lag in the different municipalities. I applied a lag variable of 1 month (MA 1) to every variable to create a stable moving average operation. Additional lag variables indicate the need for further statistical stabilization based on seasonal or pre-existing trend behavior. The magnitude of the disaster impact or the size of the "jolt" delivered by the extreme event is measured by the Chow break point test and illustrated by the cumulative sum test (CUSUM) and CUSUM of Squares test. Combining the results of these two tests can scale the strength of a disaster's impact on a specific variable. A variable that demonstrates a significant Chow break point test and creates a visual demonstration of the disruption through the CUSUM test, is most susceptible or sensitive (and thus a better indicator) to a disaster's disruption.

The cumulative sum of squares test (CUSUM of Squares test) provides the best insight into the magnitude of the disruption experienced. The CUSUM of squares test looks at the changes in pattern variance and tests the parameter stability. This test provided insight into two important components of social rhythm in the disaster context. First, the test measures the capacity of the municipal social system to absorb the jolt as determined by the variable's pattern's departure from or containment within the expected confidence interval of the test. This test also allows me to examine the processes associated with system restabilization as a variable returns to the expected levels of variance, a return to system equilibrium.

Moore, Oklahoma

All of the variables studied provided some level of significant insight into the social disruption created by the tornado event within the city with the exception of traffic citations. Table 4.3 (Appendix C) provides an overview of the results of my analysis. Table 4.4 (Appendix D) provides a summation of the effectiveness of each variable as an indicator for measuring post-disaster social disruption. Table 4.7 (Appendix G) provides a summation of the Chow Break Point results for all studied variables. An in-depth discussion of the analysis results for each variable follows.

Water Consumption. Water consumption is the strongest indicator of disruption in Moore, Oklahoma that I studied. When the raw water consumption use totals (gallons) pre- and post-tornado are placed on the same graph, the disruption in use patterns is obvious (Figure 4.1, Appendix E.) Following an initial correlogram operation within Eviews, the data indicated a seasonal trend every four months. As a result, I applied a lag variables for both one and four months. The model of estimates that I applied is located in Table 4.5 (Appendix F.)

Spearman's Correlation. Analysis demonstrated strong correlation (indicates a tightly connected rhythm) in water consumption during the fiscal years prior to the tornado event (0.98). This rhythm was disrupted significantly with the correlation between fiscal year 2012 (no disaster event) and fiscal year 2014 (the year in which the tornado struck.) The correlation fell dramatically to 0.14. This finding supports the hypotheses that municipalities do exhibit a strong rhythm within water use patterns. The loss of this rhythm demonstrated by the reduction in post-disaster correlation supports the assertion that a disaster disrupts this rhythm. Table 4.5 (Appendix F) illustrates this break in water consumption pattern.

Chow Break Point Test. The sudden jolt experienced following the tornado is clearly demonstrated by the Chow break test. This analysis indicated that the point of pattern disruption occurred in May 2013 (the month of the tornado event.) This break point was highly significant and was maintained for three months (Table 4.6, Appendix G.) As mentioned previously, the Chow break point test indicates when a "jolt" is applied to a system and determines the significance of the disruption in the expected or routine rhythm of the variable of interest. The results of this test support the conclusion that the event disrupted the social systems associated with water consumption significantly.

CUSUM test. The CUSUM test produces a visual representation of the disruption indicated by the Chow break point test. Figure 4.2 (Appendix H) clearly shows a period of disruption or non-stabilized patterns for nearly a year after disaster impact. The black line in the center of the graph at value '0' demonstrates movement of the use pattern away from the expected levels. The use pattern does not leave the 95% Confidence

Interval (CI) represented by the area between the two red lines. However, this is not the statistical test I am using to determine if the disruption was significant. This test is used to create a picture of the shifts in pattern and demonstrate the time required to restabilize (return to the stable average or 0 line.) Looking at this graph, one can clearly observe that use pattern was destabilized for several months. It appears that true restabilization does not occur until approximately June 2014, a full year after the tornado.

CUSUM of Squares Test. It is the CUSUM of Squares analysis that tests the significance of the disruption in the water consumption pattern and best illustrates the processes associated with and the time required to reach restabilization. Examining the disruption in the variance of water consumption use and not the level of water use, the CUSUM of Squares creates a graph illustrating significant departures from the expected pattern of water consumption (Figure 4.3, Appendix I.) When the use pattern variance (blue line) falls outside of the red 95% CI area, the pattern is highly variable and shows no stability. It is important to note that the direction of the variability is not of concern in terms of instability. However, it may be of great importance that variance in the water consumption pattern leaves the CI in the negative direction then quickly reverses direction and does not restabilize until July 2014. Because this test is a moving average operation, it appears that the tornado's jolt was strong enough to pull the variance pattern outside of the CI for over 5 months prior to tornado.

Sales Tax Revenue. Statistical analysis of Moore's municipal sales tax revenue supports the conclusion that this variable is a good indicator of the initial disruption created by a disaster and does a moderately good job of illustrating the process of returning to equilibrium. Figure 4.4 (Appendix J) illustrates the pre- and post-tornado patterns associated with sales tax collections. At first glance, this graph appears to show a different pattern from July 2013 (two months post-event) until approximately March 2014 (approximately 10 months post-event.) This two-month lag is most likely due to the collection and reporting process. The municipal systems associated with creating monthly reports require approximately 60 days. Considering this delay in reporting time, the point of disruption would actually be May 2013 (the month of the tornado event.) Indeed, the initial Eviews correlogram demonstrated the need for a 2-month lag variable in addition to the 1-month lag required to establish a moving average. The model of estimates that I applied to the analysis of tax revenue is located in Table 4.7, Appendix K.

Spearman's Correlation. Similar to the water consumption data, post-tornado sales tax revenue demonstrated a significant ($p \geq 0.05$) reduction in correlation compared to pre-event patterns. The two fiscal years (FY 2012 and FY 2013) prior to the tornado demonstrated a correlation of 0.77. When the fiscal year (FY 2014) immediately following the tornado was tested for correlation with the fiscal year prior to the tornado (FY 2012), the correlation fell to 0.46. (Table 4.3, Appendix C.) Like water consumption patterns, the demonstration of a shift in correlations indicates that municipal sales tax revenue does exhibit a regular rhythm within the city of Moore. The reduction in correlation was not as dramatic as the change in the same measurement for water consumption suggesting that the municipal economic system may not have experienced the same level of disruption.

Chow Break Point Test. The Chow break point test indicated that the point of significant disruption occurred in July 2013 (Table 4.6, Appendix G). As discussed previously, the delay of two months was likely due to the 60-day collection and reporting process. If this assumption is correct, the actual disruption would coincide with the tornado. Unlike water consumption, this variable demonstrated only a single month of disruption as indicated by a significant Chow break point test. The shorter period of significant break mirrors the smaller shift in correlation and suggests that tax revenue is not as strong an indicator of disaster impact as water consumption. However, the Chow break point does demonstrate that the economic system experienced a jolt delivered by the event resulting in significant disruption.

CUSUM test. The CUSUM analysis shown in Figure 4.5 (Appendix L) demonstrates that sales tax revenues reflects a period of pattern instability between July 2013 and April 2014 (or the actual period of May 2013 and February 2014.) This test does not determine if the instability was statistically significant but illustrates a shift in expected pattern or rhythm of collection.

CUSUM of Squares Test. While the Chow break point test and the CUSUM test show that there was a significant disruption or jolt at the time of the tornado, municipal sales tax revenue does not demonstrate a significant departure from the expected rhythm as tested by the CUSUM of squares test. Looking at Figure 4.6 (Appendix M), one observes that the pattern of variance (blue line) never departs from expected variance as represented by the 95% CI (red lines.) Because the variance pattern never leaves the CI, sales tax revenue does not shed much light on the process of re-stabilizing. In fact, the combination of the three tests (Chow, CUSUM and CUSUM of squares) suggest that sales tax revenue may tell a very different story. The first two test demonstrate a significant point of disruption and a shift from the expected rhythms for approximately 9 months. The non-significant CUSUM of squares test indicates that Moore’s economic system somehow absorbed this level of disruption and did not experience a period of high variability and instability. The capacity of a municipal system to absorb a significant disruption may be an indicator of the magnitude of the disaster or the strength of a system's resistance to disruption.

Citizen-generated calls for service. My citizen-generated calls for service variable is the only crime pattern variable that I analyzed that was initiated by the citizens of Moore instead of the formal law enforcement organizations. Because citizens could contact the call center for any concern, an increase in the number of citizen-generated calls for service would represent heightened security concerns. A reduced number of calls would represent positive changes associated with the altruistic or therapeutic community post-disaster. A shift in either direction would be interpreted in terms of a change or disruption to normal social rhythms and patterns. With this understanding, citizen-generated calls for service was a good indicator that disruption occurred at the time of the tornado. However, its overall strength as an indicator was less than both water consumption and sales tax revenue. Figure 4.7 (Appendix N) illustrates the pre- and post-patterns of these citizen-generated calls. Upon visual examination, it is difficult to detect any regular pattern prior to the tornado. This chart does suggest multiple periods of increased calls following the tornado. The Eviews correlogram revealed no seasonal or regular trend. As a result, I applied only the one-month lag variable required for the moving average operation. The model of estimates that I applied to the analysis of citizen-generated calls for service is presented in Appendix O (Table 4.8).

Spearman's Correlation. Unlike water consumption and sales tax revenue, citizen-generated calls for service revealed no significant shift in correlation between pre-and post-tornado patterns (Table 4.3, Appendix C.) The pre-tornado period (FY 2012 and FY 2013) exhibited a correlation of 0.54. There was a downward shift in correlation when the fiscal year (FY 2014) immediately following the tornado was tested with the fiscal year prior to the tornado (0.38). Again, this movement was not statistically significant. This lack of significance suggests that the routine rhythm of citizen-generated calls for service is not as consistent as sales tax revenue or water consumption in Moore. An alternate explanation for the lack of a significant change in correlations is that the magnitude of the social disruption caused by the tornado on citizen-generated calls for service was not as great as in the other two systems previously discussed.

Chow Break Point Test. The Chow break point test indicated that the tornado had a significant impact on the expected pattern of citizen-generated calls for service. The Chow break point was significant for three months beginning in May 2013 (the month of the event) and maintaining significance for June and July 2013 (Table 4.6, Appendix G.) This level of prolonged significance indicates that the tornado had an important disruptive impact on the social systems associated with citizen-generated calls for service. This test does not examine the direction of the disruption. However, the raw data reflects an increase number of calls suggesting that the disruption in social structures resulted in a perceived sense of heightened threat to person or property. The three-month break point reveals that the citizens and human social systems of Moore experienced a greater level of social disruption than the economic system as represented by sales tax revenue.

CUSUM test. The disruption that the Chow break point test indicates is presented visually by the CUSUM test (Figure 4.8, Appendix P.) The impact of the tornado on expected citizen-generated calls for service pattern demonstrates a departure from the expected pattern represented by the stabilized zero-variance line. However, the pattern that emerges from the CUSUM test does not reveal a dramatic shift but rather a pattern that appears to be highly variable throughout the entire period for which I collected data. Again, this is not the statistical test used to determine if the level of disruption was significant. The combination of the CUSUM test with the Chow break point test provides a mixed picture of the strength of citizen-generated calls for service as an indicator of disaster-induced social disruption and the processes associated with restabilization.

CUSUM of Squares Test. Figure 4.9 (Appendix Q) demonstrates that the CUSUM of Squares Test fails to show a significant change in variance pattern in citizen-generated calls for service. At the time immediately following the tornado, it appears the variance approaches the 95% confidence interval boundary. However, the pattern does not fall outside of the red area at any time indicating that there is no significant instability. Instead, this test suggests that the Moore social system has the capacity to absorb the significant disruption indicated by the significant Chow break point test. Because of the results from both the CUSUM and CUSUM of Squares tests, citizen-generated calls for service is a limited indicator regarding the process of return to system equilibrium. These tests reveal no significant instability.

Felony Arrests (UCR). The felony arrest rate within the Moore system appears to demonstrate a significant change in pattern when looking at the raw data following the tornado (Figure 4.10, Appendix R.) In fact, the pattern created by the raw data seems to illustrate a dramatic reduction in the numbers of felony arrests overall. Because the number of felony arrests is initiated by law enforcement personnel, if police officers are deployed for disaster-related activities the lower arrest rates may be due to the lack of availability of investigating and arresting officers. This general rhythm of decline may also be indicative of the development of an altruistic community in which citizens are bonded tightly together by the common disaster experience. As a result of this bonding, crime among the citizens is decreased. It is difficult to view this chart and determine if the rhythm of the arrest rate changed or simply the numbers of arrests made. When the data was analyzed through the Eviews correlogram, it indicated that there was no seasonal trend present. Because of the lack of seasonal variance, I used only a 1-month lag variable to establish the moving average required for further analysis. The model of estimates I applied to the felony arrest rate is found in Table 4.9 (Appendix S.)

Spearman's Correlation. Felony arrest rates revealed an unusual correlation result when comparing the pre- and post-tornado patterns (Table 4.3, Appendix C.) Instead of a reduction in correlation, the correlation between the post-tornado data increased. The two fiscal years (FY 2012 and FY 2013) prior to the tornado produced a correlation of 0.54. This correlation was very similar to the pre-tornado correlation for citizen-generated calls for service (0.54). However, when the fiscal year (FY 2014) immediately following the tornado was compared with the fiscal year prior to the tornado (FY 2012), the correlation increased to 0.68. While not significant, this increase was unexpected and suggests that felony arrest rates may not have the same value as an indicator for social disruption or the process of restabilization as the variables discussed previously.

Chow Break Point Test. The Chow break point test indicated that there was a point of significant social disruption (Table 4.6, Appendix G.) This disruption did not take place immediately but appeared in June and July of 2013, a month following the tornado. This lag may reflect the time required to investigate a crime prior to making the actual arrest. The Chow break point test does not indicate a direction of the change—whether the arrest rate spiked or dipped. Rather, it is simply apparent that the social system experienced a jolt associated with the May 2013 tornado.

CUSUM test. The significant break or jolt indicated by the Chow break point test does not seem to be illustrated by the CUSUM test (Figure 4.11, Appendix T.) The visual representation of the variance seems to be relatively stable. The pattern remains close to the zero line and does not seem to show any dramatic changes.

CUSUM of Squares Test. Similar to the CUSUM test, the CUSUM of Squares test fails to reveal a significant disruptive pattern in felony arrests following the tornado. The rhythm appears to remain relatively close to the upper 95% confidence interval boundary for the year prior to the tornado through the year after the tornado (Figure 4.12, Appendix U.) Because the Moore felony arrest rate does not demonstrate any change in rhythm, it is a poor indicator for the processes involved in restabilization. This variable appears to demonstrate another aspect of the social system that absorbs the jolt applied by the tornado.

Traffic Citations. Statistical analysis revealed that traffic citation count is similar to felony arrest rates in strength as an indicator of disruption and restabilization for the Moore social system. Figure 4.13 (Appendix V) seems to indicate that the pattern of citations following the tornado is different than the pre-tornado rhythm. Visual examination of the raw data patterns appears to demonstrate a pattern of greater variance following the tornado. The initial Eviews correlogram indicated that there was no seasonal trend to be addressed and that a 1-month lag variable required to create the moving average operation would be sufficient. The model of estimates that I applied to my statistical analysis is reported in Appendix W (Table 4.10).

Spearman's Correlation. Similar to Moore's felony arrest rate, traffic citation patterns demonstrated an increased correlation calculation when considering the post-tornado data compared to pre-tornado data (Table 4.3, Appendix C.) The two fiscal years prior to the tornado (FY 2012 and FY 2013) displayed a correlation of 0.10. When the fiscal year prior to the tornado (FY 2013) was compared to the fiscal year immediately following the tornado (FY 2014), the correlation increased to 0.33. This shift was not significant but the direction was not expected.

Chow Break Point Test. The Chow break point test indicated that the tornado created significant disruption in June and July of 2013 (Table 4.6, Appendix G.) The delay in the appearance of this disruption may be a result of a reporting delay or that the jolt was ameliorated due to the timing of the tornado late in the month. It is interesting that both of the law enforcement-generated crime variables demonstrated the same pattern of delayed significance.

CUSUM test. The jolt indicated by the significant Chow break point test is evident in the CUSUM test (Figure 4.14, Appendix X.) Approximately one month after the tornado impact, the pattern obviously shifts upwards from the zero line. The pattern remains within the 95% confidence interval, but the change is easily observed. It is interesting to note that the pattern does not seem to restabilize. It is possible that other factors may contribute to the extended change in rhythm later during January through June of 2015.

CUSUM of Squares Test. The results of the CUSUM of Squares test suggests a short-term disruption that nearly exceeds the system's capacity to absorb the change in rhythm (Figure 4.15, Appendix Y.) It appears that the pattern line brushes the 95% confidence interval boundary during June and July 2013. It returns by August 2013 indicating restabilization. Because the line does not fully leave the confidence interval boundaries, I cannot conclude that the system's capacity was exceeded. Like felony arrests, this variable is generated by law enforcement. The number of officers assigned to disaster related tasks and diverted from normal patrol duties may account for these changes in rhythm.

Stillwater, Oklahoma

The wildfires that impacted Stillwater were of a smaller magnitude in terms of damage and percentage of the population effected than the Moore tornado. Accordingly, the examined variables revealed much lower levels of disruption. Water consumption proved to be the most sensitive indicator while sales tax revenue and felony arrests showed no tornado-induced disruption at all. Table 4.11 (Appendix Z) provides an overview of the results of my analysis. Table 4.14 (Appendix AA) provides a summary of the effectiveness of each variable as an indicator for measuring post-disaster social disruption. Table 4.14 (Appendix DD) provides a summation of the Chow break point test results for all studied variables. The Stillwater graphs will differ from the Moore graphs due to the dates involved in the wildfires. Because the wildfires started during the last week of July 2012 and burned through the first week of August 2012, I have fewer data points prior to the event for analysis. Because of the limited amount of data points I had prior to the wildfires, I chose to compare the two years of data from most temporally distant years from the fires (FY 2012 and FY 2015) and the years when the fires occurred (FY 2013) and that immediately following the fires (FY 2014) to determine municipal rhythm correlation. The event crossed the monthly boundary and it is possible that any change in pattern will impact the values in both months making any break point less visible. An in-depth discussion of the analysis results for each variable follows.

Water Consumption. Water consumption is the strongest indicator of disruption caused by the Stillwater wildfires. Similar to the pattern following the Moore tornado, water consumption demonstrated significant changes in all statistical tests. When the raw consumption totals (gallons) pre- and post-wildfires are placed on the same graph the shift in use pattern is obvious. The use pattern spikes for July 2012 and seems to quickly decrease (Figure 4.16, Appendix BB.) Following an initial correlogram operation within Eviews, the data indicated a seasonal trend every four months. As a result, I created lag variables for both one and four months. The model of estimates that I applied is located in Table 4.13 (Appendix CC.)

Spearman's Correlation. A high correlation result indicates a tightly connected municipal rhythm in the variable tested. Analysis demonstrated a strong correlation (0.82) in water consumption during the periods with no wildfires (FY 2012 and FY 2015). This rhythm was disrupted significantly by the wildfires with the correlation between fiscal year 2013 (the year in which the wildfires occurred) and fiscal year 2014 (the year immediately following the wildfires.) The correlation fell dramatically to 0.30. This finding supports the hypothesis that municipalities do exhibit a strong rhythm within water use patterns. The loss of this rhythm demonstrated by the reduction in post-disaster correlation supports the assertion that a disaster disrupts the pattern of water consumption. This break in water consumption pattern is outlined in Table 4.11 (Appendix Z.)

Chow Break Point Test. The sudden jolt induced by the wildfires is clearly demonstrated by the Chow break point test. This analysis indicated that the point of pattern disruption occurred in July 2012 (the month the wildfires began.) This break was highly significant and was maintained for three months (Table 4.14, Appendix DD.) As mentioned previously, the Chow break point test indicates when a "jolt" is applied to a system and determines the significance of the disruption in the expected or routine rhythm of the variable of interest. The results of this test support the conclusion that the event disrupted social systems associated with water consumption significantly.

CUSUM test. The CUSUM tests produces a visual representation of the disruption indicated by the Chow break point test. Figure 4.17 (Appendix EE) clearly shows disruption or non-stabilized pattern at the time of the wildfires. It appears that not only was this disruption large enough to drive the use pattern outside of the 95% confidence interval but the rhythm remained elevated from the zero line throughout the studied period. Even though this is not the test that I used to determine if the disruption was significant, it does create a picture of the shifts in pattern. This test does not indicate that the use pattern restabilizes completely as the use pattern does not return to the zero line through June 2015.

CUSUM of Squares Test. The process of restabilization is not evident with the CUSUM test but it is the CUSUM of Squares analysis that best illustrates both the significance of disaster-induced disruption and the processes associated with restabilization. Examining the disruption in the variance of water consumption instead of the level of water use, the CUSUM of Squares creates a graph illustrating significant departures from the expected pattern of water consumption (Figure 4.18, Appendix FF.) When the use pattern variance (blue line) falls outside of the red 95% confidence interval area, the pattern is highly variable and shows no stability. It is important to note that the direction of the variability is not of concern in terms of instability. Water consumption patterns leave the confidence interval area immediately at the point of the wildfires. Excessive variability continues through October 2013. Stated differently, water consumption did not restabilize for 15 months following the fires. This pattern of instability differs from the pattern that appeared following the Moore tornado dramatically which may be important to note. The Moore pattern left the confidence interval boundaries in a negative direction followed by a quick reversal outside of the boundaries in the positive direction. The period of time the pattern remained outside of the boundaries was similar between the two events. The jolt to the Stillwater rhythm did not appear to be as strong as the disruption to the Moore pattern. The disruption in the Moore rhythm was strong enough to impact the pattern prior to the tornado due to the moving average operation. The Stillwater disruption was not strong enough to create the same pre-event change.

Citizen-Generated Calls For Service. As discussed when describing the analysis of Moore's citizen-generated calls for service, this is the only crime pattern variable that the residents of Stillwater initiate and is not limited by any law enforcement's capacity or action. Citizen-generated calls for service reflects the citizen's perception of personal and property safety and security. An increase in call volume would indicate a heightened sense of threat to person or property. A decrease in call numbers would represent positive social changes associated with the altruistic or therapeutic community post-disaster. A shift in either direction would be interpreted in terms of a disruption to the routine social rhythms and patterns. With this understanding, citizen-generated calls for service was a good indicator that disruption occurred at the time of the wildfires. It was not as sensitive as water consumption. Figure 4.19 (Appendix GG) illustrates the pre- and post-fire patterns of these citizen-initiated calls. Upon visual examination, it is difficult to identify the pre-event pattern. Immediately following the fires, the number of calls does reach the highest level recorded. While this spike is visible and the post-fire pattern appears highly variable, one cannot determine if there was a point of significant disruption or if this variable would help demonstrate the restabilization process for Stillwater. The Eviews correlogram indicated that Stillwater exhibited seasonal trend at 3 months. As a result, I created lag variables for both 1- and 3-months. The model of estimates that I applied to the analysis of citizen-generated calls for service is presented in Appendix HH (Table 4.15).

Spearman's Correlation. Unlike water consumption, citizen-generated calls for service revealed no significant shift in correlation between non-disaster and with-disaster patterns (Table 4.11, Appendix Z.) The non-disaster period (FY 2012 and FY 2015) exhibited a correlation of 0.78. There was a slight downward shift in correlation when the fiscal year in which the fire took place (FY 2013) and the year immediately following (FY 2014) were analyzed (0.75). This shift was small and not significant. This lack of significance suggests that the routine rhythm of citizen-generated calls for service is not as consistent as water consumption in Stillwater. An alternate explanation for the lack of a significant change in correlation is that the magnitude of the social disruption caused by the wildfires was not as great as it was on water consumption patterns.

Chow Break Point Test. The Chow break point test indicated that the wildfires had a significant impact on the expected pattern of citizen-generated calls for service. The Chow break point was significant for the two months during which the fires burned, July and August 2012 (Table 4.14, Appendix DD.) This level and timing of significance indicates that the fires had a disruptive impact on the social systems associated with citizen-generated calls for service. This test does not examine the direction of the disruption. However, examination of the raw data reflects an increase in calls suggesting that the disruption manifested in a heightened perceived sense of threat to person or property. This is a logical assumption given the nature of wildfires as fast moving and seemingly spontaneous. The public, especially those near fire zones, were invested in assisting response agencies in tracking the fires. The data from September 2012 did not reveal a significant break from the expected pattern. This return to expected pattern indicates the change in the number of citizen-generated calls for service was directly related to the active fires.

