May 2023

The Transaction Costs of Federal Environmental Policy Changes: The Effects of the Temporary COVID-19 CWA Rollback on Local Water Systems

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THE TRANSACTION COSTS OF FEDERAL ENVIRONMENTAL POLICY CHANGES: THE EFFECTS OF THE TEMPORARY COVID-19 CWA ROLLBACK ON LOCAL WATER SYSTEMS

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A dissertation submitted in partial fulfillment
of the requirements for the

Doctor of Philosophy – Public Affairs

School of Public Policy and Leadership
Greenspun College of Urban Affairs
The Graduate College

University of Nevada, Las Vegas
May 2023

UNLV | GRADUATE COLLEGE

Dissertation Approval

The Graduate College
The University of Nevada, Las Vegas

March 20, 2023

This dissertation prepared by

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entitled

The Transaction Costs of Federal Environmental Policy Changes: The Effects of the Temporary COVID-19 CWA Rollback on Local Water Systems

is approved in partial fulfillment of the requirements for the degree of

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School of Public Policy and Leadership

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Abstract

An institutional dilemma exists between the Clean Water Act (CWA) and the Safe Drinking Water Act (SDWA). US surface waters are protected from point-source pollution by the CWA. Community Water Systems (CWSs) that draw from these surface waters for potable purposes are required to treat that water to a level that meets SDWA health standards. Therefore, decreases in CWA regulations could lead to surface water quality declines and, thus, higher SDWA compliance costs for CWSs. This area of inquiry has become increasingly relevant due to Trump-era executive actions to try to decrease the federal government's role in multiple environmental policies, including the CWA. In this dissertation, a prominent CWA rollback from the Trump-era is used as a test to examine (1) whether federal compliance enforcement rollbacks result in increased SDWA non-compliance by local government-owned CWSs, and (2) whether institutional arrangements at the state and local level protect against adverse source quality effects of a federal rollback. The transaction costs of contested federalism theory is used to analyze these inquiries. This theory views local governments as being nested within state and federal institutional arrangements. Policy adoptions at the federal level that are not aligned with state and local government needs are expected to generate transaction costs that hinder the implementation of government policies at the state and local levels. This study uses the difference-in-differences quasi-experimental statistical approach to deduce whether temporary EPA rollback of CWA enforcement requirements impacted local government SDWA compliance. Overall, the results indicate that local government CWSs sourcing from surface water experienced significantly higher SDWA health violations after the federal CWA rollback. Furthermore, multiple state and local institutional factors emerged as significant moderators of the CWA rollback's effect on local governments.

Overall, this study's findings shed light on the CWA-SDWA institutional dilemma, and how a federal rollback of CWA enforcement responsibility to state governments impacts local level SDWA implementation. Additionally, this study identified key institutional factors that buffered or amplified the CWA rollback effect. This study's results provide theoretical and practical insights to the literature. Theoretically, this study's results provide association-based evidence that misaligned federal environmental policy led to poor environmental policy implementation outcomes at the local level. This finding has key implications for US environmental federalism literature. The results of this study suggest that a formal institutional linkage between the CWA and SDWA would help ensure future CWA changes account for the potential impacts they will have on local SDWA compliance. In sum, this study's findings suggest that rollbacks in CWA enforcement can adversely affect local drinking water administration. However, states and local governments can take preventative measures to overcome these effects.

Acknowledgements

I am incredibly grateful for the support and guidance of my dissertation committee, UNLV faculty, the UNLV Graduate College, my mentors, and my family throughout my academic journey. I extend my deepest gratitude to my dissertation chair, Dr. Jayce Farmer, for his instrumental role in developing and completing this project. Dr. Farmer generously took me on as his student, and we immediately jumped into building my dissertation project and identifying how my dissertation topic fits into the federalism literature. His guidance and encouragement were essential in completing this dissertation and in many other academic endeavors. Dr. Farmer's invaluable contributions have left an indelible mark on my academic journey, and I am profoundly grateful for his mentorship and support.