CUSUM test. The disruption revealed by the Chow break point test is somewhat illustrated by the CUSUM test (Figure 4.20, Appendix II.) It is possible that the elevation in the departure from the expected pattern prior to the wildfires was influenced by the large increase in calls during the fire months. However, that conclusion would require study beyond the scope of this project. This test does illustrate the reduction in calls in September resulting in a rapid reversal of trend resulting in a departure from the expected pattern in the negative direction. The combination of the CUSUM test and Chow break point results indicate that citizen-generated calls for service is a good indicator for immediate disruption. The effectiveness of this variable in providing insight into the process of restabilization will be assessed by the CUSUM of Squares test.

CUSUM of Squares Test. Figure 4.21 (Appendix JJ) demonstrates that the CUSUM of Squares test fails to show a significant change in variance pattern in citizen-generated calls for service. The changes in variance remain within the 95% confidence interval during the time period surrounding the wildfires. Instead, my data indicates a significant change in variance in June 2014. I did not investigate what event or change in the system may have created this disruption because it occurred a full 2 years after the wildfires. There was no obvious extreme event during June 2014 and the temporal distance from the wildfires suggests that the variance may be due to a change in tracking calls or some other administrative shift. Because this test indicates no significant pattern instability at the time of the significant Chow break point tests, this test suggests that the Stillwater social system had the capacity to absorb the significant disruption caused by the wildfires. Because of the results from the CUSUM and CUSUM of Squares test, citizen-generated calls for service is a limited indicator regarding the process of return to system equilibrium.

Traffic Citations. Statistical analysis revealed that traffic citation count is similar to citizen-generated calls for service in strength as an indicator of disruption and restabilization for the Stillwater social system (Table 4.11, Appendix Z.) It is likely that law enforcement resources are redirected from routine patrol responsibilities to tasks associated with the urgent situation created by an extreme event. It may be expected that the capacity of a law enforcement agency to write traffic tickets would be reduced resulting in a reduced number of citations issued during the time of the extreme event. Figure 4.22 (Appendix KK) seems to indicate that the pattern of citations following the tornado is different from the pre-tornado rhythm. However, the raw data reveals that the trend was already exhibiting downward movement. The initial Eviews correlogram indicated that there was a seasonal trend at a three-month interval that needed to be removed in addition to the one-month lag variable required for the moving average operation. The model of estimates that I applied to my statistical analysis is reported in Appendix LL (Table 4.16).

Spearman's Correlation. Similar to Stillwater's citizen-generated calls for service rate, traffic citation patterns demonstrated a slightly reduced correlation between pre- and post-wildfire patterns. This shift in correlation was not statistically significant (Table 4.11, Appendix Z.) The two years farthest from the fires (FY 2012 and FY 2015) exhibited a correlation of 0.81. The fiscal years closest to the event (FY 2013 and FY 2014) were compared, the correlation diminished to 0.74. While the correlation was reduced, it was not significant.

Chow Break Point Test. The Chow break point test indicated that the wildfires produced significant disruption in traffic citation patterns in August 2012 and September

2012 (Table 4.14, Appendix DD.) While the break may seem somehow delayed, the processing time for traffic citations would explain why July 2012 (the first month of the wildfires) would not demonstrate the break while the month after the wildfires (September 2012) would.

CUSUM test. The results of the CUSUM test are inconclusive regarding the significant disruption indicated by the Chow break point test (Figure 4.23, Appendix MM.) The pattern had left the expected pattern represented by the zero line prior to the wildfires and the direction of this movement was maintained until December 2014. At no time does the pattern line leave the 95% confidence interval. The effectiveness of traffic citation count as an indicator of disruption is evident by the Chow break point test while the CUSUM test is less revealing.

CUSUM of Squares Test. The results of the CUSUM of Squares test indicate that traffic citation count variance due to the wildfires did not exceed the system's capacity to absorb the change in rhythm. The departure of the pattern in citation from the 95% confidence interval beginning in September 2013 (a year after the wildfires) through January 2015 is most likely attributable to changes in speed zone classifications, the creation of multiple construction zones throughout the city, and a change in the staffing levels for traffic control. None of these administrative decisions were related to the 2012 wildfires. Because any departure from the confidence interval boundaries occurred temporally distant from the wildfires, I cannot conclude that the system's capacity was exceeded. Because of this, I must conclude that traffic citation count does not provide insight to the processes associated with re-establishing system equilibrium.

Sales Tax Revenue. Statistical analysis of Stillwater's municipal sales tax revenue does not support the use of this indicator to measure the disruption created by the wildfires or to illustrate the process of restabilization. This is different from the findings produced by the Moore tornado data. The potential reasons for these differences will be discussed in Chapter V. Figure 4.25 (Appendix OO) illustrates the pre- and post-wildfire patterns associated with sales tax collections. From simple observation it is difficult to ascertain if the peaks and valleys exhibit a regular rhythm with the increase in total collections due to new industry or other economic factors unrelated to the wildfires. It should be noted that there was no change in sales tax rates for the city of Stillwater. Like the Moore municipal accounting system, Stillwater's sales tax collection and reporting process requires 60 days. Unlike the Moore pre- and post-event raw data graph, a dramatic shift in pattern is not demonstrated when the 2-month reporting delay is considered. The initial Eviews correlogram did indicate a need for a 2-month lag variable in addition to the 1-month lag required to establish a moving average. The model of estimates that I applied to the analysis of tax revenue is located in Table 4.17 (Appendix PP.)

Spearman's Correlation. Similar to Moore's felony arrest rate and traffic citation rate data, Stillwater's sales tax revenue pattern demonstrated an increased correlation calculation when considering the with-event data (Table 4.11, Appendix Z.) The two fiscal years most distant from the wildfires (FY 2012 and FY 2015) produced a correlation of 0.68. When the fiscal year with the wild fires (FY 2013) was compared to the year immediately following the fire events (FY 2014), the correlation increased to 0.80. This shift was not significant. However, the direction was unexpected.

Chow Break Point Test. The Chow break point test indicated that the Stillwater municipal system experienced no significant jolt in sales tax collections (Table 4.14, Appendix DD.) The Chow break point test results neared significance in September 2012. September 2012 was the most significant month of our collection period. Without a demonstration of significance, Stillwater's sales tax collection data is unlikely to produce valuable insight into the restabilization process.

CUSUM test. Not surprisingly, the CUSUM test fails to illustrate any significant change in collection patterns (Figure 4.26, Appendix QQ.) The pattern line remains elevated above the zero line throughout the examination period. The pattern also remains within the 95% confidence interval further supporting the results of the Chow break test that there was no significant disruption in sales tax collections caused by the wildfires.

CUSUM of Squares Test. Given the lack of significant disruption revealed by the Chow break point test and CUSUM test, it was a bit surprising to observe how close the sales tax collection variance pattern comes to the 95% confidence interval boundaries between May 2012 and October 2012. If the 2-month delay in reporting is put into consideration this period reflects actual collections for the period of March 2012 through August 2012. This suggests that the system may have experienced a high level of disruption just under the capacity threshold for significance. This conclusion supports the use of sales tax collections as a valid measure of the intensity of the disruption to the municipal system induced by a specific event.

Felony Arrests (UCR). Unlike Moore's felony arrest patterns, the felony arrest rate for Stillwater appears to spike immediately following the wildfires (Figure 28,

Appendix SS.) Local law enforcement personnel initiate felony arrests, like traffic citations. If an extreme event is large enough to require the re-assignment of personnel from normal crime-related activities to disaster-related duties, one would expect a decreased arrest rate due to the unavailability of investigating and arresting officers. A decrease in the commission of crime could also be attributed to the creation of an altruistic community resulting in tighter social bonds among community members. The raw data from Stillwater flies in the face of both of these assumptions. It appears that not only did the rate of arrests spike for approximately 9 months following the fires but this period also represents a major break in the long-term rhythm of felony crime rate. The initial Eviews correlogram indicated that the data revealed no seasonal trend. Because of the lack of seasonal variance, I used only a 1-month lag variable to establish the moving average required for further analysis. The model of estimates I applied to the felony arrest rate is found in Table 4.18 (Appendix TT.)

Spearman's Correlation. Felony arrest rates revealed an unusual correlation result when comparing no-event and with-event patterns (Table 4.11, Appendix Z.) The two fiscal years most temporally distant from the wildfires (FY 2012 and FY 2015) produced a correlation of -0.27. This was the lowest correlation found in any of the studied Stillwater variables. When the fiscal year during which the fires occurred (FY 2013) and the year immediately following (FY 2014) were compared, the correlation increased to -0.46. This shift was not significant. However, the direction of the shift was unexpected and suggests that felony arrests rates may not have the same value as an indicator for social disruption or the process of restabilization as some of the variables discussed previously.

Chow Break Point Test. Despite the initial appearance of the raw data, the Chow break point test revealed no significant break point (Table 4.14, Appendix DD.) The analysis shows that the calculation for September 2012 reaches most closely to significance but the results quickly retreat by October. Due to the lack of significance, I cannot conclude that the wildfires created significant social disruption reflected in felony arrest rates. I will discuss additional implications and considerations regarding felony arrest rates for both studied events in Chapter 5.

CUSUM test. The CUSUM test illustrates the felony arrest spike in September 2012 followed by another potential period of concern in February 2013 (Figure 4.29, Appendix UU.). Other than these two sharp, but relatively small spikes, the felony arrest pattern or rhythm appears to be rather flat. These spikes are more visible but similar to the pattern that emerged in Moore. These similarities may warrant further study and are discussed in more depth in Chapter 5.

CUSUM of Squares Test. Considering the results of Chow break point test and CUSUM test, the CUSUM of Squares test provided a surprising twist (Figure 4.30, Appendix VV.) While the felony arrest rate skirts the 95% confidence interval boundary at the time of the wildfires, it changes direction and steadily progresses to exit the boundary by February 2013. The period between the wildfires and February 2013 encompasses the period that included the two spikes visible in the CUSUM test. Once the pattern leaves the confidence interval boundary, it remains outside for 10 months. Restabilization begins in January 2014 and arrests appear to remain nearly flat for the remainder of my study period. This test demonstrates that something occurred to exceed the system's capacity but does not provide any further explanation. Potential explanations and further discussion occurs in Chapter 5.

Summary

This research sought answers to six primary research questions:

1. Can social rhythms be quantified through the examination of water consumption, sales tax revenue, and crime patterns?
2. Are water consumption, sales tax revenue, and crime patterns valid proxies for social and economic rhythms?
3. Does each municipality have a unique "rhythm of life" prior to disaster?
4. If disaster induces measurable disruption, does it create the same disruptive patterns despite the different disaster agent?
5. Do changes in infrastructure rhythms create a quantified representation of the process involved in recovering from an extreme event?
6. Are disrupted infrastructure patterns demonstrated by quantifiable shifts in variance of water consumption, sales tax revenue, and crime patterns? Can the establishment of a new "normal" or routine be measured by the re-stabilization of the variance within these variables?

In the final analysis, time series analysis revealed that disruption can be quantified and some indicators are much more sensitive than others despite the disaster agent or the magnitude of the disaster. The first three research questions were satisfied positively through time series analysis. All of the studied variables reflect a rhythmic pattern prior to and following disaster in each city. It appears that these variables do act as proxy to social and economic patterns of life in each municipality. Each municipality had a unique rhythm of life prior to the extreme event. This unique rhythm was uncovered at the first step of time series analysis: the Eviews correlogram. Had the rhythms been identical, I would have had to apply the same lag variables for each of my studied variables category of data. As Table 4.3 (Appendix C) and Table 4.11 (Appendix Z) illustrate, both citizen-generated calls for service and traffic citation rhythms required different lag variables.

The fourth, fifth and sixth questions regarding post-event patterns between the cities is not as clear-cut. It appears that post-event patterns and which variables reflect disaster-induced disruption are unique between the cities. The order of sensitivity differs (Table 4.12, Appendix AA and Table 4.4, Appendix D) as does the pattern and timing of restabilization between the two cities. Water consumption is the most sensitive variable in both types of events and restabilization required nearly a full year in both cities. However, the pattern of the disruption in water consumption differed greatly as demonstrated by the CUSUM of Squares test (Figure 4.3, Appendix I and Figure 4.18, Appendix FF.) This study did demonstrate that the processes associated with restabilization are reflected through quantifiable variables and restabilization is clearly demonstrated through time series analysis.

CHAPTER V

CONCLUSIONS

The primary purpose of this study was to determine if it is possible to quantify disaster-induced social and economic disruption through the measurement of water consumption, sales tax revenue, and crime patterns. A secondary purpose was to test Social Routine Theory (Neal, 2013) as a framework from which to examine the restabilization processes municipalities experience following an extreme event. Time series analysis of 4 fiscal years demonstrated that the “rhythm of life” reflected through water consumption, sales tax revenue, and crime patterns does provide insight into the magnitude of disruption induced by a disaster, the city’s ability to absorb the sudden “jolt” introduced by an extreme event, and the processes involved in restabilization and the establishment of a new normal or new rhythm. Chapter V discusses conclusions drawn from the findings presented in the previous chapter along with recommendations for future research.

Conclusions

Our lives are made up of multiple social routines that impact the rhythms of life around which we schedule events and activities (Neal, 2013). These rhythms are not simply temporal but also spatial. For example, during the work week we go to the office for work and return home for family and/or leisure activities. Because disasters may impact our homes, our social groups, our regular daily patterns; the predictability of life is diminished (Morrow, 1997). This predictability relies on our daily rhythms, our social routines. These routines translate into regular rhythms at the municipal level as well (Alesch and Siembieda, 2012). Water consumption, sales tax revenue, and crime patterns reflect our social rhythms. If many of a city's citizens experience a change in priority or life patterns due to a disaster, it will take time for the variance in social rhythms to restabilize to create a new "normal" that allows life to once again become predictable (Black, 2015). Water consumption, sales tax revenue, and crime patterns offer an opportunity for quantifying disaster-induced social disruption.

This research sought answers to six primary research questions:

1. Can social rhythms be quantified through the examination of water consumption, sales tax revenue, and crime patterns?
2. Are water consumption, sales tax revenue, and crime patterns valid proxies for social and economic rhythms?
3. Does each municipality have a unique "rhythm of life" prior to disaster?
4. If disaster induces measurable disruption, does it create the same disruptive patterns despite the different disaster agent?

5. Do changes in infrastructure rhythms create a quantified representation of the process involved in recovering from an extreme event?
6. Are disrupted infrastructure patterns demonstrated by quantifiable shifts in variance of water consumption, sales tax revenue, and crime patterns? Can the establishment of a new "normal" or routine be measured by the re-stabilization of the variance within these variables?

In order to answer these research questions, each variable will be considered for each city and disaster agent. Following the individual municipal conclusions, general conclusions will be discussed.

Moore, Oklahoma

Every variable examined demonstrated a significant break in pattern following the tornado. The Chow break point test indicated that the level of disruption caused by the tornado was significant in May 2013 (the month of the tornado) or June 2013 with the exception of sales tax revenue. Sales tax revenue demonstrated the significant break in rhythm 2 months later due to the 60-day collection and reporting delay inherent in the administrative system. This break in rhythm represents the "jolt" that a disaster delivers to the municipal system. While each variable demonstrated a significant break at the time of the tornado, the overall sensitivity of the indicator varied.

Water consumption. Water consumption was the most sensitive indicator of disruption in Moore. The correlation of pre-tornado rhythm to post-tornado rhythm was significantly reduced. In addition to the significant break in rhythm indicated by the Chow break point test, the CUSUM test verified the break visually. However, the

CUSUM of Squares test revealed the duration required to return to equilibrium. Water consumption patterns exhibited a highly variable pattern in two directions. While my analysis was not concerned with the direction of the break in rhythm (increase vs. decrease), the fact that the variance pattern left the 95% confidence interval in a downward direction initially followed by a rapid reversal resulting in a departure from the confidence interval in the opposite direction is important. It should also be noted that the initial disruption in consumption patterns was so great that the change in variance pulled the variance line from the expected confidence interval for 6 months *prior* to the tornado. As a result, the water consumption pattern variance exhibited significant instability for a total of 20 months.

Sales Tax Revenue. Like water consumption patterns, sales tax revenue demonstrated a significant reduction in rhythm correlation when pre- and post-tornado periods were compared. The CUSUM test demonstrated the significant disaster-induced disruption as well but not as dramatically as water consumption patterns. This test also illustrates that the disrupted pattern continues through April 2014. With the 2-month lag in reporting, this pattern represents a 9 month change in pattern. While the first two tests suggest significant changes, the CUSUM of Squares test indicates that sales tax revenue pattern variance never exceeded the 95% confidence level. This combination of statistical findings suggest that the Moore economic system was able to absorb the impact of the tornado without exceeding its capacity. The ability or capacity of a system to absorb disaster impact may have implications for future studies of municipal resilience.

Citizen-Generated Calls For Service. This variable reflects the citizenry's perception of threat to self or property. An increase in citizen-generated calls for service can be interpreted as an increased perception of threat potentially created by a breakdown of social order. A decrease in citizen-generated calls for service would reflect a depressed sense of threat that could be produced by the formation of an altruistic community (Barton, 1969). While there was a reduction in the correlation between pre- and post-tornado periods, this shift was not significant. However, the Chow break point test revealed significant disruption in May 2013 that remained significant for 3 months. While the Chow break point test does not consider the direction of the change, examination of the raw data indicates that the number of calls increased considerably. The CUSUM test showed some elevation in the pattern at the time of the tornado, but the indication was weak and the CUSUM of Squares test demonstrated no departure from the confidence interval of the expected variance pattern. These results may be interpreted to mean that the increase in calls was due to the actual disaster agent. The spike in calls immediately related to the extreme event was significant enough to demonstrate disruption but the not maintained long enough to create a significant CUSUM of Squares test. This analysis mimics those of sales tax revenue patterns by suggesting that the Moore system had the capacity to absorb the changes in call patterns created by the tornado. This pattern does not permit me to draw conclusions regarding the creation of an altruistic community or the processes associated with restabilization.

Felony Arrests. Because this variable is generated by law enforcement, any significant change in rhythm may be related to the increased or decreased availability of investigating and arresting officers. The shift in availability would likely indicate that officers were re-directed to tornado-related activities. This variable demonstrated an unexpected shift in correlation following the tornado. Prior to the event, correlation was

0.54 (very similar to citizen-generated calls for service). Following the tornado, the correlation increased to 0.68. I have no explanation for this increase. Felony arrest count did demonstrate a significant disruption in expected patterns for June and July of 2013 according to the Chow break point test. The CUSUM test reveals very little movement from the zero line and does not demonstrate the significant Chow break point test. The CUSUM of Squares test echoes the CUSUM results. The variance pattern is elevated near the upper boundaries for the majority of the examined time period. My analysis provides very little insight into the processes associated with restabilization. Other research suggests that aggregate felony arrest data may not tell the true story of the disruption caused by disaster. Instead, examining specific types of crime (gender-based violence, contractor fraud) may provide a clearer picture of the post-tornado social system.

Traffic Citations. Traffic citations represent the opposite end of the severity continuum compared to felony arrests. While also generated by law enforcement, traffic citations suggest routine, daily activities. Law enforcement officers maintain regular patrol patterns and citation count reflects a rhythm of work day vs. weekend or school being in session or out for summer break. If an extreme event pulls officers from regular patrol duty for disaster-related support tasks, the number of citations written would be expected to decrease. If roads are impassable, the likelihood of receiving a traffic citation would also be reduced. It is interesting that this variable, like felony arrests, had an increased correlation following the tornado. The law enforcement generated variables were the only variables to demonstrate this pattern in Moore. The Chow break test reveals a significant disruption in traffic citation pattern in June and July 2013, the same result as the felony arrest pattern. The CUSUM test does not illustrate a clear departure from expected pattern. However, the CUSUM of Squares test does show that the variance pattern skims the lower boundary of the 95% confidence interval immediately following the tornado until it returns fully in August 2013. This pattern is different than the felony arrest result suggesting that traffic citation count may indicate a change in law enforcement activity and redirection.

Stillwater, Oklahoma

Only water consumption, citizen-generated calls for service and traffic citations demonstrated significant disruption due to the wildfires in July and August of 2012 in Stillwater. Water consumption and citizen-generated calls for service also demonstrated a significant reduction in correlation when comparing the years temporally farthest from the wildfires to those associated with the event. Traffic citations also demonstrated a decreased correlation, but the shift was not significant. Only water consumption patterns provided insight into the process of restabilization following the wildfires suggesting that the wildfires had a limited impact on the municipal rhythms of Stillwater or the Stillwater social and economic systems were able to absorb the wildfire-induced disruption to a great degree.

Water consumption. Water consumption was the most sensitive indicator of disruption within the city of Stillwater. The comparative correlations between the years without the wildfires and the years closest to the wildfires fell significantly from 0.82 to 0.30. The Chow break point test indicated significant disruption for July, August, and September 2012. This disruption was clearly illustrated by the CUSUM test as the spike created at the time of the wildfires left the 95% confidence interval boundaries. This disruption created significant departure from the expected variance pattern as demonstrated by the CUSUM of Squares test as well. The variance pattern left the upper boundary of the confidence interval immediately at the time of the wildfires and remained outside of the boundaries for 15 months until it returned to the expected pattern of variance in October 2013. The combination of the disruption indices support the conclusion that water consumption is a good indicator for measuring disaster-induced municipal disruption.

Citizen-Generated Calls For Service. In a wildfire situation, it is reasonable to believe that citizens would be valuable sources of information regarding the initiation and movement of the fires. In order to provide this information, citizens would call into the dispatch center and relay locations and perceived levels of threat. With this in mind, I expected an increase in the number of citizen-generated calls for service. Indeed, the raw data does demonstrate a spike in call traffic at the time of the wildfires. Unlike water consumption, while calls for service did exhibit a decreased in correlation between event and non-event years but the change was not significant. The Chow break point test also supports the proposition that the increased number of calls was directly related to the wildfires as both July and August of 2012 demonstrated a significant level of disruption in call patterns but the disruption was alleviated by September 2012. The CUSUM test illustrates this phenomenon well revealing a rapidly reduced pattern in September 2012. The CUSUM of Squares test yielded unexpected results. During the period of time associated with the wildfires, the variance pattern stayed well within the confidence interval boundaries. However, in June 2014 (2 years after the wildfires) the variance briefly leaves the lower boundary. Given the temporal distance from the wildfires of this departure, I do not believe it was related to the wildfires. I could find no evidence of any form of extreme event in Stillwater or its home county that would explain a shift in variance. A change in the method of tracking calls or some other administrative shift might explain such an occurrence although no city official could account for such a change. Because the CUSUM of Squares test shows no significant pattern instability at the time of the positive Chow break point tests, I conclude that Stillwater's social system had the capacity to absorb the significant disruption delivered by the onset of the wildfires. The results of the CUSUM of Squares test also suggests that citizen-generated calls for service provides little insight into the process of restabilization in this case.

Traffic citations. Examination of the raw data indicates that traffic citation count was reduced at the time of the Stillwater wildfires. This is likely due to the re-assignment of patrol personnel from regular duties to duties associated with the wildfires. Similar to the citizen-generated calls for service data, while correlation between with-event years and without-event years decreased, the change was not significant. The Chow break point test also indicates that the level of disruption was significant for August and September 2012. Because of the time required to process citations, this disruption actually occurred in July and August 2012. It is difficult to draw any firm conclusions from the results of the CUSUM test. While the pattern line appears to be trending downward, there is no visible break point in the line. The CUSUM of Squares test results are more difficult to interpret. The variance pattern remains within the 95% confidence interval during the period surrounding the wildfires but leaves the lower boundary beginning in September 2013. The variance does not return to the expected pattern until

January 2015. Because of the temporal distance from the wildfires of this pattern departure, it is likely that the wildfires had no impact on the pattern in September 2013. Further investigation suggested that the change in pattern was likely due to the combination of changes in speed zone classifications, the creation of multiple construction zones throughout the city, and a change in staffing levels for traffic control. None of these administrative changes were related to the wildfires but would influence the traffic citation count. Because of the lack of variance pattern departure at the time of the wildfires, I conclude that traffic citation count provides no insight into the process of re-establishing system equilibrium.

Sales Tax Revenue. Sales tax revenue provided no insight into potential disruption of the economic system by the wildfires or the processes associated with restabilization. This variable demonstrated the same non-significant increase in correlation in the years with the wildfires compared to those with no event that Moore's felony arrest and traffic citation counts data produced. The Stillwater data reflected the same 60-day delay in collection and reporting that Moore's sales tax exhibited. The Chow break point test indicated that the Stillwater economic system experienced no significant jolt due to the wildfires. No month produced a significant Chow break point test. September 2012 (which actually represents July 2012 due to the 2-month collection and reporting delay) came closest but missed significance even at the $p \geq 0.10$ level. This lack of significance can be interpreted in two ways: 1) the wildfire event did not impact enough of the Stillwater system to create disruption or 2) the Stillwater system had the capacity to absorb the disruption that was created. In accordance with the lack of a significant Chow break point test, the CUSUM test failed to illustrate any significant change in collection patterns. The CUSUM of Squares test produced unexpected results considering the lack of significance in the Chow break point and CUSUM tests. The variance pattern approaches the upper boundary of the 95% confidence interval at the time of the wildfires. This suggests that the system experienced disruption just within its capacity threshold. The combination of these test results suggest that sales tax revenue may be a good indicator regarding disruption and the processes associated with restabilization. The Stillwater wildfires simply did not reach the magnitude of disaster to induce significant disruption.

Felony Arrests. Stillwater's felony arrest rate appears to spike immediately following the wildfires. Similar to traffic citations, the felony arrest count is initiated by law enforcement. If law enforcement personnel are re-assigned to disaster-related duties, one would expect a decreased arrest rate due to lack of personnel to investigate and process crime. A reduction in crime rate could also be attributed to the creation of an altruistic community following a disaster. The raw data from Stillwater disputes both of these assumptions. Felony arrest rates in Stillwater appear to rise for approximately 9 months following the fires. This period of increased felony arrest rates also represents a major break in the long-term rhythm of felony crime rate. This variable produced the lowest correlation in both the Moore and Stillwater data sets and the shift in correlation during the wildfire years actually improved. However, the pattern that is suggested by the raw data was not borne out by the Chow break point test. The Chow break point test approached significance in September 2012 but quickly reversed in October 2012. The CUSUM test illustrates a spike in the arrest rate in September 2012 followed by another potential period of concern in February 2013. Following these two low level spikes, the pattern is relatively flat. The CUSUM of Squares test illustrates an even more unusual pattern considering the lack of a significant Chow break point test. At the time of the wildfires, the variance pattern skirts the lower confidence interval boundary. The variance pattern rapidly moves upwards through the confidence interval until it leaves the upper boundary in February 2013. The period of August 2012 through February 2013 matches the period of the two spikes illustrated in the CUSUM test. The variance pattern remains outside of the confidence interval for 10 months and restabilization begins at that time. This pattern suggests that aggregate crime rates may not be adequate for use as an indicator of social system disruption following disaster. Similar to the findings in Moore, examining gender-based or fraud related crime may yield better insight.

Similarities.

It is important to recognize the similarities between two distinct cities experiencing different disaster agents. The scope of the damage produced by each disaster also varied. The Moore tornado created demands that warranted a Presidential Disaster Declaration while the Stillwater wildfires were addressed using only local and regional resources. With this in mind, any similarities between the two disasters supports the level of sensitivity that variable brings to the determination of the magnitude of social disruption and overall scope of the disaster experience.

Water Consumption. Water consumption was the most sensitive indicator of disruption in both municipalities. Water consumption patterns demonstrated significant disruption for three months according to the Chow break point test results. This disruption was clearly illustrated through the CUSUM test as well. This variable also provided insight into the process of restabilization through the CUSUM of Squares test. At the municipal level, water consumption may be viewed as a metabolic lifeline that impacts the social and economic systems of a city (Mitchell, 2008). The cause of the dramatically changed water consumption patterns may stem from different types of impacted activity. For example, the initial break in use pattern for Moore would appear to be related to the loss of considerable housing stock. During the wildfires, the initial change in consumption was likely due to the demand for water in order to fight the actual fires since the loss of housing stock was fairly limited. This study does not attempt to determine the locus of the disruption in use pattern. Instead, the presence of disruption (Chow break point test) and the process required to restabilize the variance in use patterns (CUSUM of Squares test) are of primary interest. The differences in the pattern of disruption and restabilization is important and will be discussed in greater detail in the next section. Due to the sensitivity to disruption displayed in both disaster settings, I conclude that water consumption is an important indicator of disruption and restabilization processes and should be included in any index created to determine the magnitude of disruption or disaster impact.

Citizen-Generated Calls For Service. Citizen-generated calls for service also exhibited similar patterns following the different events. Correlation in municipal rhythms demonstrated non-significant reductions when comparing periods of no event with periods that included or immediately followed the event in both cities. This variable did exhibit significant disruption at the time of disaster. The tornado produced significant Chow break point tests for three consecutive months, while the wildfires created significant breaks for only two months. It may be possible to conclude that the increased scope or magnitude of the disruption produced by the tornado is reflected in the longer period of disruption indicated by the Chow break point test. It is important to note that this citizen-generated variable was a good indicator in both cases of a change in the social system. The value of citizen-generated calls for service in the study was limited to the detection of disruption. Neither case produced insight into the process of restabilization suggesting that both municipal systems had the capacity to absorb the level of disruption induced by their respective events. This finding may be important to note in terms of determining the magnitude of the disaster experienced. Should an event create disruption great and prolonged enough to create a positive CUSUM of Squares test, it is likely that the magnitude of the actual event was likely catastrophic (or at least greater than an EF5 tornado) or the municipality has a very limited capacity to absorb any level of disruption in this variable.

Traffic Citations. The number of traffic citations issued by law enforcement is dependent upon the availability of personnel to monitor regular traffic patterns. An event that disrupts typical transportation patterns or reduces the availability of traffic officers should create a change in the rhythm of citation counts. In a disaster situation, re-assignment of law enforcement personnel from routine assignments like traffic patrol to disaster-related duties suggests that both traffic patterns and staffing availability would be negatively impacted resulting in a reduced number of citations issued.

When the raw data in Moore is examined, it appears that there was a dramatic reduction in the number of citations issued at the time of the tornado. Indeed, the Chow break point test confirmed significant pattern disruption in both June and July 2013. The apparent one-month delay can be attributed to the processing time requirement from writing the initial citation to assignment of responsibility (my data tracked only completed citations in both cities.) When considering the delay due to processing, the actual disruption occurred at the time of the tornado.

The raw data from Stillwater did not show the same dramatic downward shift, but it does illustrate a change in pattern. The Chow break point test results mirrored the results from Moore. Significant disruption in citation patterns were revealed for August and September 2012. This disruption once again reflects the delay due to citation processing. These similar findings regarding the presence and timing of significant disruption support the conclusion that a disrupted traffic citation pattern should be expected in the event of a disaster. The magnitude of the disruption expressed by the length of time required to re-establish system equilibrium differed, however. I discuss the implications of this difference in the next section.

Felony Arrest Rate. The similarities between the two events in terms of felony arrest rate encourage further study. In both cities, the correlation of arrest rate patterns in periods of disaster increased over the rhythm present in periods without an extreme event. The difference in variable response was housed in the significance of the Chow break point test. The Moore tornado resulted in a significant break in arrest rate pattern for two months (June and July 2013). The Stillwater wildfires produced no significant break in arrest rate pattern.

However, the CUSUM test revealed an interesting similarity. In both cases, the CUSUM pattern line revealed spikes or increases in the arrest rate in the third month following disaster onset and again at approximately 6 months following the disaster.

These spikes are most visible in the Stillwater CUSUM test but Moore's test also suggests a similar pattern. This apparent delay in increased arrest rates could be related to the time that passes before the fraud associated with disaster rebuilding begins to appear. Contractor fraud could also explain the similar pattern in Moore. The raw felony arrest rate data indicated that Stillwater had a very stable arrest rate prior to the wildfires and low numbers of arrests while Moore's arrest rate exhibited a pattern of overall decline. These obvious changes in arrest rate patterns could also be related to a single large criminal investigation and arrest process as might occur with a multi-person drug operation. In either case, further study of the specifics of the felony arrest rate may be warranted. As discussed previously in this dissertation, closer study of specific types of crimes might reveal important findings regarding gender-based crime or contractor fraud related to the process of rebuilding.

Differences.

The differences exposed by data analysis may offer the most insight into the differentiation of magnitude of extreme events. While the presence of significant disruption may be the same, the length of time that the disruption is maintained may differ greatly. Greater discernment between major and lesser disasters is revealed when the pattern of restabilization between the two events is investigated. Discussion regarding these differences follow.

Sales Tax Revenue. Sales tax revenue was the variable that exhibited the greatest level of difference between the two cities and events. Nearly every aspect of this variable differed. Disruption was much more evident in Moore following the tornado than in Stillwater. My first level of analysis, Spearman's correlation between non- and with-event time periods, clearly demonstrated something different was occurring in each city. In Moore, the correlation of municipal sales tax revenue rhythms decreased significantly following the tornado. Stillwater's rhythms actually became more tightly correlated following the wildfires. The increase in level of correlation following an extreme event that occurred in Stillwater's sales tax revenue pattern mirrors the results from Moore's traffic citations and felony arrests and Stillwater's felony arrests. The meaning of this unexpected change in correlation is undetermined. It may indicate that the variable is not a sound indicator for social disruption in that particular case and should be removed from any future index. Correlation shifts may also simply demonstrate a change in pattern no matter the direction the movement.

Both cities had a 60 day delay in collection and reporting built into their administrative system. Keeping this in mind, Moore experienced significant disruption that appeared in July 2013 that corresponds with disruption occurring at the time of the tornado. Stillwater's data expressed no significant disruption at the time of the wildfires. This difference suggests that a disaster must reach a threshold of scope before sales tax revenue will indicate disruption within the municipal economic system. Less severe disasters will not create significant disruption within the economy. This assumption leads to the conclusion that sales tax revenue should be included in any Degree of Disaster Index.

When the CUSUM and CUSUM of Squares tests are examined for Stillwater, it appears that sales tax revenue pattern disruption was just under the threshold for significance. The CUSUM test reflects a sharp change at the time of the wildfires while the CUSUM of Squares test demonstrates that this disruption comes very close to leaving the upper boundary but does not. These same tests applied to the Moore data reveal that the pre-tornado rhythms may have experienced significant disruption but that disruption was absorbed by the municipal economic system. These findings may be interpreted as indicating that it will require a disaster of great magnitude to overwhelm the economic capacity of a city.

Traffic Citations. I have already discussed the similarities between Moore and Stillwater revealed in the analysis of traffic citation rate. The CUSUM of Squares test exposed the primary difference between the cities' disaster experiences. In Moore, the disruption exceeded the system's capacity to absorb the change in rhythm and the pattern line left the lower boundary of the confidence interval for approximately 2 months following the tornado. Stillwater's data also created a CUSUM of Squares test indicating pattern changes that exceeded expected variance. The timing of the departure from expected variance pattern appears to be unrelated to the wildfires. The pattern line does not leave the confidence interval until a year after the event. The obvious change in Stillwater's citation rhythm demonstrated by the CUSUM of Squares test can be attributed to changes in speed zone classifications, the creation of numerous construction zones throughout the city, and changes in staffing levels associated with traffic control. These administrative changes coincide with the period of time during which the pattern line falls outside of the confidence interval. Given these differences, I would suggest that traffic citation be included in the development of a Degree of Disaster Index as an indicator of the magnitude of the disruption created by an event.

Water Consumption. As discussed previously, water consumption appears to be the most sensitive indicator of social disruption included in this study. While both events created significant pattern disruption, the insight provided by the CUSUM of Squares test is valuable in explaining the differences in the restabilization process between a major and lesser disaster event. Stillwater's pattern of disruption and time require to restabilize exceeds the system's capacity in a single direction. The disruption occurred immediately at the time of the event and quickly returns to the expected pattern of variance. The disaster-induced pressure on the system was quickly reduced following the wildfires. In this case, I believe that the disruption was due to the water required to fight the fires. Once the fires were out, the water demand pattern returned to pre-wildfire rhythm.

The water consumption pattern following the Moore tornado tells a very different story in terms of social disruption. The change in water consumption rhythms is so great that it pulls the variance line outside of the lower confidence interval boundary 5 months prior to the actual event. The raw data does not demonstrate any unusual shift in water consumption during the pre-tornado period so the departure from the confidence interval can be attributed to the dramatic impact of the tornado. The variance pattern line remained outside of the lower boundary until August 2013 (3 months post-tornado). At that point, the variance pattern rapidly changed direction and within a single month (September 2013) the variance pattern line exceeded the upper confidence interval line. The line remains outside of the upper boundary until July 2014 when the variance begins to restabilize. It should be noted that the line did re-enter the confidence interval in January 2014 but departed again in February 2014. In total, the variance pattern exceeded the expected confidence interval for 18 months.

This study did not examine reconstruction progress. However, this type of pattern suggests that water consumption was depressed due to the loss of a large number of homes and the relocation of several residents to housing in nearby Oklahoma City and other surrounding towns. The destroyed housing also translated into the reduced need for lawn care and recreational water use including swimming pools. The rapid increase demonstrated in September 2013 (4 months post-tornado) appears to coincide with insurance pay-outs, the completion of less major home repairs allowing residents to return, and a construction "boom" associated with rebuilding those structures that had been completely destroyed. This reconstruction continued through July 2014 until it began to taper off and the variance began to restabilize.

Recommendations for Future Study

The patterns associated with water consumption highlights the need to consider all of these variables in the greater disaster context. Looking at simple use levels does not explain the processes a municipal social and economic system experiences following a disaster. Time series analysis allows one to examine the patterns and processes associated with the re-establishment of system equilibrium or restabilization. Restabilization does not mean a return to the pre-disaster status quo in terms of variable value. Instead, restabilization requires that the variance within municipal rhythms be considered. By applying the principles of social rhythm and routine as proposed by Neal (2013), this project supports the use of regularly collected and publicly available municipal data to monitor a city's progress towards a new "normal". The application of time series analysis to this data also provides an opportunity to develop an index to measure the magnitude of a disaster by determining which variables are significantly disrupted and the duration of instability as the city moves to equilibrium.

This study considered only five potential variables associated with a municipal system's regular rhythm. Additional study should be conducted to identify other variables that could provide a sharper picture of the social disruption that a disaster creates and the patterns associated with re-establishing regular rhythms. Potential variables would include electricity and natural gas use, construction variables including building permits, contractor licensing, and number of home sales; economic factors including business starts, business closures, home values, and property tax valuation. Additional social variables could include school enrollment patterns, transportation patterns, non-profit organization activities, church attendance, civic organization participation, demographic shifts, and marriage/divorce rates. I also recommend that the crime pattern data that I collected for this project be broken down and specific types of crime be examined. Two forms of crime that should be given attention are gender-based violence and all forms of fraud.

In addition to increasing the number of variables examined, I recommend that other cities and regions be included in similar studies. It is possible that the Oklahoma region was unique in its ability to absorb the disruption the tornado and wildfires created in the social and economic systems of these two small cities. It is possible that smaller or more rural cities would experience the same disasters differently. The same may be true of larger and more urban municipalities.

The effect of social vulnerability was not considered in this project. Because of the differential impact experienced by the citizens of any city, I recommend that this work be duplicated for different units of analysis that would include household, neighborhoods, or sub-communities. It is likely that many different patterns of restabilization will be revealed within a single municipality when smaller units of analysis are considered.

The temporal unit of analysis represents another potential limitation of this project. I was unable to access data in less than monthly increments. Daily or weekly data may provide more insight into the patterns associated with disruption and restabilization of municipal rhythms of life. In the same way, a more longitudinal study may also provide greater insight. If I had been able to collect data representing 3 fiscal years prior to an event and 3 fiscal years following the event, the social routines of a city would be much better established and the sensitivity to variation would be increased.

Finally, the impact of a municipal disaster subculture as discussed by Wenger (1972) should be considered. The Moore city administration had substantial experience with responding to a tornadic disaster. The return to equilibrium may have been facilitated by decisions made prior to the 2013 event due to this experience. Comparison between Moore, Oklahoma and a similar city that experienced an EF 5 tornado would shed light on if disaster experience speeds restabilization. Such a comparison could also identify what actions an experienced city administration takes that differ from an administration that experiences a disaster for the first time. The pre-impact period would increase in importance as it would provide more information than presenting pre-disaster municipal rhythms.

Concluding Remarks

This project provided answers to all six research questions outlined previously. My analysis established that every city has a unique "rhythm of life" that represented the aggregate social and economic routines within it. Using the framework of the Social Routine Theory (Neal, 2013), these rhythms and routines may be quantified through regularly collected, publicly available, quantitative data. This study confirmed that water consumption, sales tax revenue, and crime pattern data are effective proxies for social and economic municipal rhythms. By using these variables to represent social routine and disaster-induced disruption, and index to measure the magnitude of a disaster can be created through the examination of the initial jolt, the number of systems disrupted, and the duration for these systems to restablilize. For example, if a city's water consumption pattern does not demonstrate significant disruption, it is likely the city experienced little more than a routine emergency. On the other hand, if the municipal sales tax revenue rhythm is not only significantly disrupted but exceeds the system's ability to absorb the disruption for an extended period of time, it most likely represents a very large disaster or catastrophic event. The pattern of variance that the data exposes through time series analysis also sheds light on the magnitude of disaster. Using water consumption as an example, the distinct pattern of variance following the Moore tornado is indicative of a greater magnitude of disaster compared to the simple, short-lived spike demonstrated by the Stillwater data. Further study and the development of a wider array of potential variables should provide a strong foundation for the creation of a Degree of Disaster Index (DDI) allowing valid comparisons between events with different agents and environments based on common magnitude of disruption.

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.

APPENDICES

Appendix A

Table 4.1 Descriptive Statistics Moore, Oklahoma

Variable	N	Minimum	Maximum	Mean	Std. Deviation
Water Consumption, Moore	48	114,288,391	485,899,419	173,883,528.56	77,261,911.90
Sales Tax Revenue, Moore	48	1,678,118.31	2,778,964.69	2,331,710.82	271,649.26
Felony Arrests, Moore	48	107	305	210.29	50.69
Citizen-generated calls for service, Moore	48	2,987	4,786	3928.15	402.91
Traffic citations, Moore	48	228	691	465.46	105.67

Appendix B

Table 4.2 Descriptive Statistics, Stillwater, OK

Variable	N	Minimum	Maximum	Mean	Std. Deviation
Water Consumption, Stillwater	48	113,105,300	287,586,303	166,967,543.17	41,706,135.79
Sales Tax Revenue, Stillwater	48	1,725,055.55	2,804,305.84	2,253,132.18	244,367.69
Felony Arrests, Stillwater	48	114	414	181.21	56.56
Citizen-generated calls for service, Stillwater	48	2,182	3,222	2,703.88	299.49
Traffic Citations, Stillwater	48	106	435	246.17	84.09

Appendix C

Table 4.3 Findings Moore, Oklahoma

	RHYTHM CORRELATION						
VARIABLE	**NO EVENT (FY12 vs. FY13)**	**WITH EVENT FY12 vs. FY14)**	**LAG VARIABLES**	**CHOW BREAK POINT (FIRST MONTH)**	**SIGNFICANCE**	**CUSUM test**	**CUSUM of squares**
WATER CONSUMPTION	0.98	0.14	MA 1, MA 4	May 2013	0.00	Demonstrates point of break	Leaves CI twice in different directions
SALES TAX REVENUE	0.77	0.46	MA 1, MA 2	July 2013	0.02	Demonstrates point of break	Does not leave CI
CITIZEN-GENERATED CALLS FOR SERVICE	0.54	0.38	MA 1	May 2013	0.01	Demonstrates weak point of break	Does not leave CI
FELONY ARRESTS	0.54	0.68	MA 1	June 2013	0.00	Does NOT demonstrate point of break	Does not leave CI
TRAFFIC CITATIONS	0.10	0.33	MA 1	June 2013	0.03	Does NOT demonstrate point of break	Crosses the CI but quickly returns

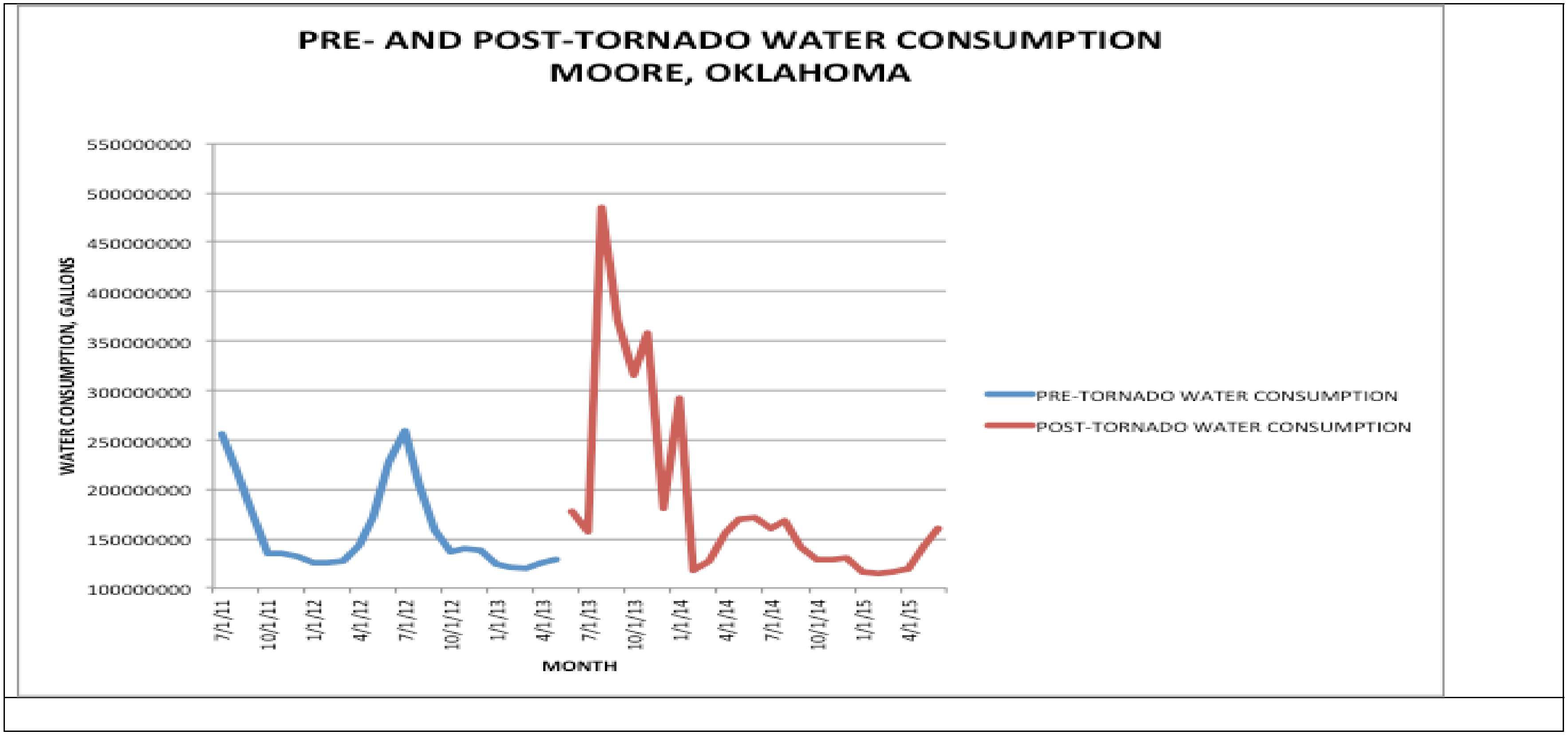
Appendix D

Table 4.4 Indicator Effectiveness (In order of effectiveness)—Moore, Oklahoma

VARIABLE	INDICATOR OF SYSTEM SENSITIVITY (SIGNIFICANT CHOW BREAK POINT TEST)	INDICATOR OF PROCESS OF RETURN TO EQUILIBRIUM (CUSUM AND CUSUM OF SQUARES TESTS)
WATER CONSUMPTION	GOOD MAY 2013	GOOD RETURN APPROXIMATELY JUNE 2014
SALES TAX REVENUE	GOOD JULY 2013 (2 month lag due to report collection)	MODERATE RETURN APPROXIMATELY APRIL 2014
CITIZEN-GENERATED CALLS FOR SERVICE	GOOD MAY 2013	NO SIGNIFICANT DEVIATION FROM EQUILIBRIUM
UCR—FELONY ARRESTS	GOOD JUNE 2013	NO SIGNIFICANT DEVIATION FROM EQUILIBRIUM
TRAFFIC CITATIONS	GOOD JUNE 2013	NO SIGNIFICANT DEVIATION FROM EQUILIBRIUM