I also express my sincere gratitude to my committee members, who provided crucial support for my dissertation and academic journey. I extend my thanks to Dr. Krystyna Stave for providing invaluable guidance in helping me understand the broader significance of my dissertation research and for being one of my earliest mentors at UNLV. I am also immensely grateful to Dr. Shawn McCoy for his early insights and support and his continued assistance in understanding advanced statistical modeling. I also want to thank Dr. Edgar Ramirez De La Cruz for supporting me as a student and providing valuable insight into my study variables and research design. I thank Dr. Christopher Stream for his guidance on my dissertation and support throughout my Ph.D. journey.

Other UNLV faculty and institutions have supported me immensely throughout my academic career. I sincerely thank Dr. Anjala Krishen for the guidance and support she has provided me since we first started collaborating on research over five years ago. I also extend thanks to Dr. Eduardo Robleto, Dr. Han-Fen Hu, and Dr. Jaewon Lim for supporting my research and professional development. I also thank the UNLV Graduate College and the School of Public Policy and Leadership for supporting my academic career for the past four years.

Lastly, I want to thank my family. Thank you to my brother Nick and aunt Rita for your love and support from afar. I want to express my heartfelt appreciation to my partner, future Dr. Axenya Kachen, for always supporting and encouraging me to pursue my passion for research and academia. I have spent countless hours in labs or buried in my laptop for the past six years of graduate school, and I appreciate their unwavering support and encouragement. Thank you for indulging my monologues about US environmental policy and multilevel governance. Overall, thank you so much to all my family, friends, colleagues, and mentors who have helped me along the way!

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List of Abbreviations

CWA	Clean Water Act
CWS	Community Water System
DWSRF	Drinking Water State Revolving Fund
CWSRF	Clean Water State Revolving Fund
DID	Difference-In-Differences
EPA	Environmental Protection Agency
FE	Fixed Effects
NPDES	National Pollutant Discharge Elimination System
SDWA	Safe Drinking Water Act
Temporary Policy	EPA COVID-19 Temporary Enforcement Policy