Appendix E

Figure 4.1. Pre- and Post- Tornado Use Comparison Water Consumption, Moore, Oklahoma



Appendix F

Table 4.5 Model of Estimates, Water Consumption Moore, Oklahoma

VARIABLE	COEFFICIENT	STD. ERROR	PROBABILITY
CONSTANT	-338394.9	980284.0	0.7316
MA (1)	-0.602767	0.097430	0.0000
MA (4)	-0.396616	0.098066	0.0002

NUMBER OF OBS.	47
ADJUSTED R^2	0.233625
LOG LIKELIHOOD	-907.5886

***** represents significance at $p > 0.05$

Appendix G

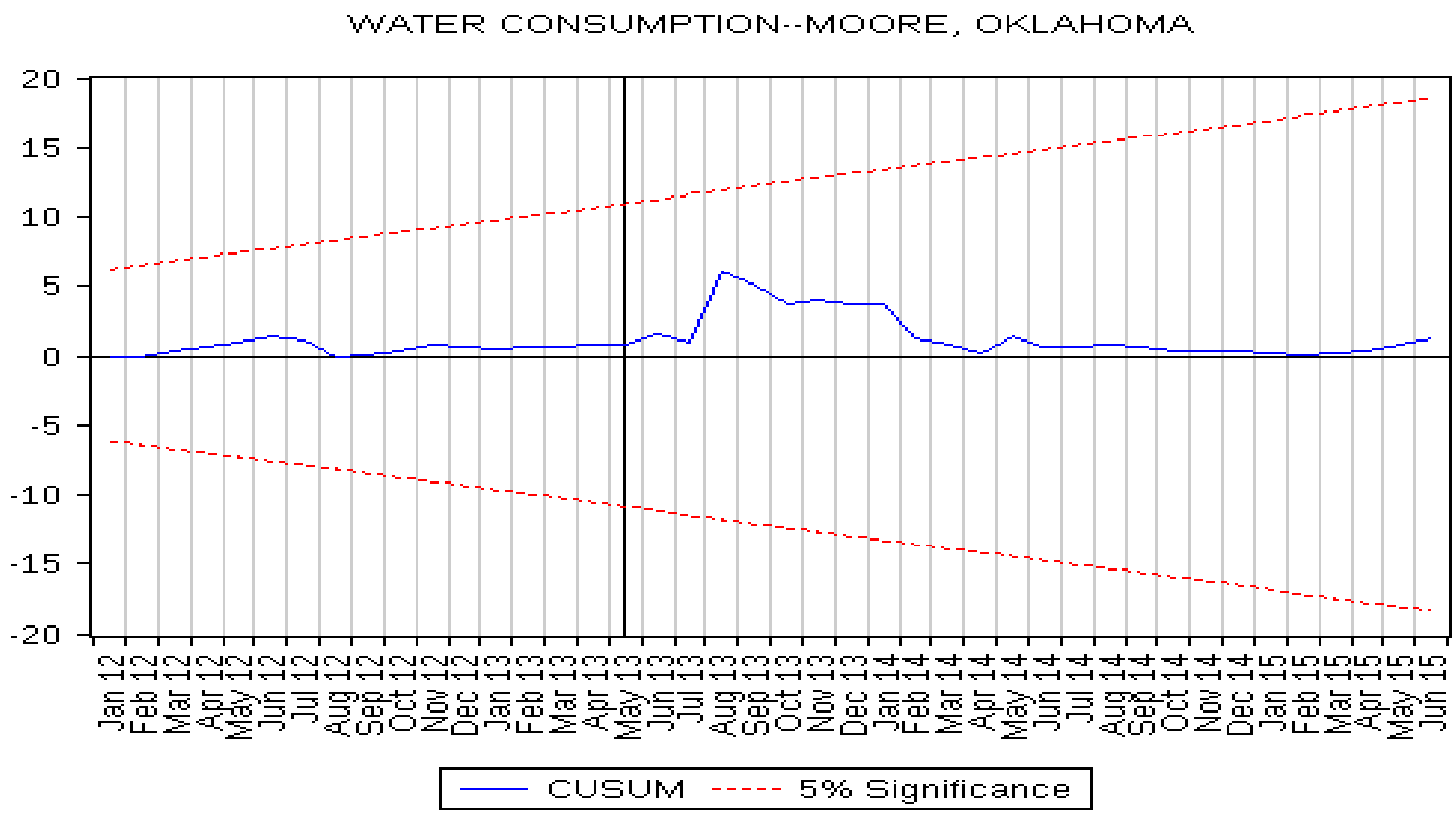
Table 4.6 Chow Break Point Tests (indication of system disruption)-- Moore, Oklahoma

VARIABLE	MONTH	SIGNIFICANCE (p > 0.05)
WATER CONSUMPTION		
	MAY 2013	0.00*
	JUNE 2013	0.00*
	JULY 2013	0.01*
SALES TAX REVENUE		
	MAY 2013	0.11
	JUNE 2013	0.37
	JULY 2013	0.02*
CITIZEN-GENERATED CALLS FOR SERVICE		
	MAY 2013	0.01*
	JUNE 2013	0.04*
	JULY 2013	0.04*
UCR—FELONY ARREST		
	MAY 2013	0.06
	JUNE 2013	0.00*
	JULY 2013	0.21
TRAFFIC CITATIONS		
	MAY 2013	0.06
	JUNE 2013	0.03*
	JULY 2013	0.00*

* indicates significance at p > 0.05

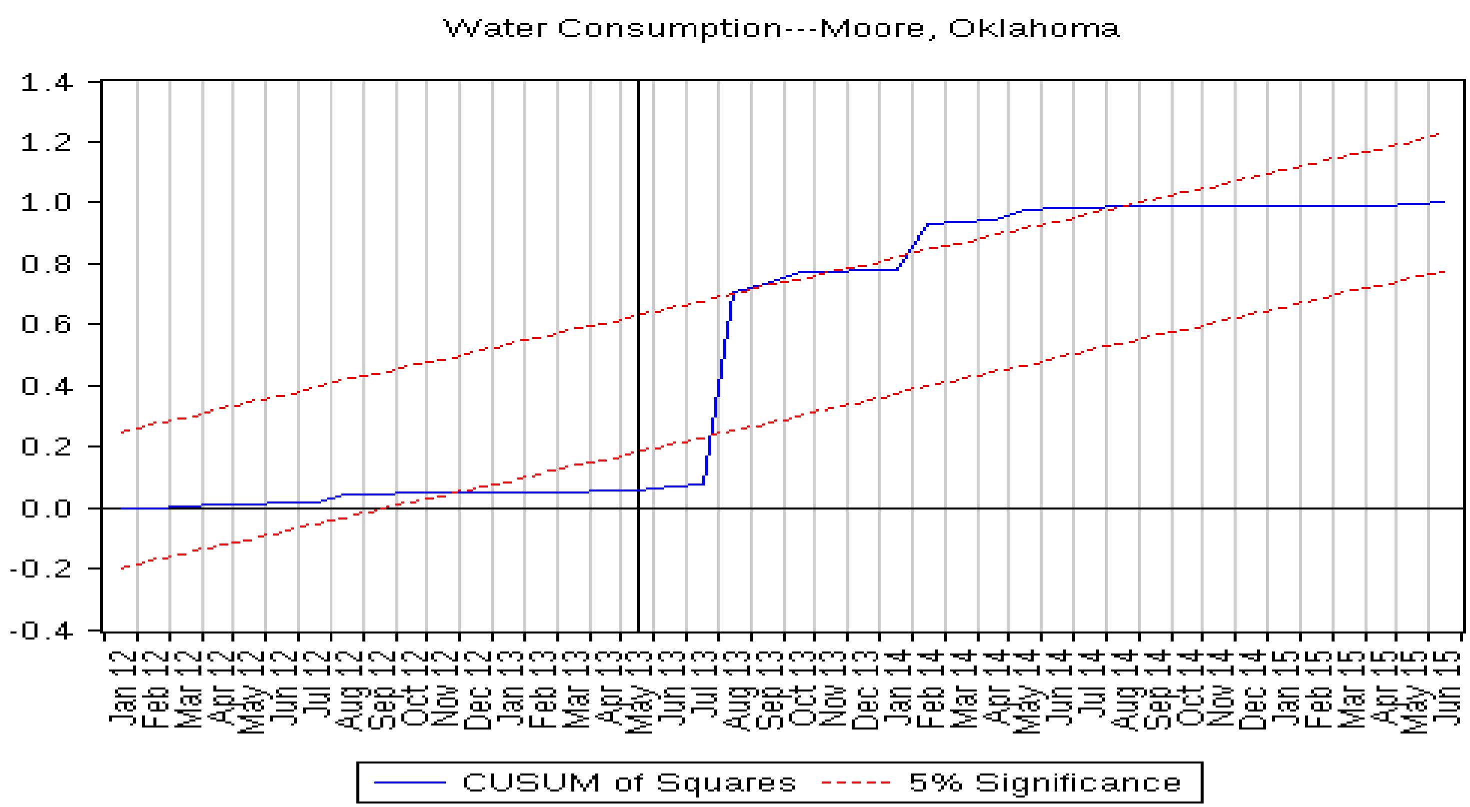
Appendix H

Figure 4.2 Water Consumption, CUSUM test, 95% Confidence Interval Moore, Oklahoma



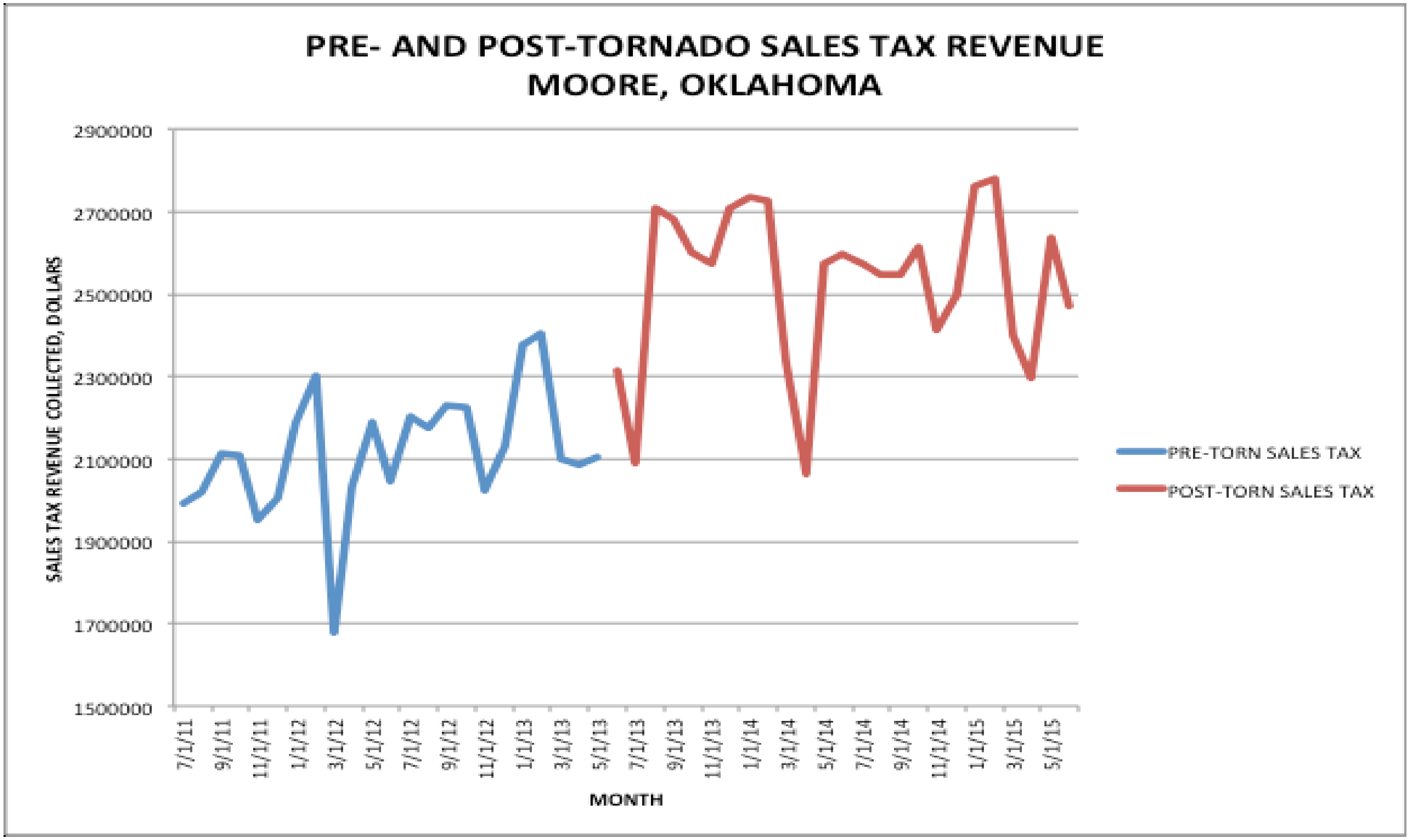
Appendix I

Figure 4.3 Water Consumption, CUSUM of Squares Test, 95% Confidence Interval Moore, Oklahoma



Appendix J

Figure 4.4 Sales Tax Revenue, Pre- and Post Tornado Moore, Oklahoma



Appendix K

Table 4.7 Model of Estimates, Sales Tax Revenue Moore, Oklahoma

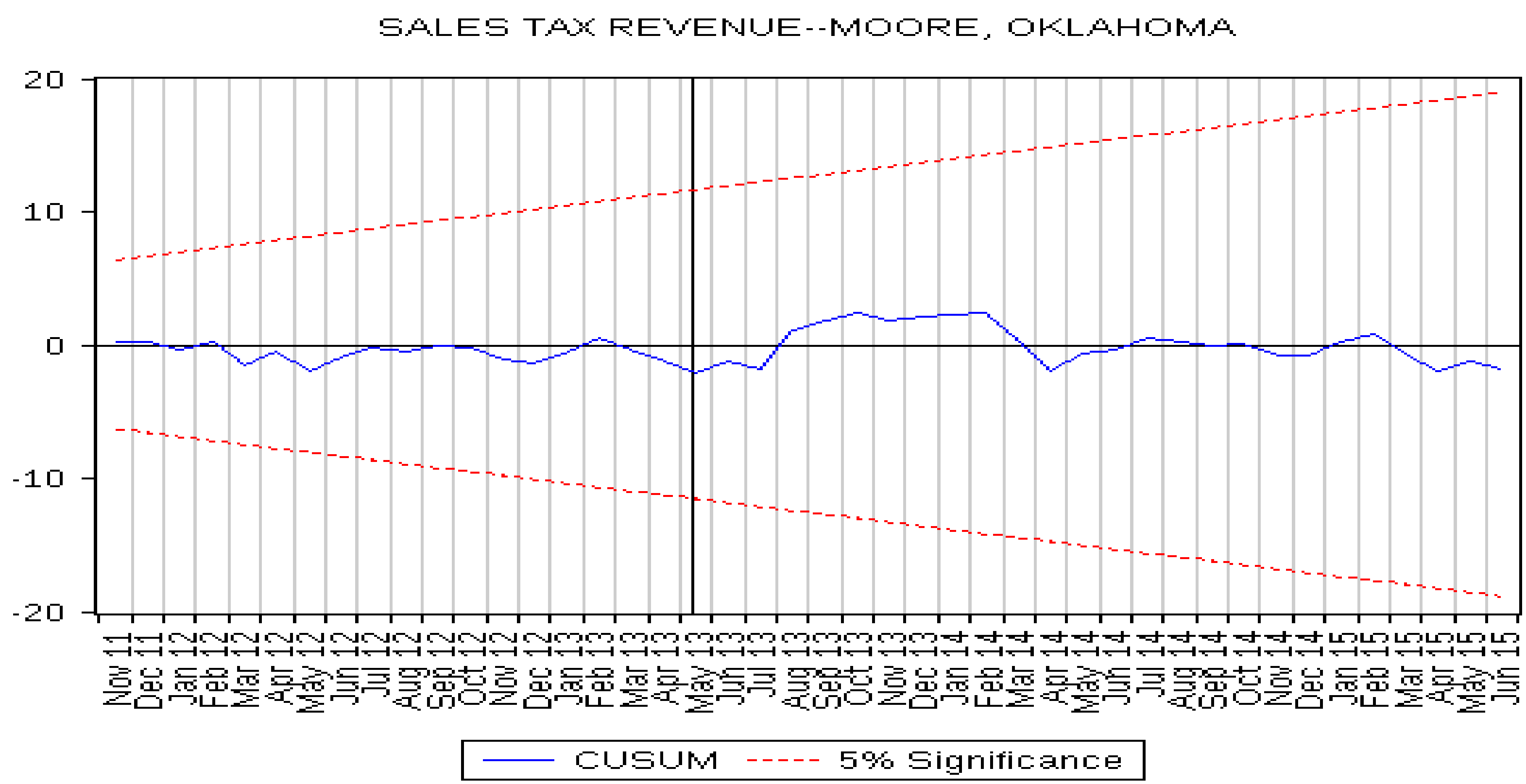
VARIABLE	COEFFICIENT	STD. ERROR	PROBABILITY
CONSTANT	15961.57	3264.890	0.0000*
MA (1)	-0.866633	0.188257	0.0000*
MA (2)	-0.458448	0.190523	0.0204*

NUMBER OF OBS.	47
ADJUSTED R^2	0.515685
LOG LIKELIHOOD	-626.9392

* represents significance at $p > 0.05$

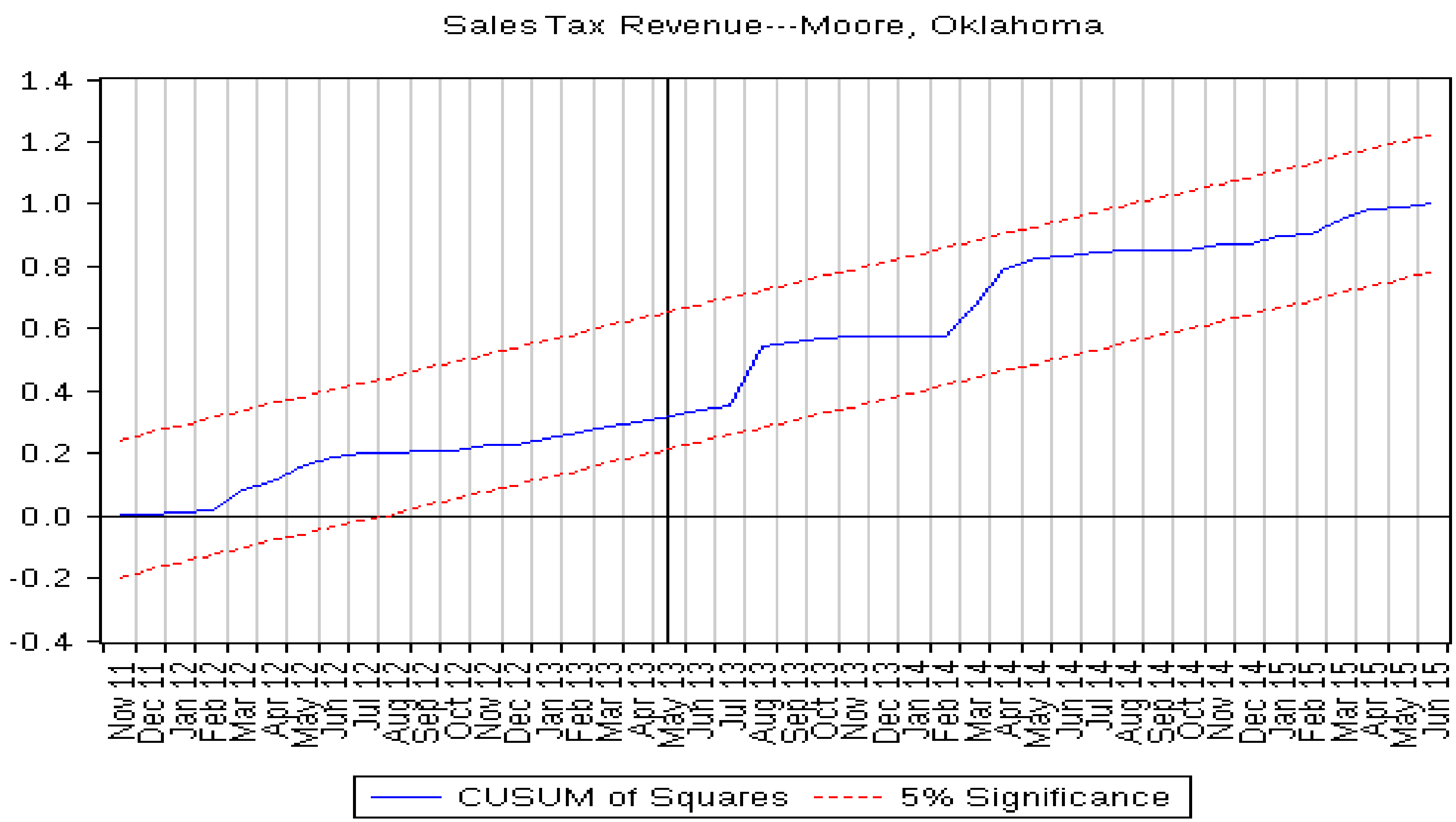
Appendix L

Figure 4.5 Sales Tax Revenue, CUSUM test with 95% Confidence Interval Moore, Oklahoma



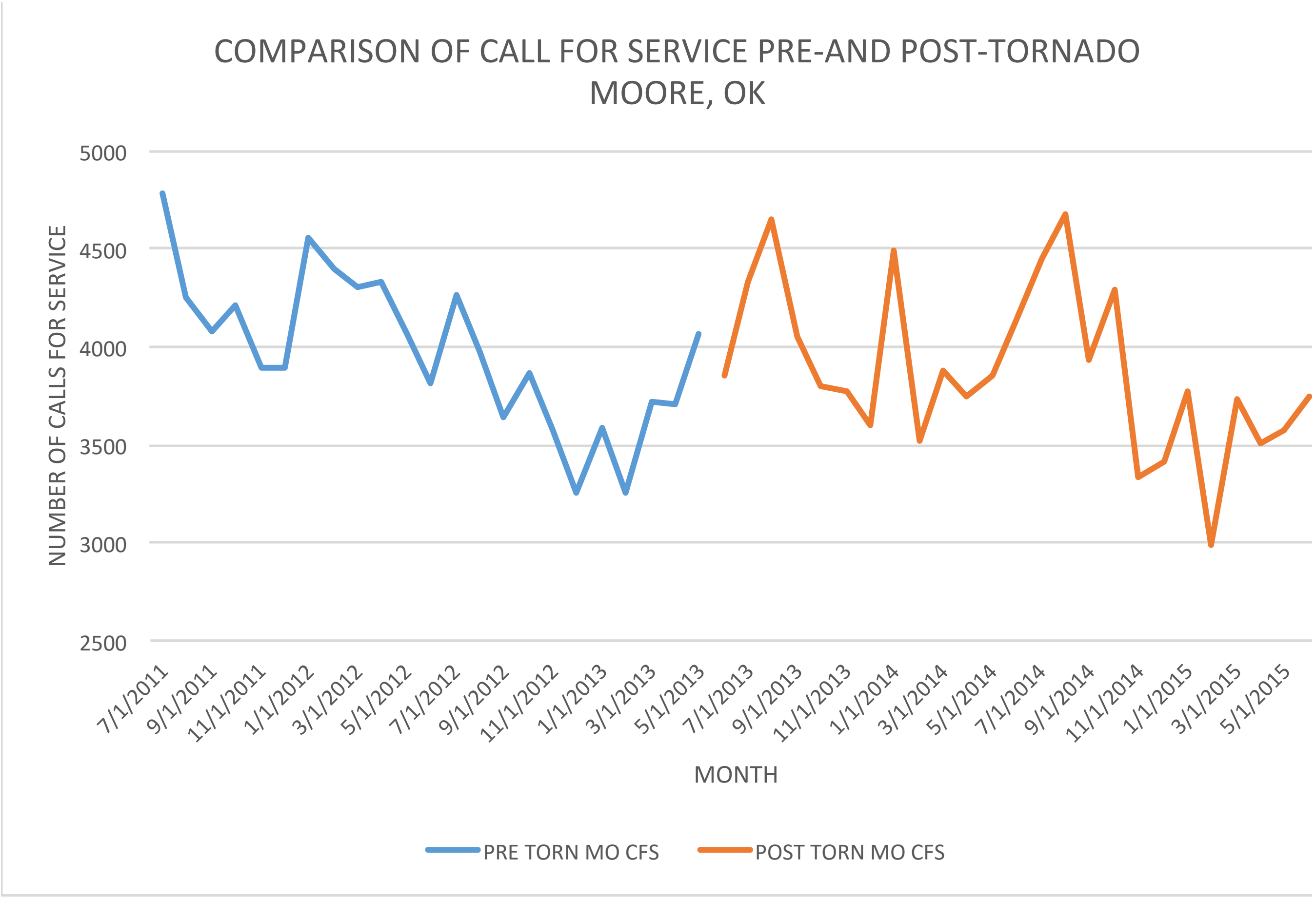
Appendix M

Figure 4.6 Sales Tax Revenue, CUSUM of Squares test with 95% Confidence Interval Moore, Oklahoma



Appendix N

Figure 4.7 Citizen-Generated Calls For Service, Pre-and Post-Event Moore, Oklahoma



Appendix O

Table 4.8 Model of Estimates, Citizen-Generated Calls For Service Moore, Oklahoma

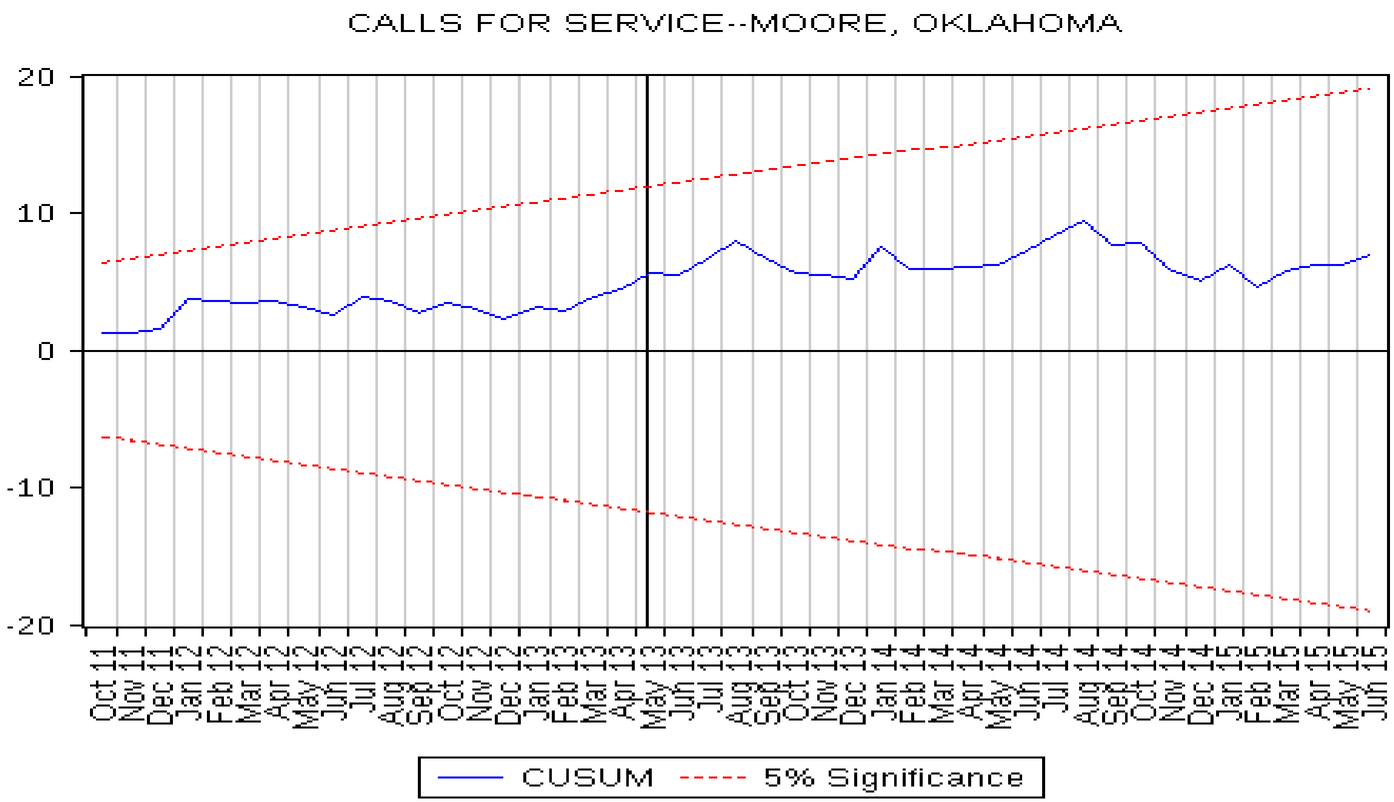
VARIABLE	COEFFICIENT	STD. ERROR	PROBABILITY
CONSTANT	-16.12432	23.29147	0.4923
MA (1)	-0.584979	0.117320	0.0000*

NUMBER OF OBS.	47
ADJUSTED R^2	0.219647
LOG LIKELIHOOD	-343.77254.19

***** represents significance at p > 0.05

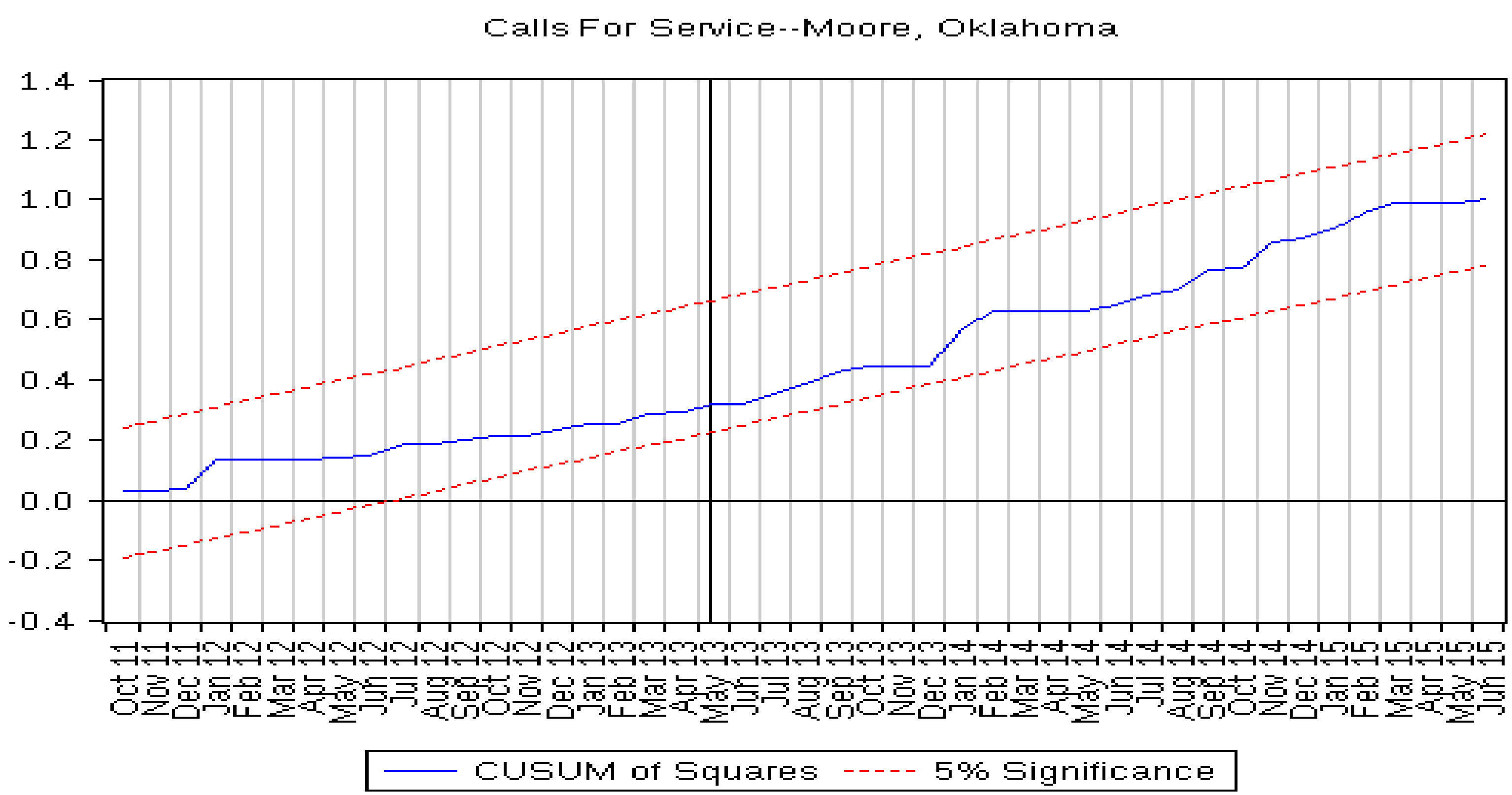
Appendix P

Figure 4.8 Citizen-Generated Calls for Service, CUSUM test with 95% Confidence Interval Moore, Oklahoma



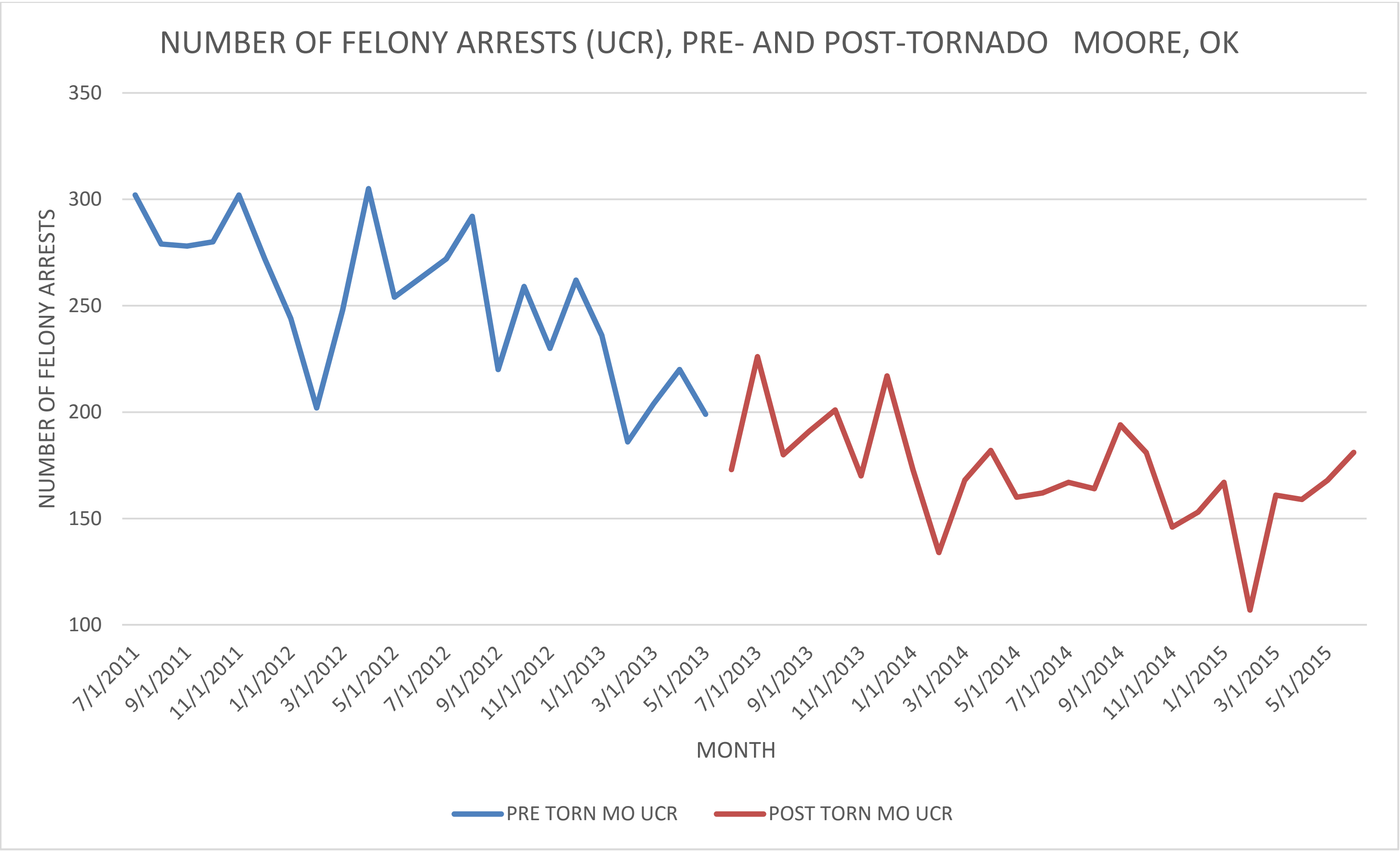
Appendix Q

Figure 4.9 Citizen-Generated Calls For Service, CUSUM of Squares test with 95% Confidence Interval Moore, Oklahoma



Appendix R

Figure 4.10 Felony Arrests, Pre- and Post-Tornado Moore, Oklahoma



Appendix S

Table 4.9 Table of Estimates, Felony Arrests Moore, Oklahoma

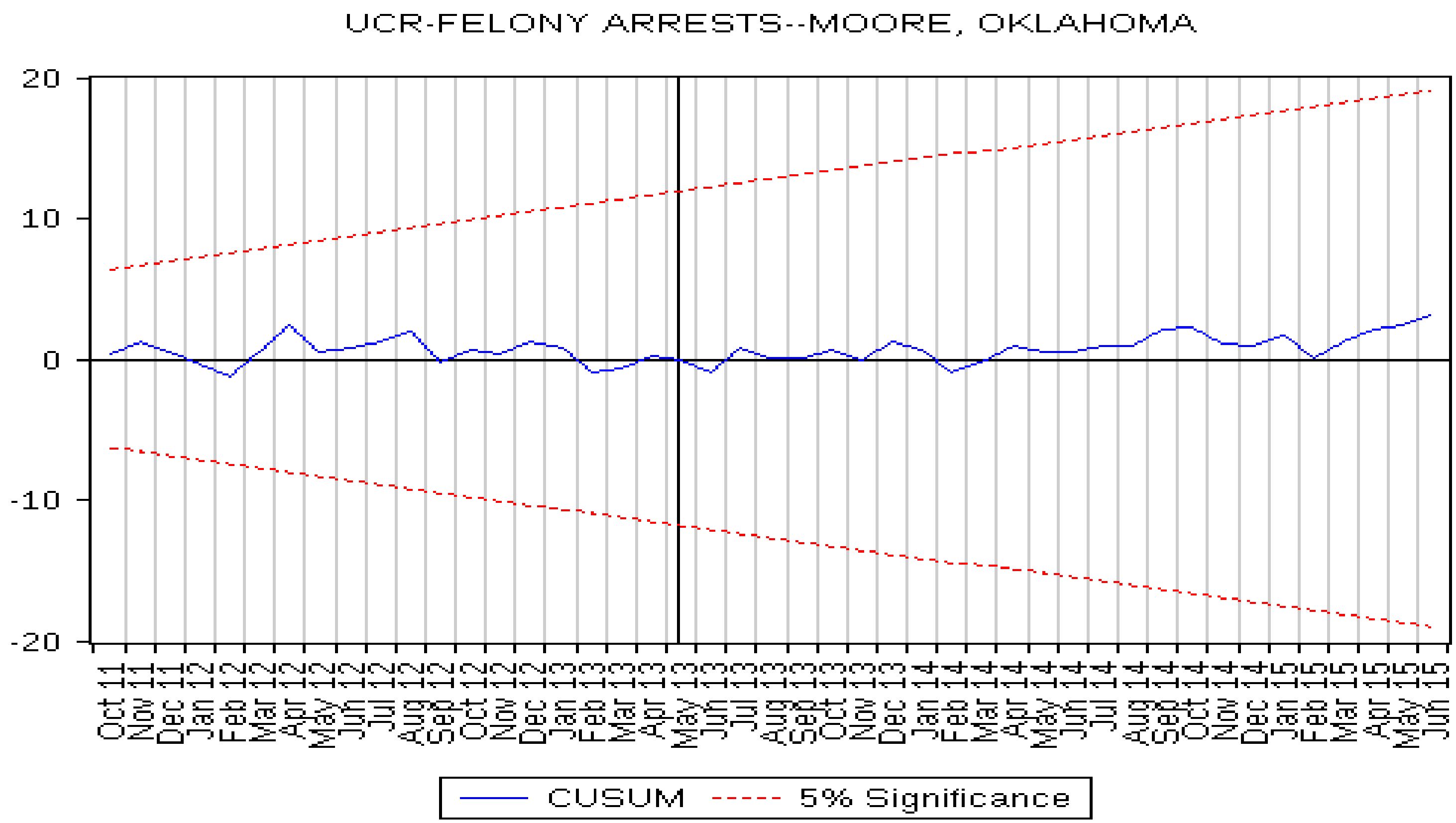
VARIABLE	COEFFICIENT	STD. ERROR	PROBABILITY
CONSTANT	-3.065054	0.472752	0.0000*
MA (1)	-0.941924	0.064932	0.0000*

NUMBER OF OBS.	47
ADJUSTED R^2	0.369145
LOG LIKELIHOOD	-218.6982

***** represents significance at $p > 0.05$

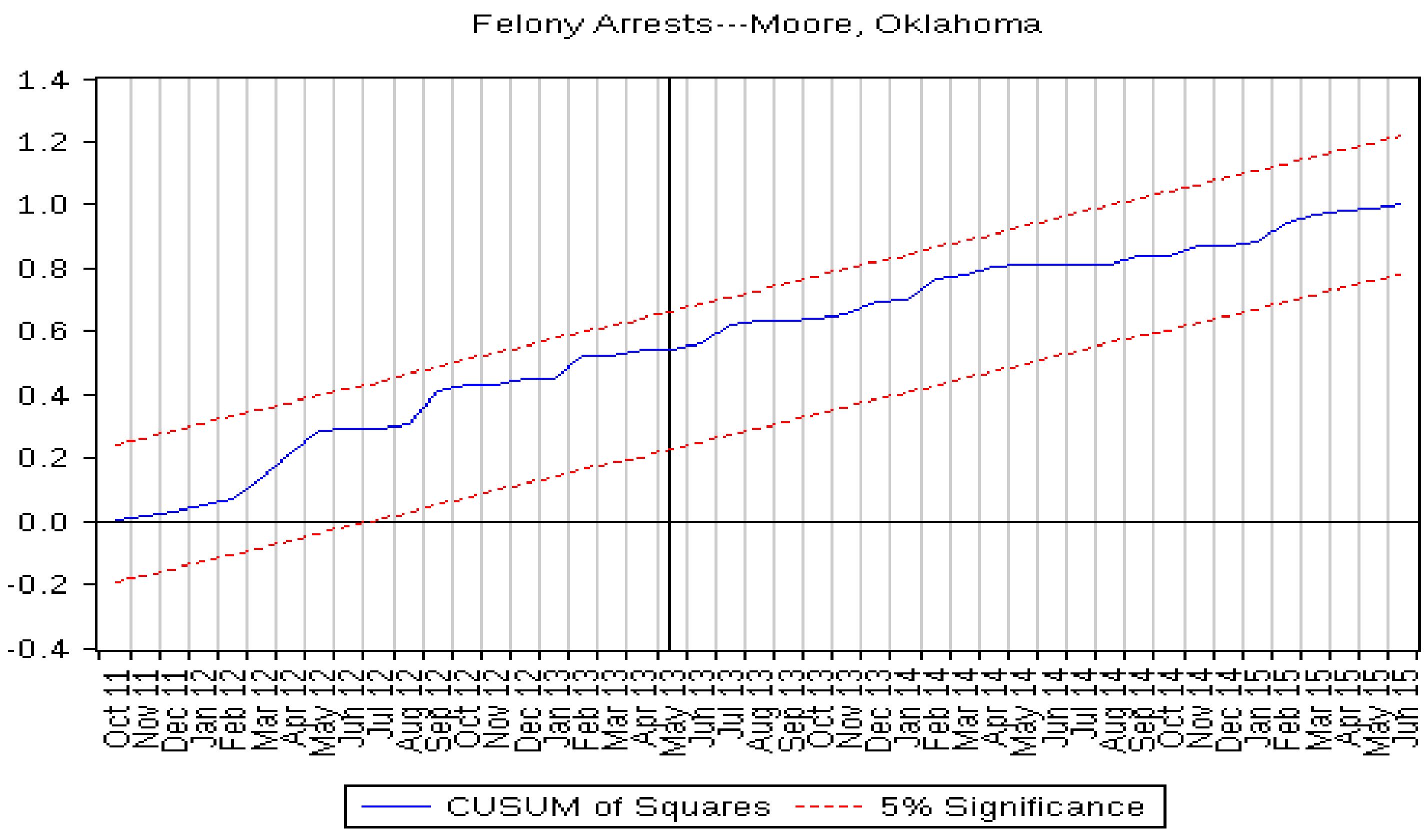
Appendix T

Figure 4.11 Felony Arrests, CUSUM test with 95% Confidence Interval Moore, Oklahoma



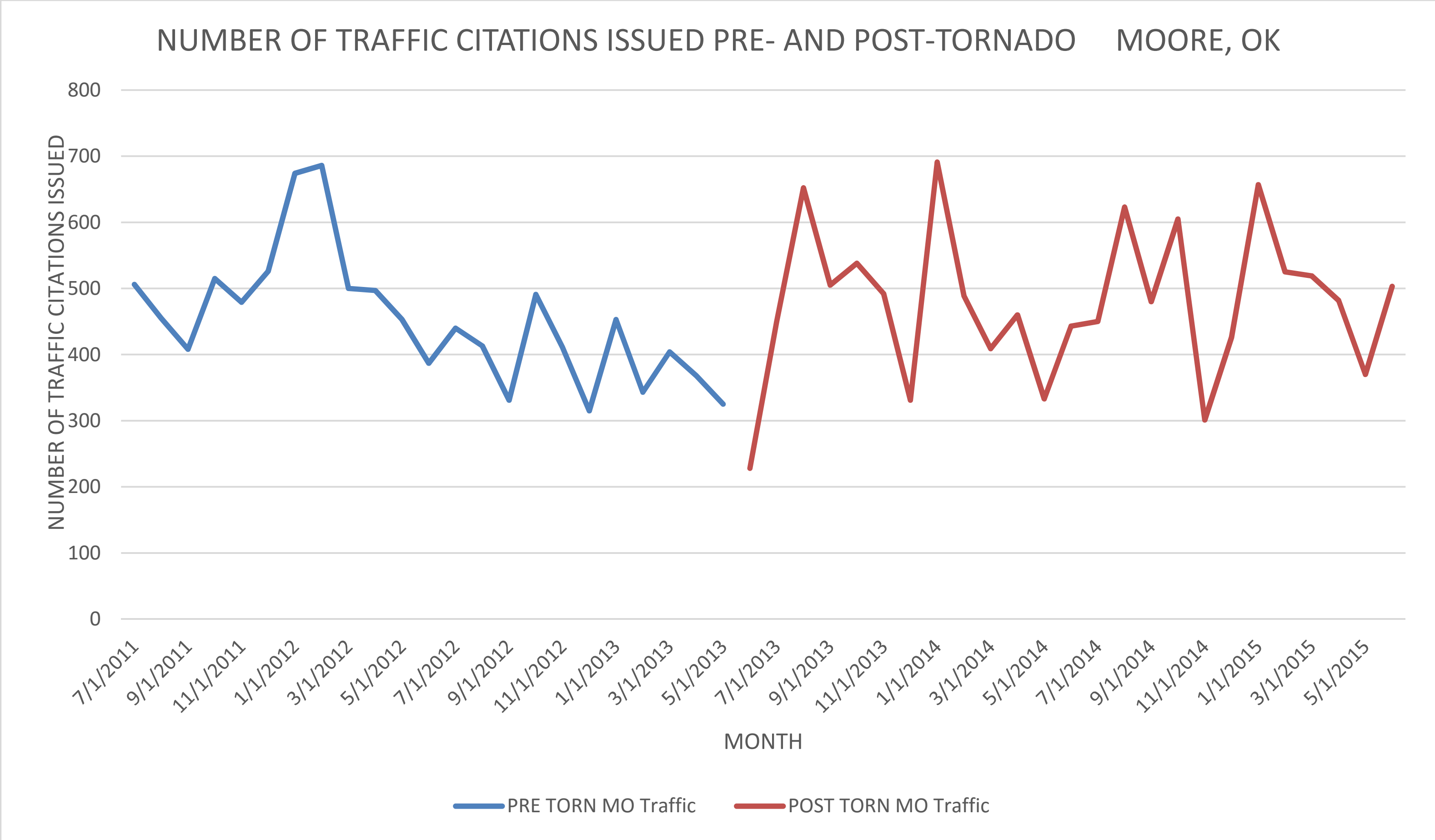
Appendix U

Figure 4.12 Felony Arrests, CUSUM of Squares Test with 95% Confidence Interval Moore, Oklahoma