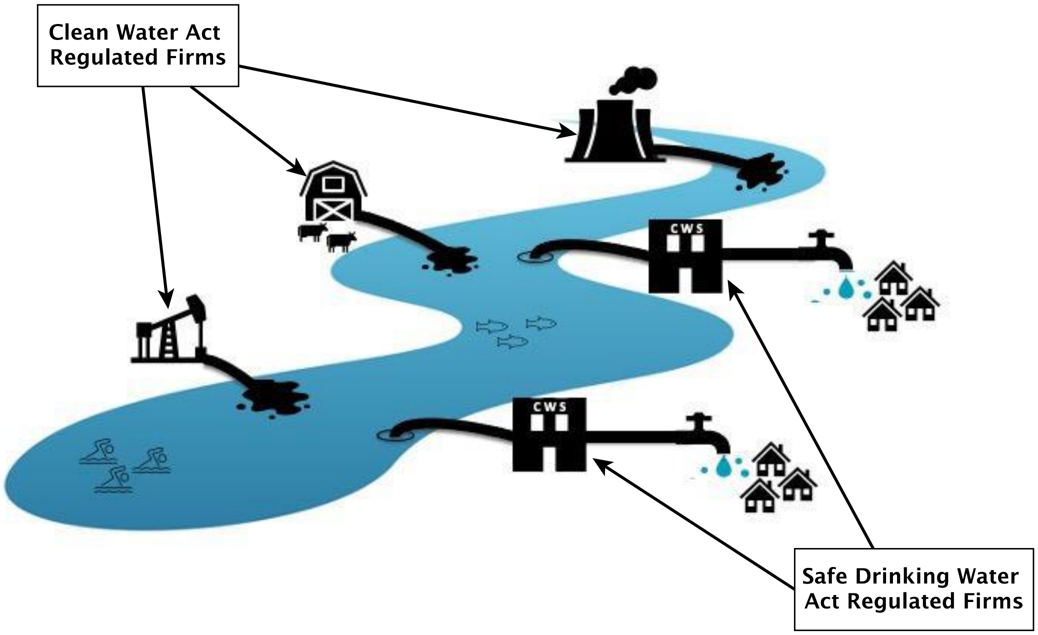
Chapter 1: Introduction

1. Problem Statement

1.1. Institutional Dilemma in the US Water Sector

The 1974 Safe Drinking Water Act (SDWA) requires Community Water Systems (CWSs) to adhere to minimum standards for drinking water quality and treatment to ensure that US residents receive safe drinking water (Humphreys, 2022). The SDWA also requires state governments to monitor potential sources of contamination in their drinking water sources (i.e., lakes, rivers, reservoirs, springs, and groundwater wells) annually (Humphreys & Tiemann, 2021; Tiemann, 2014). Interestingly, the SDWA does not regulate wastewater discharges into source waters (Humphreys & Tieman, 2021). The Clean Water Act (CWA) sets regulatory standards for pollutants that firms may discharge into navigable waters (i.e., surface water) (Walsh & Ward, 2022). The US federal government adopted the CWA to protect navigable waters, while the SDWA was adopted to protect drinking water. CWA regulated entities are permitted to discharge wastewater through the National Pollutant Discharge Elimination System (NPDES) (Earnhart & Friesen, 2021). The CWA generated this permitting system to regulate firms and maintain safe surface waters. Incidentally, the CWA regulates and protects most lakes, rivers, and other surface waters from which CWSs source to implement the SDWA; however, this informal arrangement is not legally codified. Figure 1 provides a visual depiction of the CWA-SDWA link. CWA regulated firms discharge into surface waters that CWSs utilize to implement the SDWA.

Figure 1: Visual depiction of the interrelatedness of CWA and SDWA regulated firms



A potential institutional dilemma exists between the CWA and the SDWA in that federal changes to the CWA do not require formal consideration of the SDWA (Allaire et al., 2018). Given that these two policies are inherently interrelated but institutionally separate, scholars have recently suggested that the linkage between CWA implementation and SDWA compliance should be explored as "vulnerable communities may face the additional challenge of rising [SDWA] compliance cost that is driven by source water impairment" (Allaire et al., 2018, p. 2083). Strictly enforcing the CWA should theoretically reduce compliance costs for CWSs sourcing from surface waters (Teodoro et al., 2018). Thus, decreased CWA implementation could result in increased point source discharges and increased compliance costs for CWSs sourcing from surface waters. Increased contaminants in source water supplies could lead CWSs with limited drinking water treatment technology and infrastructure to experience SDWA health violations by not correctly removing contaminants from source water before distributing it to the community for consumption (Michielssen et al., 2020; Pennino et al., 2020). Even though implementation of the CWA has significantly improved water quality since the 1970s, the question of how CWA enforcement links with SDWA compliance has become increasingly prevalent as political polarization over the federal government's role in environmental policy implementation has increased (Fiorino & Weted, 2020; Rabe, 2022).

1.2. Intergovernmental Contestation in the Drinking Water Sector

US environmental policy implementation relies on a shared multilevel governance structure, where the costs of implementing federal environmental policy are distributed across federal, state, and local governments (Farmer, 2022a; Farmer & Lombeida, 2021; Fiorino & Weted, 2020; Karch, 2021). Beginning in the 1980s, the Reagan administration began pushing (i.e., devolving) a higher share of environmental policy implementation responsibility to state governments (Gerlak, 2006; Glendening, 2018). The administration's primary goal was to downsize the federal government's share in environmental policy implementation (Gerlak, 2006). The administration suggested that state governments could effectively manage environmental policy implementation with minimal federal interference. Since then, the republican party has predominantly remained committed to downsizing federal authority over environmental policy (Rabe, 2022). In contrast to republican views, democratic policymakers assert that states can effectively implement environmental policies with federal guidance and financial support (Glaser et al., 2023; Goelzhauser & Konisky, 2021).