Appendix V

Figure 4.13 Traffic Citations, Pre-and Post-Tornado Moore, Oklahoma



Appendix W

Table 4.10 Table of Estimates, Traffic Citations Moore, Oklahoma

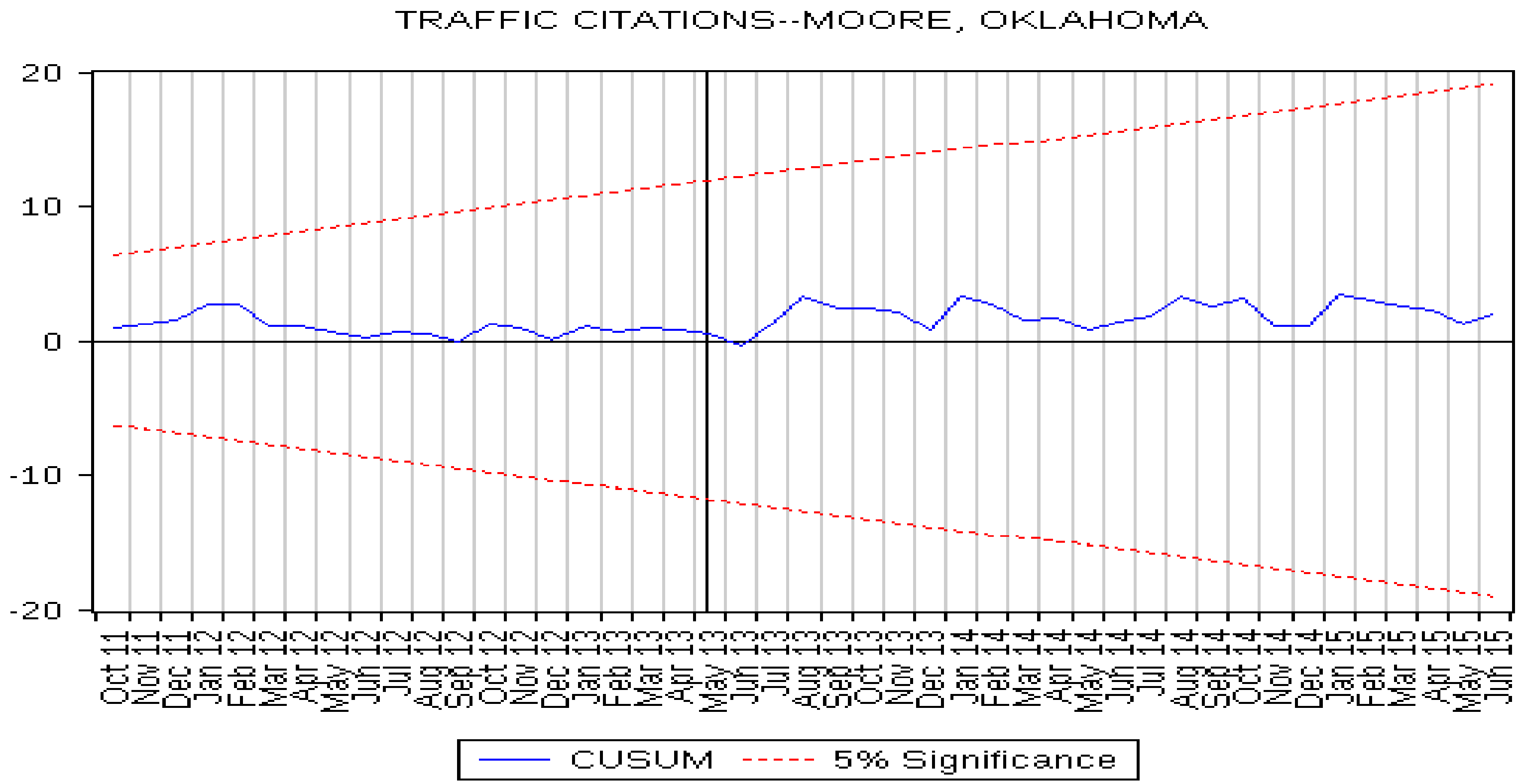
VARIABLE	COEFFICIENT	STD. ERROR	PROBABILITY
CONSTANT	0.494990	1.129287	0.6633
MA (1)	-0.981794	0.030455	0.0000*

NUMBER OF OBS.	47
ADJUSTED R^2	0.336206
LOG LIKELIHOOD	-286.1948

***** represents significance at $p > 0.05$

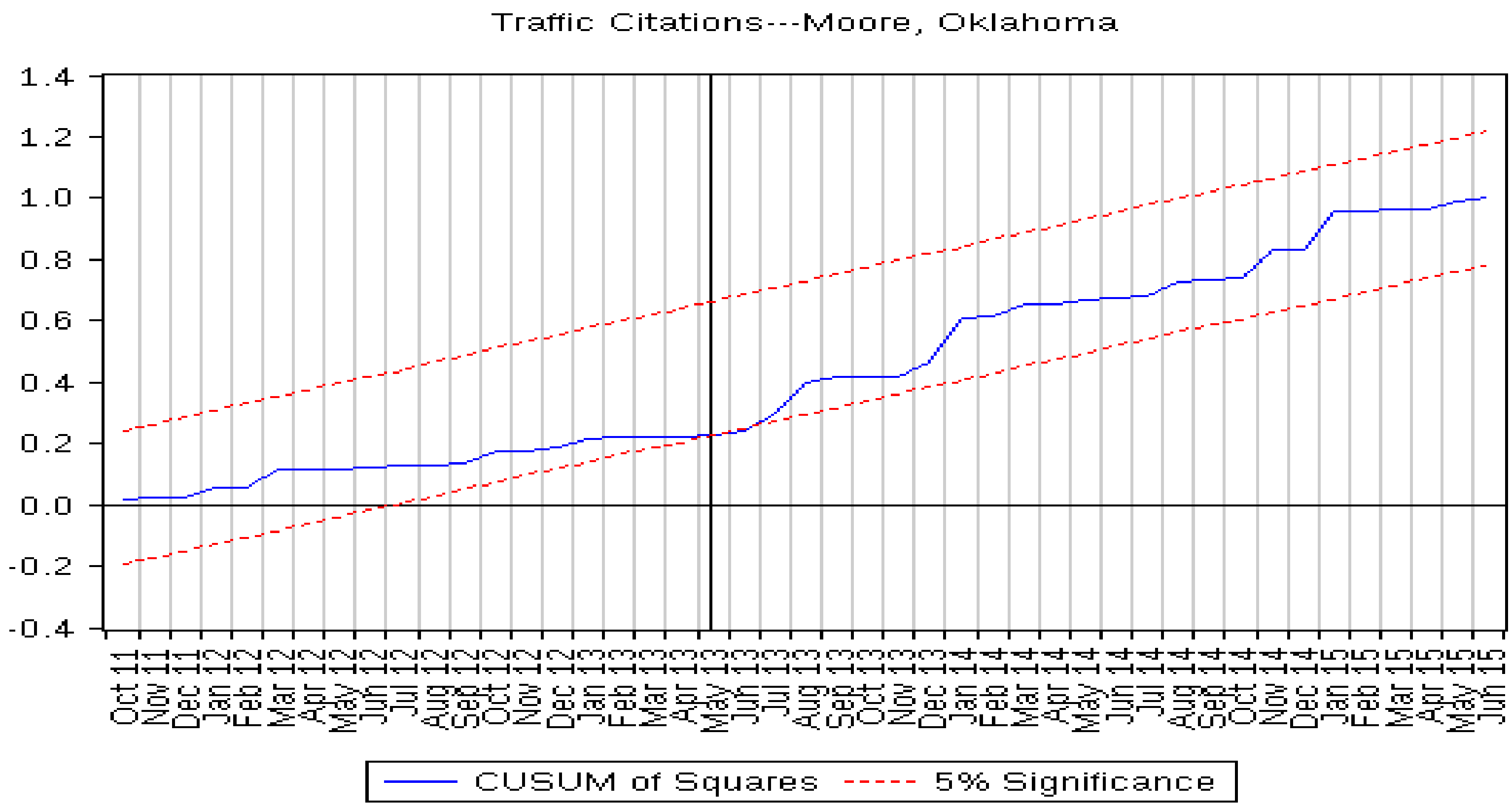
Appendix X

Figure 4.14 Traffic Citations, CUSUM Test with 95% Confidence Interval Moore Oklahoma



Appendix Y

Figure 4.15 Traffic Citations, CUSUM of Squares Test with 95% Confidence Interval Moore Oklahoma



Appendix Z

Table 4.11 Findings Stillwater, Oklahoma

	RHYTHM CORRELATION						
VARIABLE	**NO EVENT (FY12 vs. FY15)**	**WITH EVENT FY13 vs. FY14)**	**LAG VARIABLES**	**CHOW BREAK POINT (First Month)**	**SIGNFICANCE of BREAK POINT (First Month)**	**CUSUM test**	**CUSUM of squares**
WATER CONSUMPTION	0.82	0.30	MA 1, MA 4	July 2012	0.02	Demonstrates point of break, leaves CI	Leaves CI and gradually returns or restabilizes
CITIZEN-GENERATED CALLS FOR SERVICE	0.78	0.75	MA 1, MA 3	July 2012	0.01	Demonstrates weak point of break	Does not leave CI
TRAFFIC CITATIONS	0.81	0.74	MA 1, MA 3	August 2012	0.04	Does not demonstrate break point at time of event	Does not leave CI at time of event
SALES TAX REVENUE	0.68	0.80	MA 1, MA 2	No significant break point	0.11	Demonstrates weak point of break	Does not leave CI
FELONY ARRESTS	-0.27	-0.46	MA 1	No significant break point	0.10	Demonstrates potential break point	Does not leave CI until non-disaster event occurs

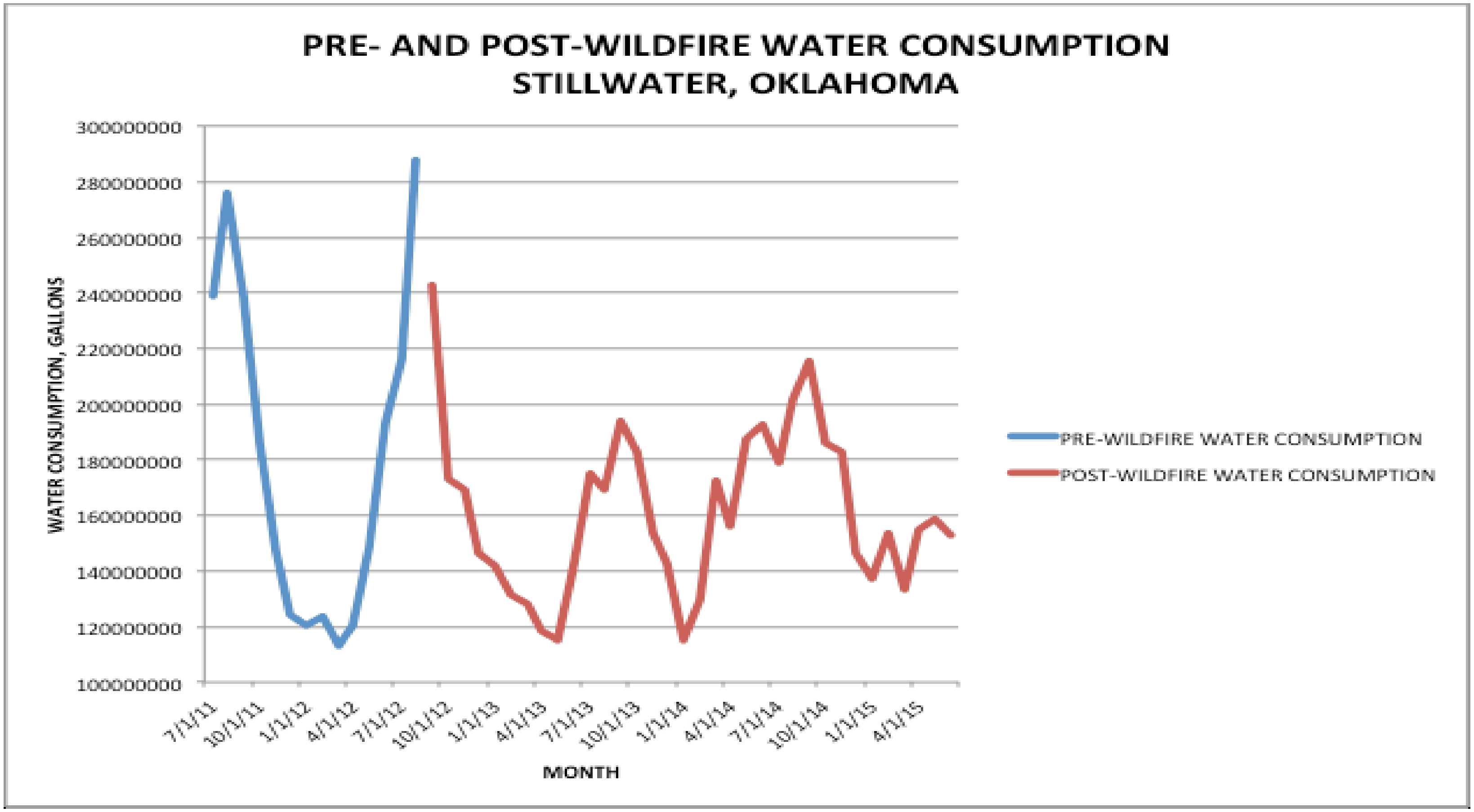
Appendix AA

Table 4.12 Indicator Effectiveness (in Order of Effectiveness) Stillwater, Oklahoma

VARIABLE	**INDICATOR OF SYSTEM SENSITIVITY** (SIGNIFICANT CHOW BREAK POINT TEST)	**INDICATOR OF PROCESS OF RETURN TO EQUILIBRIUM** (CUSUM AND CUSUM OF SQUARES TESTS)
WATER CONSUMPTION	GOOD JULY 2012	MODERATE RETURN TO EQUILIBRIUM APPROXIMATELY MAY 2013
CITIZEN-GENERATED CALLS FOR SERVICE	GOOD JULY 2012	NO SIGNIFICANT DEVIATION FROM EQUILIBRIUM
TRAFFIC CITATIONS	GOOD AUGUST 2012	NO SIGNIFICANT DEVIATION FROM EQUILIBRIUM
SALES TAX REVENUE	NO SIGNIFICANT BREAK	NO SIGNIFICANT DEVIATION FROM EQUILIBRIUM
UCR—FELONY ARRESTS	NO SIGNIFICANT BREAK	NO SIGNIFICANT DEVIATION FROM EQUILIBRIUM

Appendix BB

Figure 4.16 Water Consumption, Pre- and Post-Event Stillwater, Oklahoma



Appendix CC

Table 4.13 Model of Estimates, Water Consumption Stillwater, Oklahoma

VARIABLE	COEFFICIENT	STD. ERROR	PROBABILITY
CONSTANT	247993.4	845214.8	0.7706
MA (4)	-0.950631	0.030094	0.0000*

NUMBER OF OBS.	47
ADJUSTED R^2	0.414052
LOG LIKELIHOOD	-858.8857

* represents significance at $p > 0.05$

Appendix DD

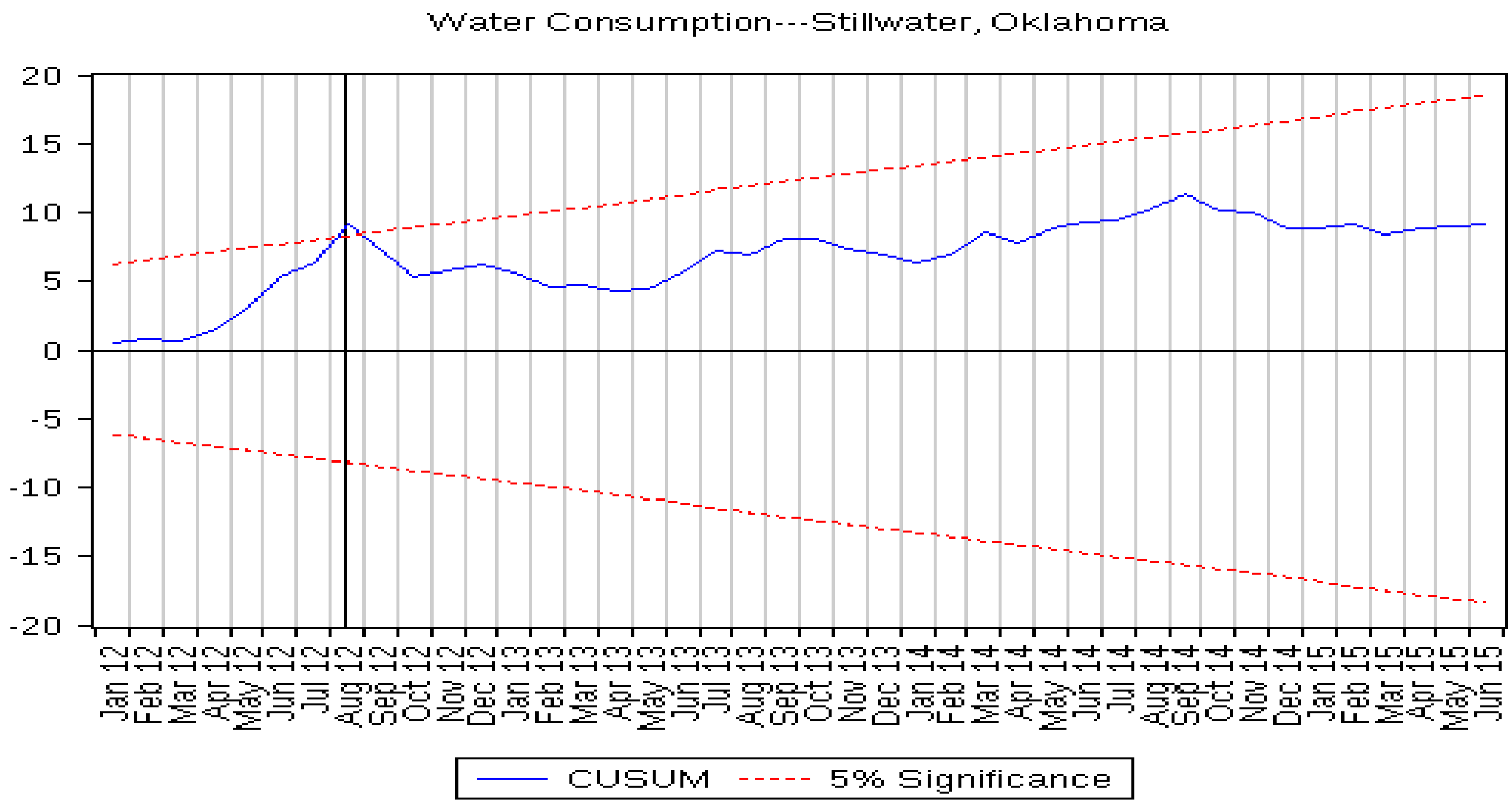
Table 4.14 Chow Break Point Test, All Variables (indication of system disruption) Stillwater, Oklahoma

VARIABLE	**MONTH**	**SIGNIFICANCE (p > 0.05)** (F-statistic)
WATER CONSUMPTION		
	JULY 2012	0.02*
	AUGUST 2012	0.01*
	SEPTEMBER 2012	0.00*
CITIZEN-GENERATED CALLS FOR SERVICE		
	JULY 2012	0.01*
	AUGUST 2012	0.01*
	SEPTEMBER 2012	0.64
TRAFFIC CITATIONS		
	JULY 2012	0.06
	AUGUST 2012	0.04*
	SEPTEMBER 2012	0.03*
SALES TAX REVENUE		
	JULY 2012	0.11
	AUGUST 2012	0.23
	SEPTEMBER 2012	0.06
UCR—FELONY ARREST		
	JULY 2012	0.25
	AUGUST 2012	0.10
	SEPTEMBER 2012	0.07

* represents significance at $p > 0.05$

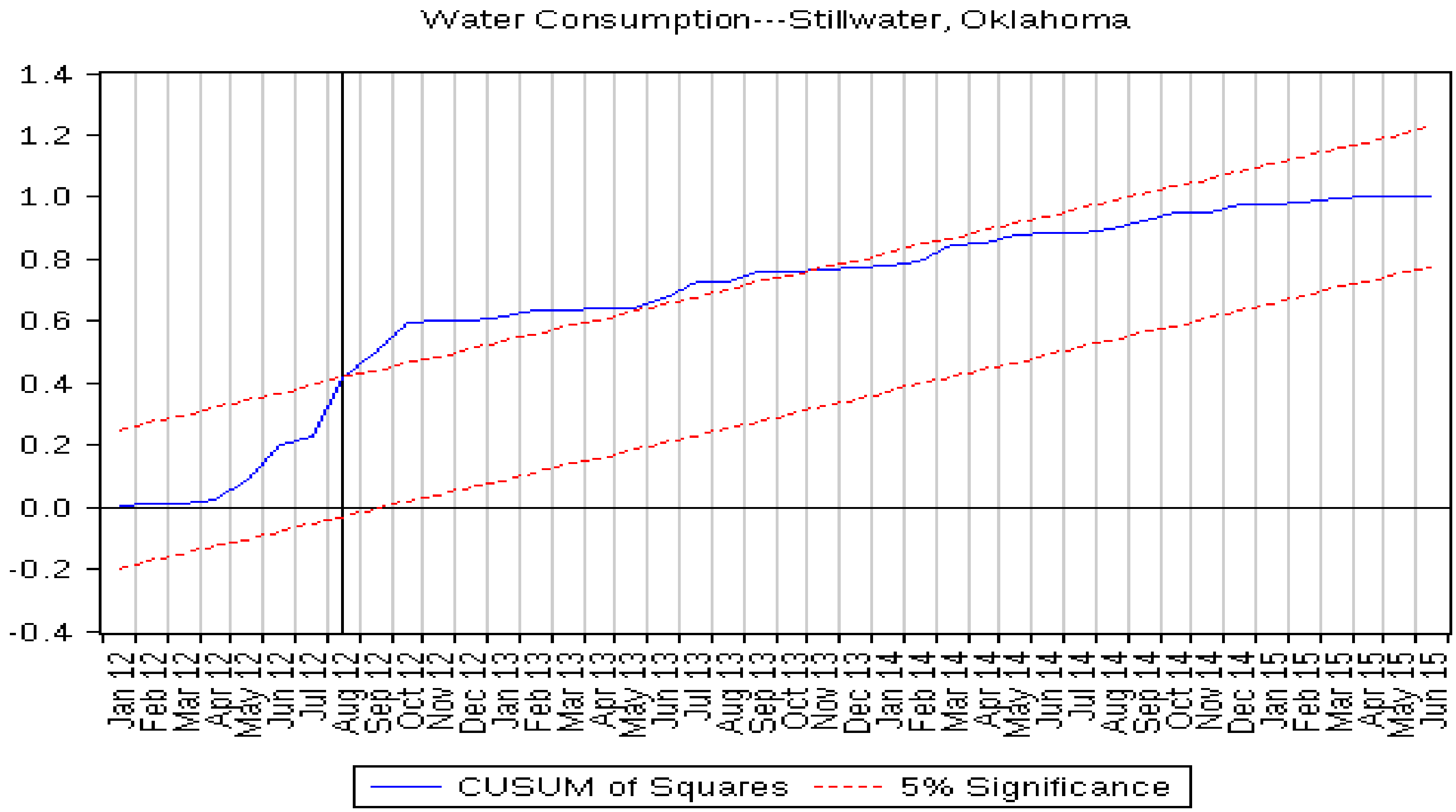
Appendix EE

Figure 4.17 Water Consumption, CUSUM Test with 95% Confidence Interval Stillwater, Oklahoma