This party-line debate, paired with increased political polarization since the 2000s, has resulted in federal Congressional gridlock and inaction on environmental policy (Rabe, 2022). Gridlock has forced state and local governments to take on additional environmental policy implementation responsibilities in response to changing climatic conditions, aging infrastructure, and other stressors (Earnhart & Friesen, 2021, 2022; Karch, 2021; Krane et al., 2004; Woods, 2021a). Currently, state governments "operate more than 90 percent of all federal environmental programs that can be delegated to them[,]" and delegate much of the compliance costs to the local level (i.e., local governments, regulated entities) to implement environmental policy (Rabe, 2022; p.37). Local and state governments have increasingly had to fill the void left by the federal government (Karch, 2021). Environmental federalism literature suggests "state and local government[s] are adjusting to this new era of federalism, where they are essentially required to fend for themselves fiscally, while being subject to federal mandates" (Gamkhar & Pickerill, 2012, p. 361). Rabe (2011) conceptualizes this current competitive and misaligned US multilevel governance system as "Contested Federalism."

Due to Congressional stagnation, presidential administrations have increasingly attempted to use executive actions to enhance or roll back federal environmental legislation to meet political party goals (Fiorino & Weted, 2020; Rabe, 2022). The Clinton and Bush administrations used executive actions to make federal environmental policy changes, but such presidential actions became particularly politicized and contested during the Obama administration (Fisher, 2013; Rabe, 2022). In an unprecedented move, the Obama administration redefined surface waters regulated by the CWA to include small, adjacent, and ephemeral streams (Rabe, 2022). This executive action, the Clean Water Rule, would have substantially increased the federal government's CWA oversight authority. This Obama-era policy went into effect for less than a month before it was stayed in federal court by republican state attorney generals who sued the EPA arguing the rule was a federal overreach (Konisky & Nolette, 2021; Konisky & Woods, 2016, 2018). The move to significantly increase federal CWA oversight by the Obama administration pushed the CWA and other environmental policies onto the republican political agenda to roll back (Rabe, 2022). The Trump administration rolled back or stayed nearly every Obama-era environmental policy rule, including the Clean Water Rule, and took numerous executive actions to reduce the federal government's role in environmental policy implementation (Vig, 2022).

2. Research Questions

This dissertation explores the potential institutional conflict between the CWA and SDWA within the context of a recent Trump-era rollback of the CWA. This study will also explore if CWSs operating in state or local institutional arrangements that support local government SDWA implementation safeguarded local governments from the negative externalities brought on by the federal rollback. The primary research questions to be explored in this dissertation include: (1) Do federal CWA compliance enforcement rollbacks lead to increased SDWA non-compliance by local government owned CWSs sourcing from surface waters? (2) Do state and local institutional governance arrangements buffer against the potential adverse effects of federal CWA rollbacks on surface water quality? These questions are addressed by drawing upon the theoretical lens of transaction cost federalism to explain how a competitive federal mandate, such as the temporary EPA policy, could increase SDWA compliance costs and lead to poor drinking water outcomes at the local level.

3. Background and Policy Issue

This dissertation emphasizes a recent Trump-era rollback that went into effect, albeit temporarily, nationally during the COVID-19 pandemic. The CWA and other environmental policies became highly politicized in response to an Obama-era executive action to increase federal CWA requirements (Rabe, 2022). This politicization led the Trump administration to take sweeping actions to roll back, stall, or weaken the CWA. The temporary EPA policy was one Trump-era CWA rollback that was not immediately stayed in federal court and went into effect from March 26th to August 31st, 2020.