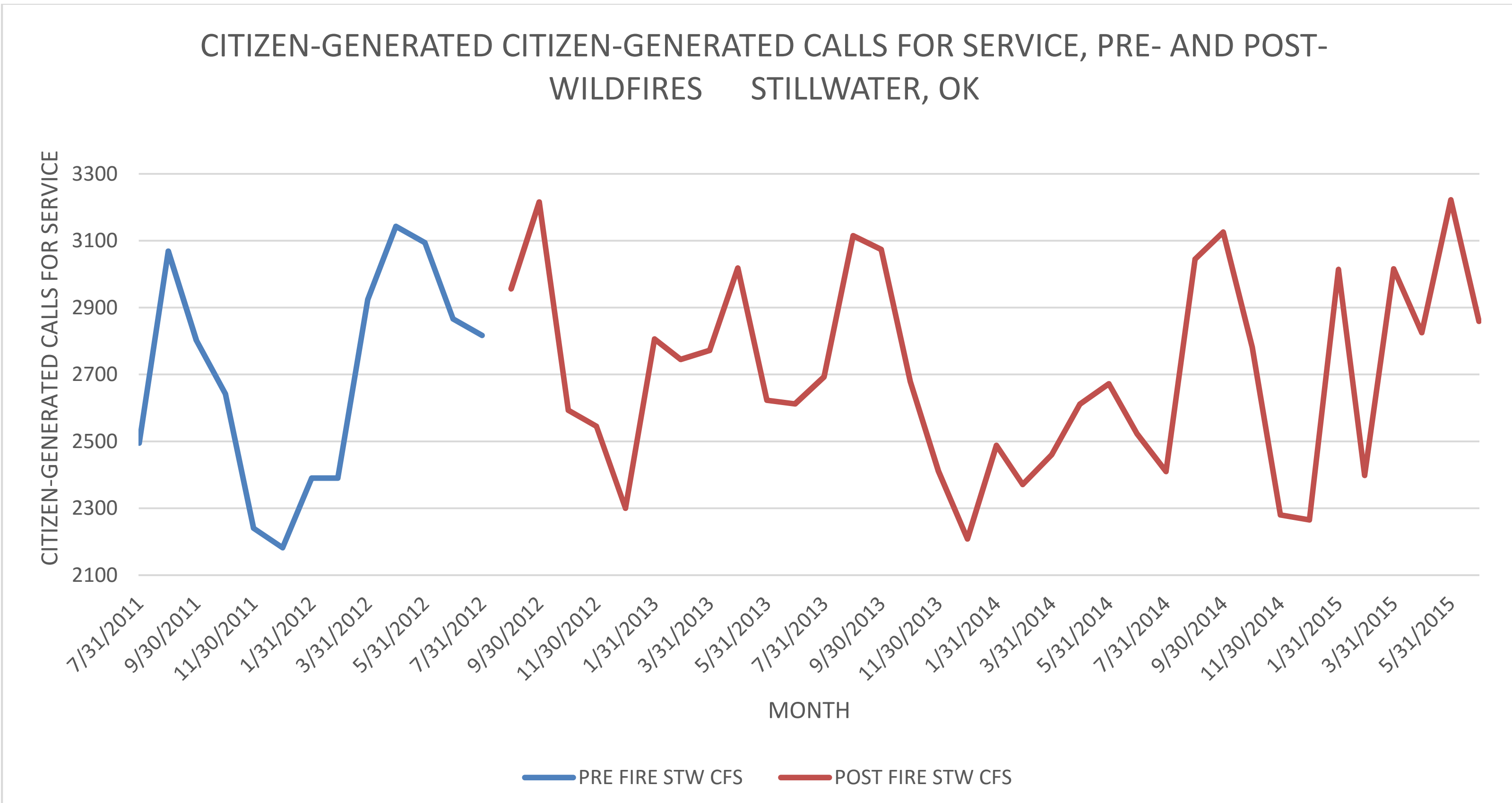
Appendix FF

Figure 4.18 Water Consumption, CUSUM of Squares Test with 95% Confidence Interval Stillwater, Oklahoma



Appendix GG

Figure 4.19 Citizen-Generated Calls For Service, Pre- and Post-Event Stillwater, OK



Appendix HH

Table 4.15 Model of Estimates, Citizen-Generated Calls For Service   Stillwater, OK

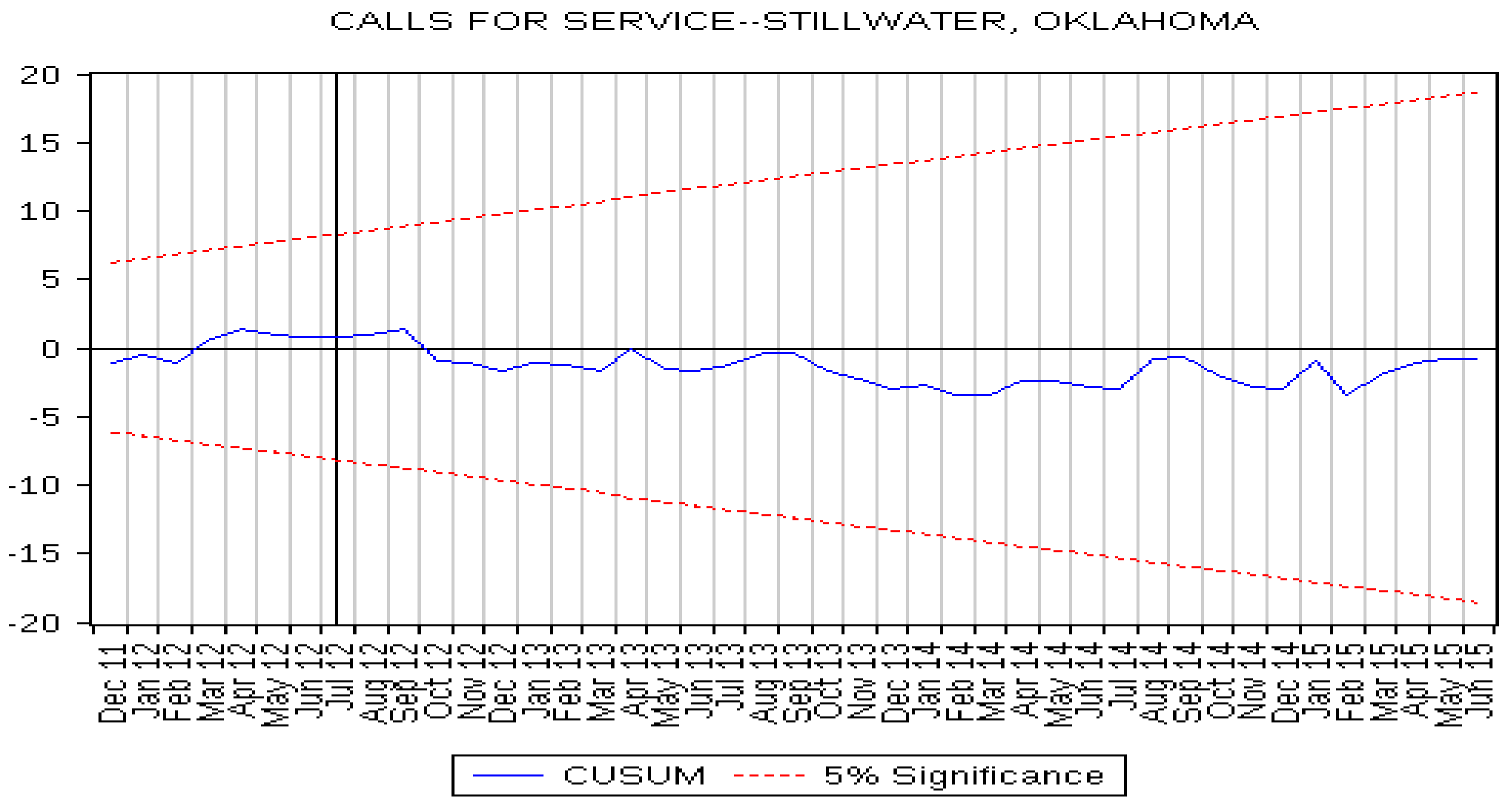
VARIABLE	COEFFICIENT	STD. ERROR	PROBABILITY
CONSTANT	4.987778	4.946781	0.3188
MA (1)	-0.199675	0.090609	0.0328*
MA (3)	-0.800300	0.093699	0.0000*

NUMBER OF OBS.	47
ADJUSTED R^2	0.378553
LOG LIKELIHOOD	-326.8536

* represents significance at $p > 0.05$

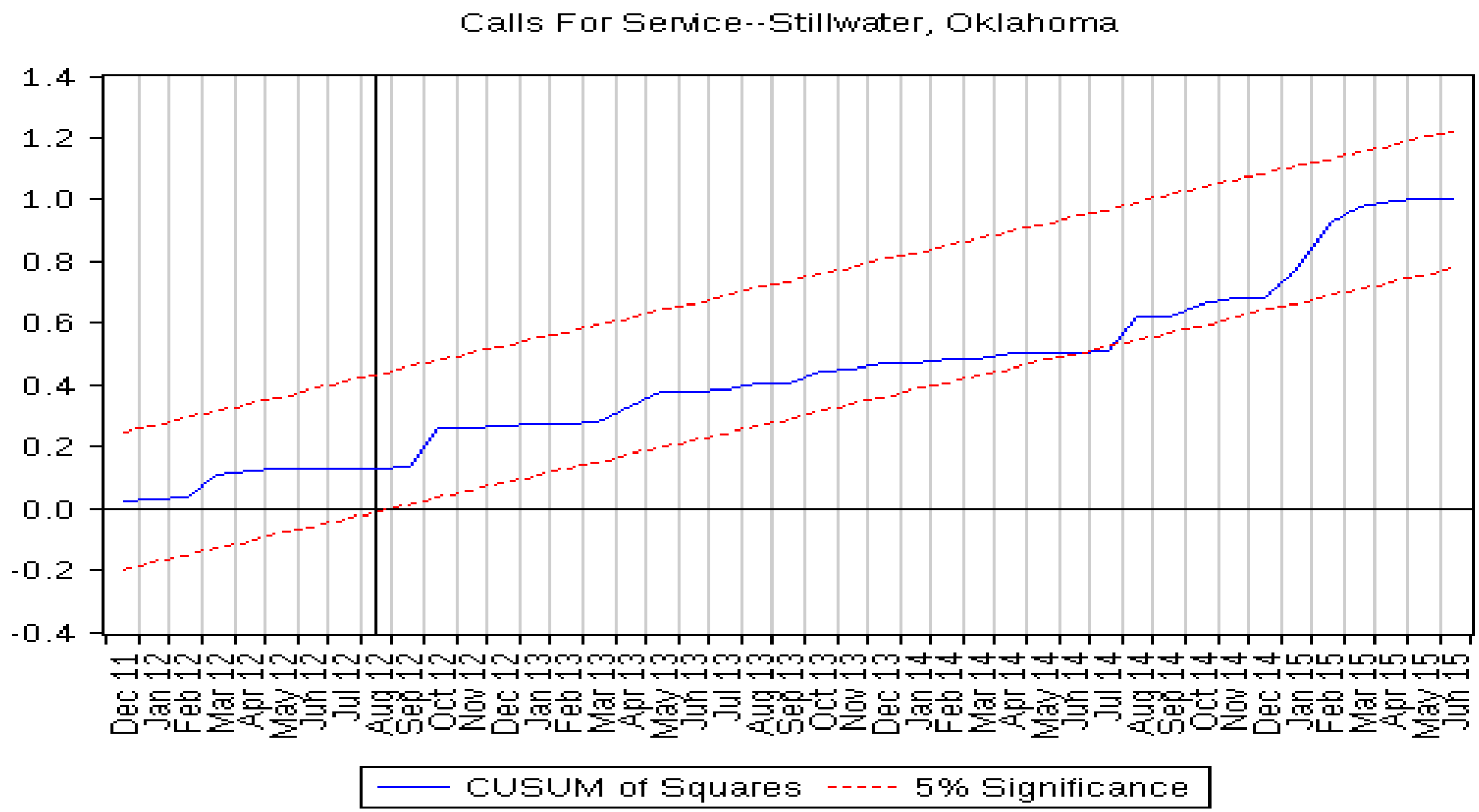
Appendix II

Figure 4.20 Citizen-Generated Calls For Service, CUSUM Test with 95% Confidence Interval Stillwater, Oklahoma



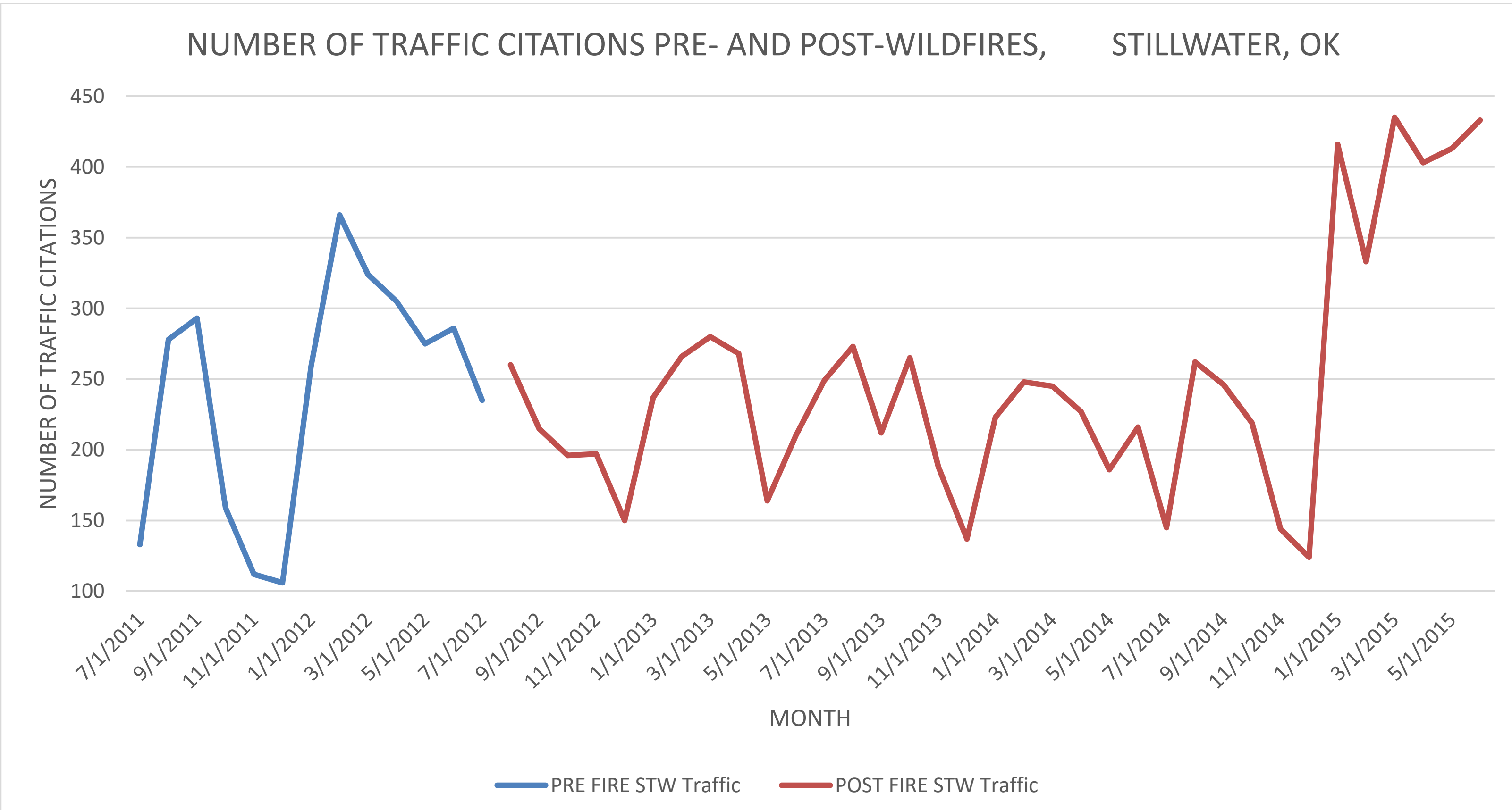
Appendix JJ

Figure 4.21 Citizen-Generated Calls For Service, CUSUM of Squares Test with 95% Confidence Interval Stillwater, Oklahoma



Appendix KK

Figure 4.22 Traffic Citations, Pre- and Post-Event Stillwater, Oklahoma



Appendix LL

Table 4.16 Model of Estimates, Traffic Citations Stillwater, Oklahoma

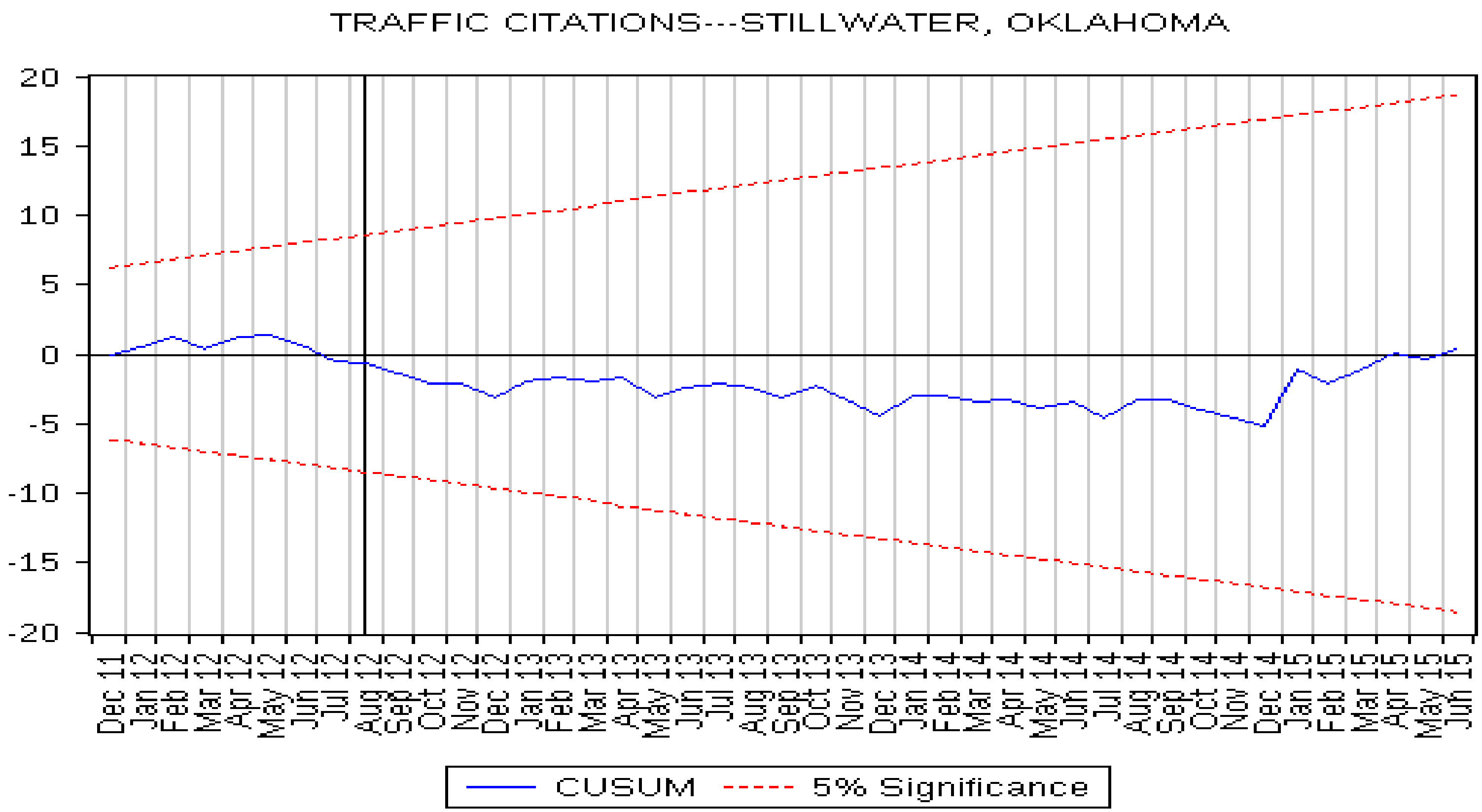
VARIABLE	COEFFICIENT	STD. ERROR	PROBABILITY
CONSTANT	2.075366	1.866525	0.2722
MA (1)	-0.371294	0.102689	0.0008*
MA (3)	-0.556521	0.099316	0.0000*

NUMBER OF OBS.	47
ADJUSTED R^2	0.194745
LOG LIKELIHOOD	-263.5291

* represents significance at $p > 0.05$

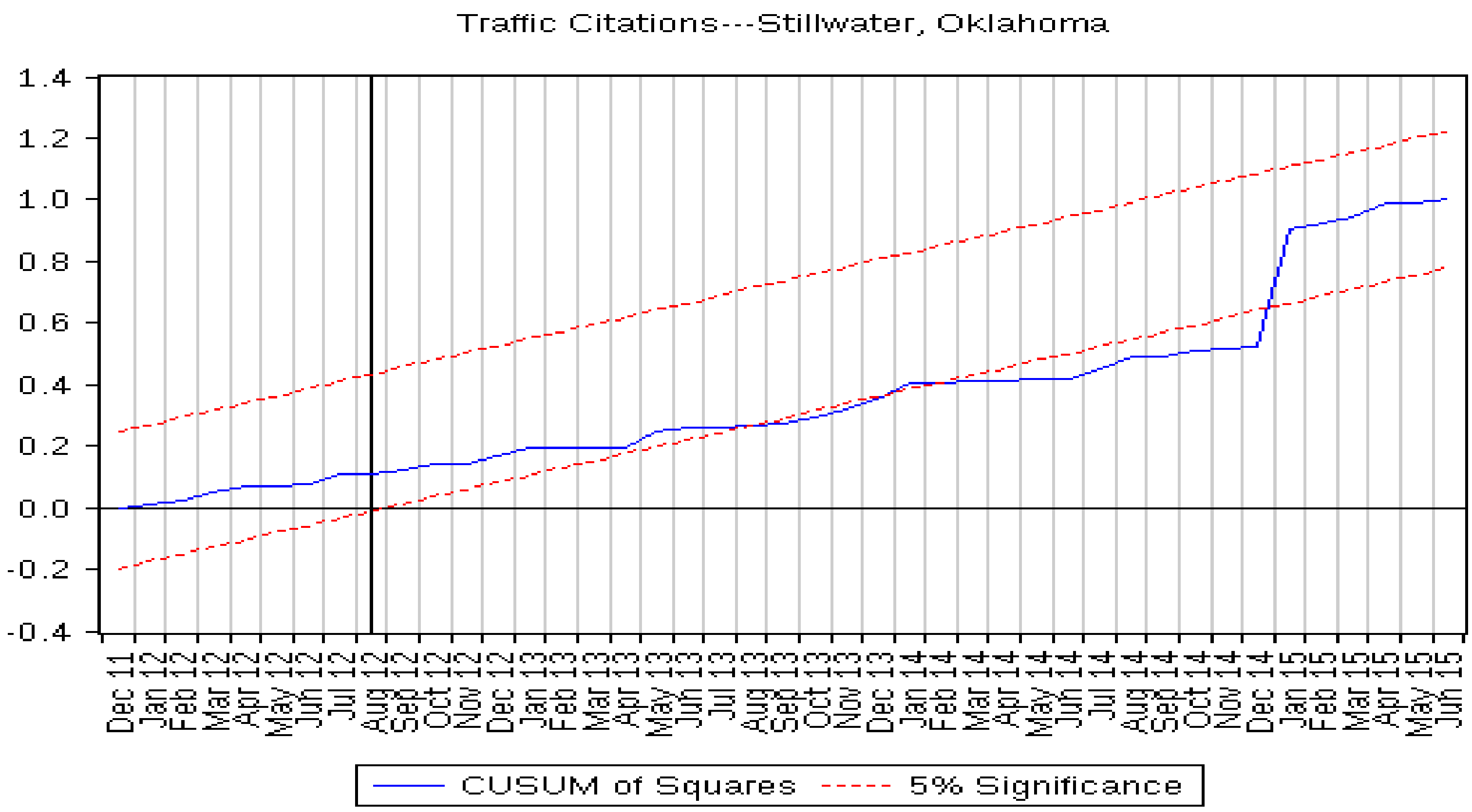
Appendix MM

Figure 4.23 Traffic Citations, CUSUM Test with 95% Confidence Interval   Stillwater, Oklahoma



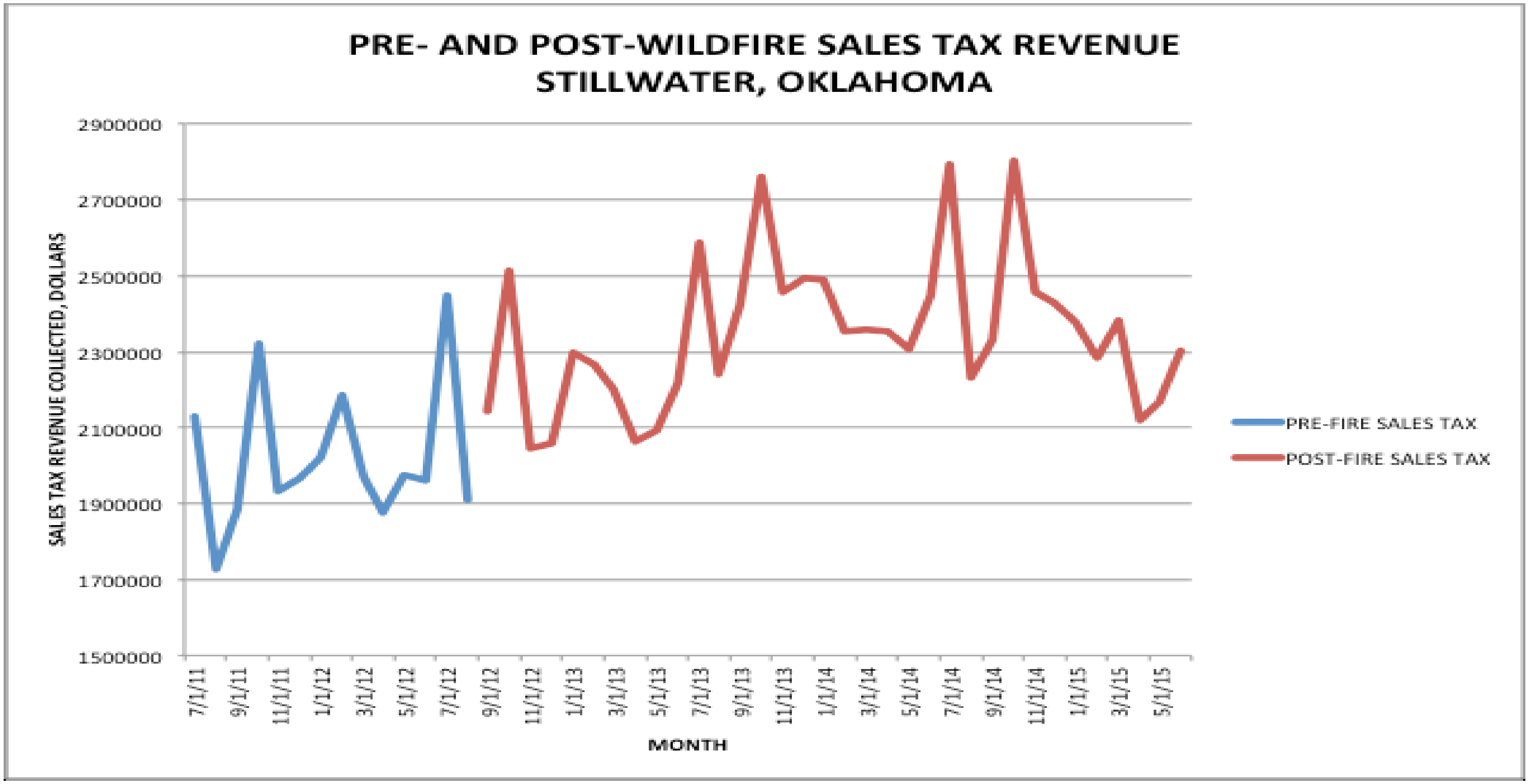
Appendix NN

Figure 4.24 Traffic Citations, CUSUM Test with 95% Confidence Interval Stillwater, Oklahoma



Appendix OO

Figure 4.25 Sales Tax Revenue, Pre- and Post-Event Stillwater, Oklahoma



Appendix PP

Table 4.17 Model of Estimates, Sales Tax Revenue Stillwater, Oklahoma

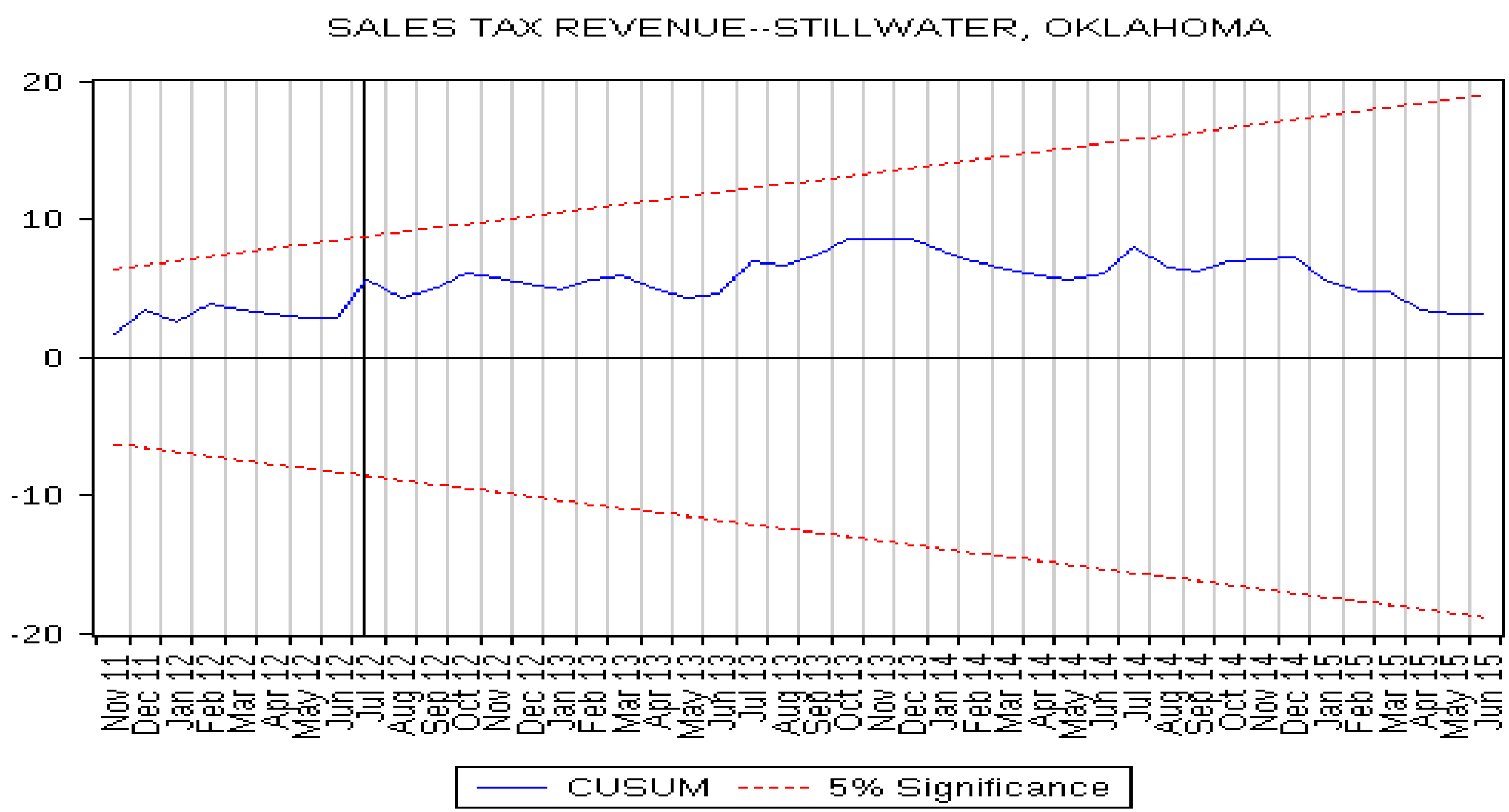
VARIABLE	COEFFICIENT	STD. ERROR	PROBABILITY
CONSTANT	-14786.07	14029.49	0.2977
MA (1)	-0.673213	0.144324	0.0000*
MA (2)	-0.564859	0.167171	0.0015*

NUMBER OF OBS.	47
ADJUSTED R^2	0.388093
LOG LIKELIHOOD	-639.4533

* represents significance at $p > 0.05$

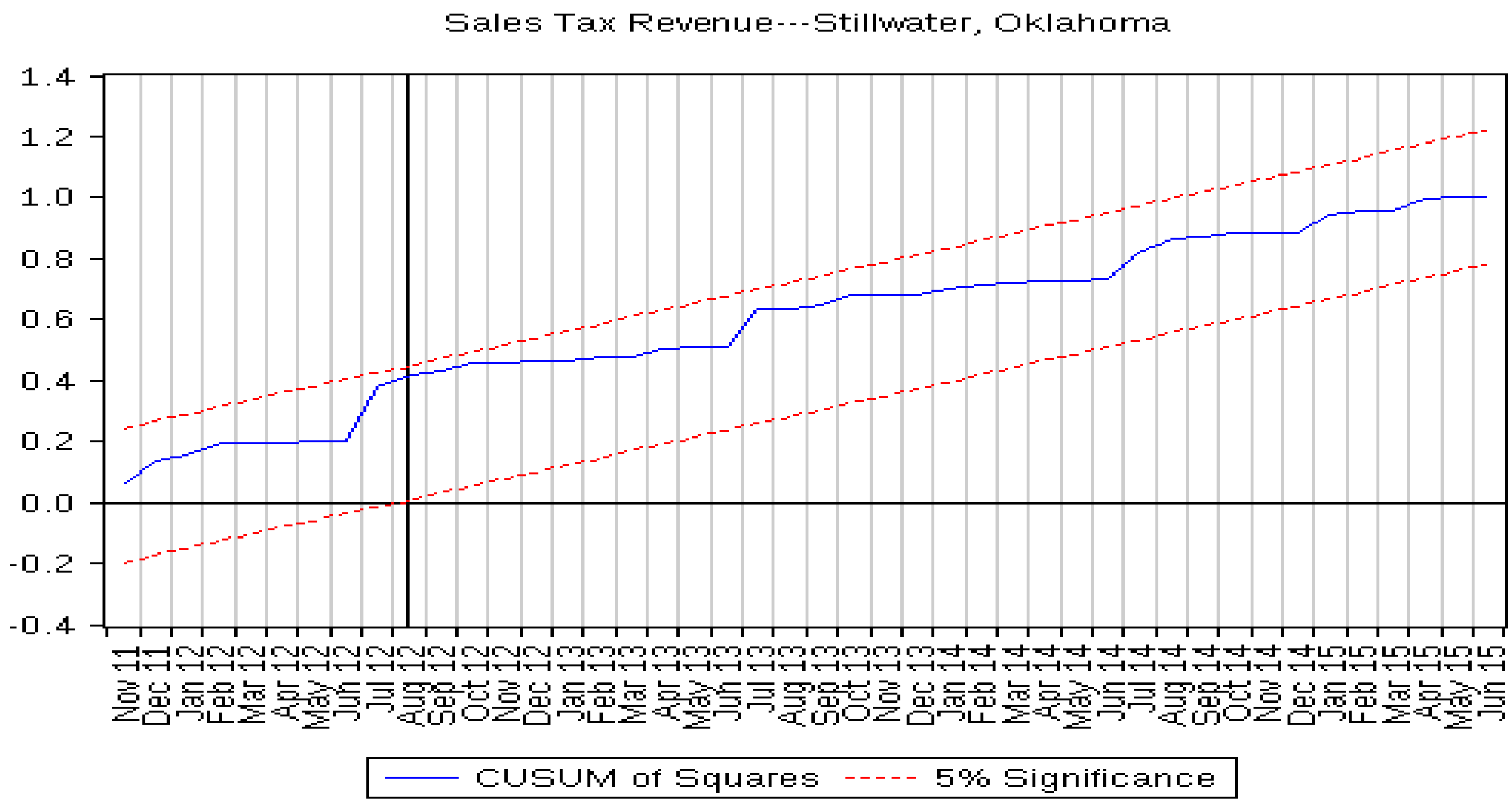
Appendix QQ

Figure 4.26 Sales Tax Revenue, CUSUM Test with 95% Confidence Interval Stillwater, Oklahoma



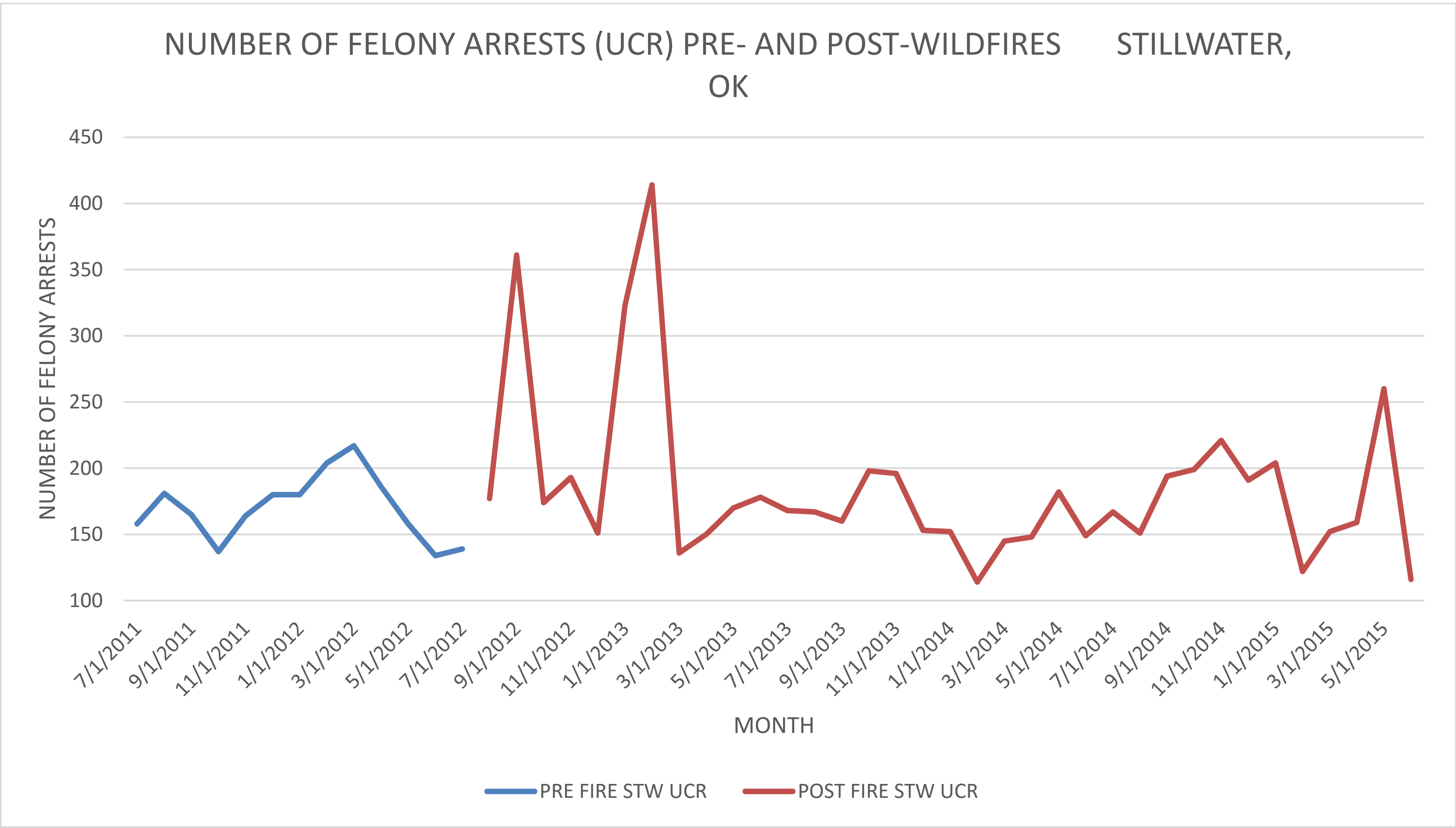
Appendix RR

Figure 4.27 Sales Tax Revenue, CUSUM of Squares Test with 95% Confidence Interval Stillwater, Oklahoma



Appendix SS

Figure 4.28 Felony Arrests, Pre- and Post-Event Stillwater, Oklahoma



Appendix TT

Table 4.18 Model of Estimates, Felony Arrests Stillwater, Oklahoma

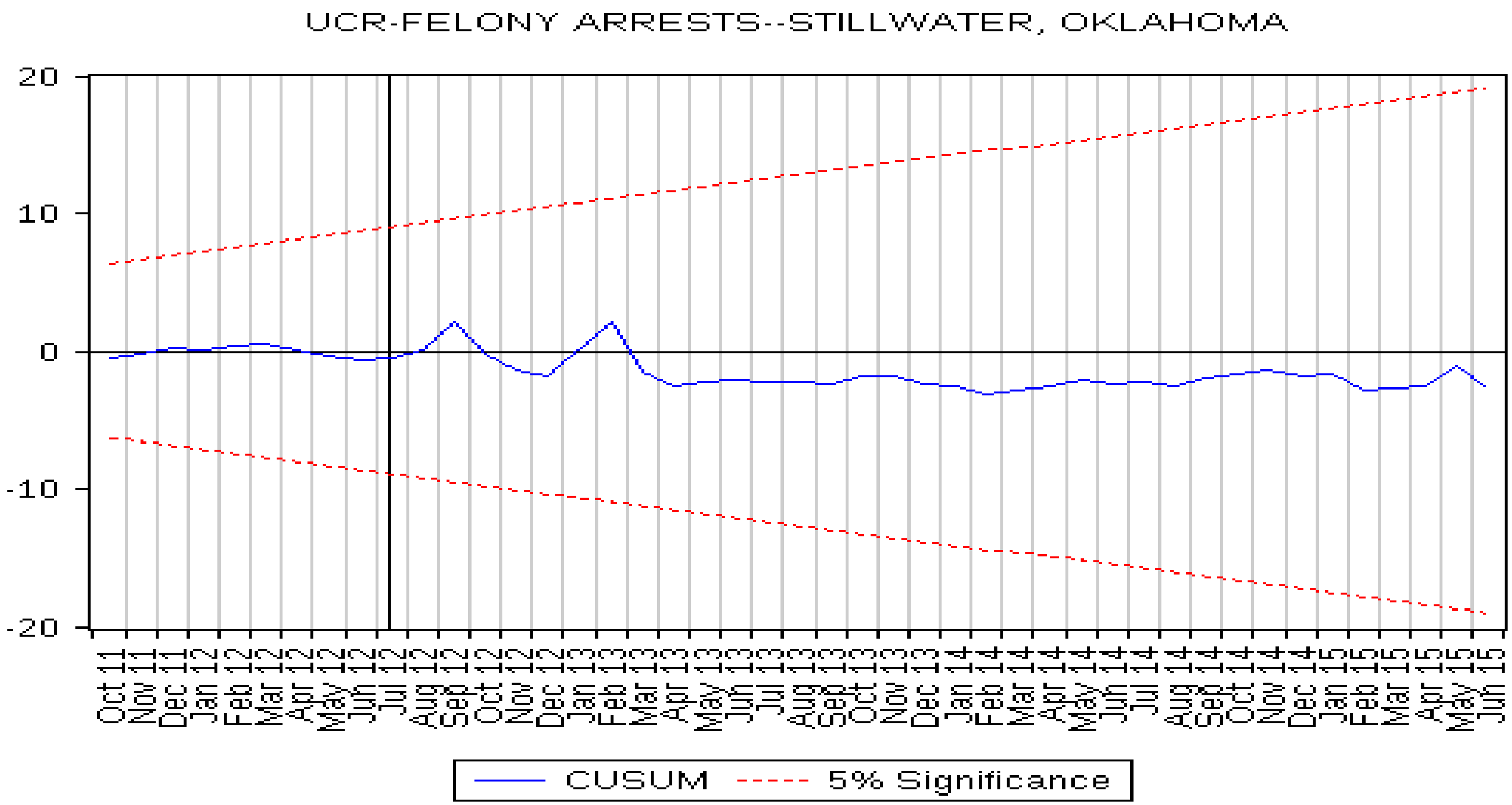
VARIABLE	COEFFICIENT	STD. ERROR	PROBABILITY
CONSTANT	-0.409377	0.751554	0.5886
MA (1)	-0.959586	0.036573	0.0000*

NUMBER OF OBS.	47
ADJUSTED R^2	0.353785
LOG LIKELIHOOD	-257.0016

* represents significance at $p > 0.05$

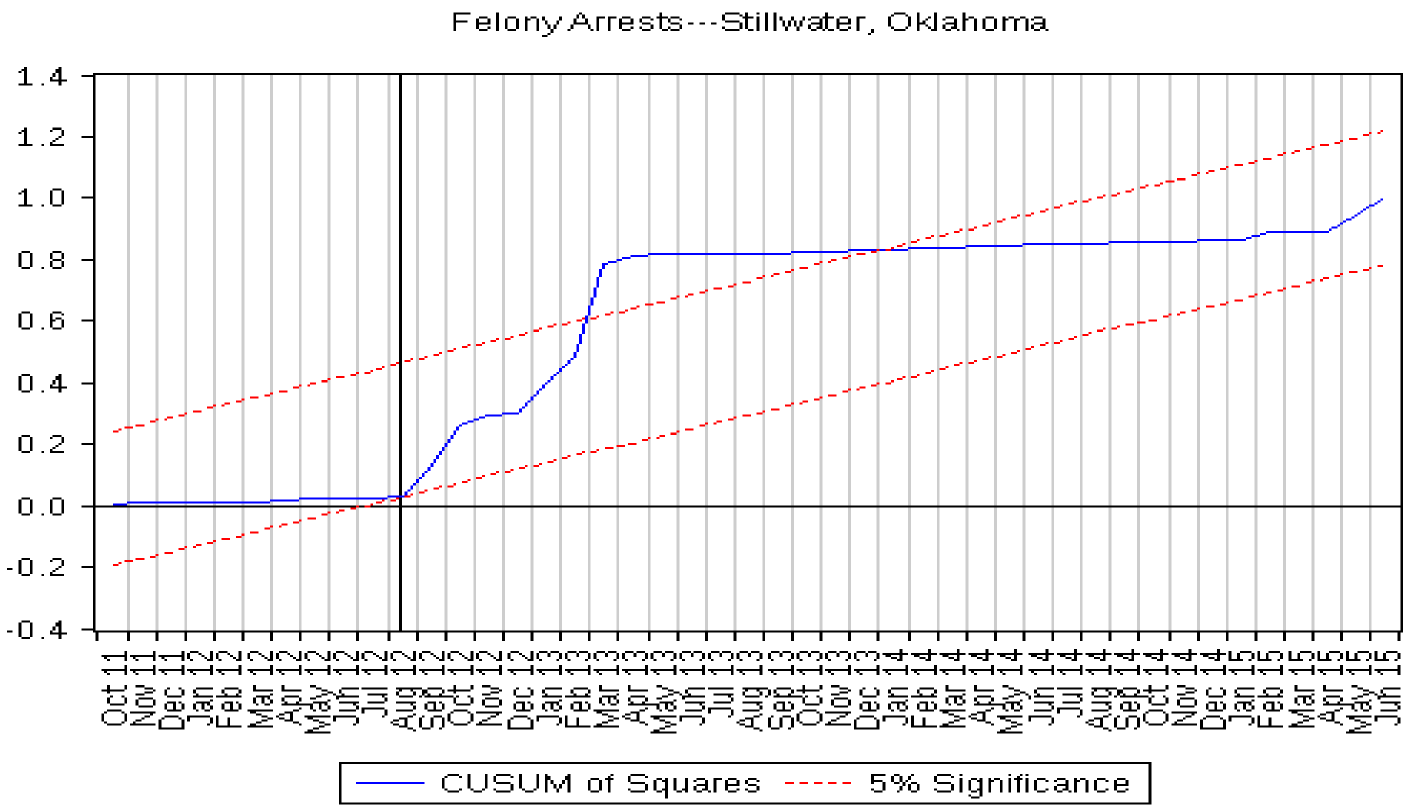
Appendix UU

Figure 4.29 Felony Arrests, CUSUM Test with 95% Confidence Interval Stillwater, Oklahoma



Appendix VV

Figure 4.30 Felony Arrests, CUSUM of Squares Test with 95% Confidence Interval Stillwater, Oklahoma



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VITA

Caroline S. Hackerott

Candidate for the Degree of

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Gender Disaster Network

International Association of Emergency Management