The temporary EPA policy was one of the most contested Trump-era environmental policy actions (Esworthy & Bearden, 2020). In response to the COVID-19 epidemic, the EPA issued a temporary compliance enforcement mandate easing penalties against regulated entities violating monitoring and reporting requirements over environmental pollution discharges to the air, land, and water (Bodine, 2020). The temporary policy memorandum justified the EPA's decision by stating that "consequences of the pandemic may constrain the ability of regulated entities to perform routine compliance monitoring, integrity testing, sampling, laboratory analysis, training, reporting or certification" due to worker shortages or other related issues (Bodine, 2020). The EPA memorandum furthered that the EPA "d[id] not expect to seek penalties for violations of routine compliance monitoring . . . where the EPA agrees that COVID-19 was the cause of the noncompliance" (Bodine, 2020). However, even though the EPA argued that the pandemic might make it challenging for firms to comply with environmental pollutant discharge requirements, the EPA expected CWSs to "continue normal operations and maintenance as well as required sampling to ensure the safety of our drinking water supplies" (Bodine, 2020). The policy eased enforcement requirements for waste dischargers, including wastewater discharge to surface waters, but required CWSs to maintain normal operations.

Opponents of this temporary rollback suggested it endangered public water consumers being served by CWSs sourcing from surface waters.

This policy also rolled back the Clean Air Act compliance requirements. As a result of this policy, Persico and Johnson (2021) found that air quality decreased significantly in several counties across the US between March 26th and June 3rd, 2020. Moreover, they found that counties with decreased air quality also had more COVID-19 deaths due to poor respiratory conditions. They provide the first empirical evidence that the temporary rollback negatively affected local environmental policy outcomes (e.g., air quality). How the temporary policy has affected the water sector still needs to be determined. A recent study suggests, without evidence, this temporary policy likely negatively impacted surface water quality across the country and led vulnerable CWSs to distribute contaminated drinking water to their communities (Esworthy & Bearden, 2020). However, no study to date has tested this hypothesis. Considering Persico and Johnson (2021) found a positive correlation between temporary policy adoption and increased air pollution, it is likely that the temporary policy also led to increased surface water pollution.

3.1. State and Local Responses to the Temporary EPA Rollback

Institutional factors at the state and local levels may buffer against the potential adverse effects of a federal CWA rollback. States can acquire enforcement primacy over the CWA and SDWA from the EPA through an application process. In order to fill voids in federal enforcement, states have taken over these policies to enforce them in a manner that suits their needs, especially regarding the CWA (Grigg, 2023; Switzer, 2019; Woods, 2021a, 2021b). In 2020, forty-six states had CWA enforcement primacy over managing and distributing wastewater discharge permits (NPDES permits). Forty-nine states also had enforcement primacy of the

SDWA (i.e., monitoring CWS compliance). As a result of the federal rollback, states that had enhanced CWA compliance requirements prior to 2020 were possibly more successful at maintaining CWA compliance than states without stringent primacy.

Furthermore, at the local level, local governments own and manage 24,000 CWSs nationwide (serving 87 percent of tap water users) and receive minimal state funding to maintain compliance with the SDWA (Allaire et al., 2018; Dobbin & Fencl, 2021; Fu et al., 2020; Humphreys & Tiemann, 2021). In order to safeguard against potential declines in the quantity and quality of source water, many local governments (e.g., cities, counties) have taken precautionary measures (e.g., join regional collaborative arrangements focused on watershed protection) (Homsy, 2020; Homsy & Warner, 2020). Therefore, even if a state government could or would not maintain strict CWA compliance in response to the temporary CWA rollback, local governments with precautionary measures already in place (e.g., advanced treatment technology, alternative water sources) to contend with declines in source water quality may have been able to maintain compliance while the temporary CWA rollback was in effect. Overall, it is expected that state and local institutional arrangements may function as a buffer against the potential negative effects of a federal CWA rollback on local drinking water administration.

4. The Purpose of this Study

The purpose of this dissertation is to provide both a practical and a theoretical understanding of this multilevel governance issue. From a practical perspective, this study identifies that the temporary policy led to an increase in SDWA health violations, indicating the CWA-SDWA institutional dilemma is a problem area that needs further analysis. This study also identifies key institutional factors that likely buffered local government SDWA compliance from the federal CWA rollback. Additionally, it identifies several institutional factors that likely made local governments more vulnerable to experiencing a health violation after the CWA rollback. Likewise, this study gives the first empirical example of how a federal CWA rollback impacts local SDWA compliance, which can help inform future CWA-SDWA policy decisions.

From a theoretical perspective, this study finds key implications for the environmental federalism literature. First, this dissertation provides evidence that contested federalism in the multilevel governance system likely led to poor policy implementation outcomes at the local level. Second, this study shows that federal delegation of environmental policy enforcement to state governments likely led to poor environmental policy implementation outcomes. These findings bring insight into the degree to which policy responsibility should remain federally centralized rather than devolving responsibilities down to the local levels. Overall, these contributions require further validation in future studies, but the implications from this study's contribution pave the way for future US contested federalism, environmental policy, and governance research.

5. Dissertation Overview

The premise behind this study is that the transaction costs of multilevel institutional governance can impact how local-level authorities implement the SDWA. Therefore, this study proposes that local governments operating in vertical institutional arrangements with increased compliance costs would be negatively impacted more by the temporary policy relative to local governments operating in institutional arrangements that mitigate SDWA implementation compliance costs. This dissertation proceeds in examining this premise as follows. Chapter Two provides an in-depth literature review of the transaction costs federalism theory, the CWA and the SDWA, the EPA's temporary COVID-19 policy, and this study's hypotheses. Chapter Three reviews the data used to operationalize this study's variables and the empirical DID design used to test the hypotheses. Chapter Four provides this study's results. Chapter Five discusses the results and their practical and theoretical implications. Finally, Chapter 6 highlights the conclusion, which outlines the limitations of this study that provide avenues for further scholarly exploration.

Chapter 2: Literature Review

1. Transaction Costs Federalism Theory Development

Feiock (2008) conceptually developed the general transaction costs theory of federalism. The basic structural premise behind his theoretical approach is that the intergovernmental relations between federal, state, and local governments operate in a hierarchical authority structure, where the federal government has the discretion to delegate policy implementation authority to states, and state governments have the discretion to delegate authority to local governments. In this intergovernmental arrangement, state governmental rules operate conceptually as contracts between either the federal government and state governments or state governments and local governments. In this framework, the federal government functions as the principal over agent states, and states operate as principals over their local governments (Youm & Feiock, 2019a). This principal-agent contract between the principal government(s) and the agent governments in this system creates transaction costs, and principals use various mechanisms to ensure actors do not renege on the contract by shirking the transaction costs inherent in the contract(s) (Feiock, 2008). How much discretion principal governments choose to delegate to actor governments and how principal governments choose to ensure actor compliance can ultimately generate increased transaction costs for local governments.

The two key overarching problems that emerge from a principal government delegating authority to agent governments include adverse selection and moral hazard (Feiock, 2008; Moe, 1984). Adverse selection occurs because principals (e.g., federal government) rely on agents (e.g., state governments) to provide information about a policy area, and only the agents have full knowledge of the reported situation. This information asymmetry can be used to the advantage of agent governments, necessitating principals to monitor and regulate the activities of agent governments. As the number of agent governments increases in number and diversity, monitoring and regulation costs increase for principal governments. Principals rely more on agent information disclosure as complexity increases across agent governments. Agents that capitalize on the information asymmetry in a way that does not align with principal government goals can generate moral hazard costs (Feiock, 2008). The concept of moral hazard is when opportunistic agent governments technically abide by the principal's laws but use information asymmetry to circumvent the rules in the legal contract (Feiock, 2008).

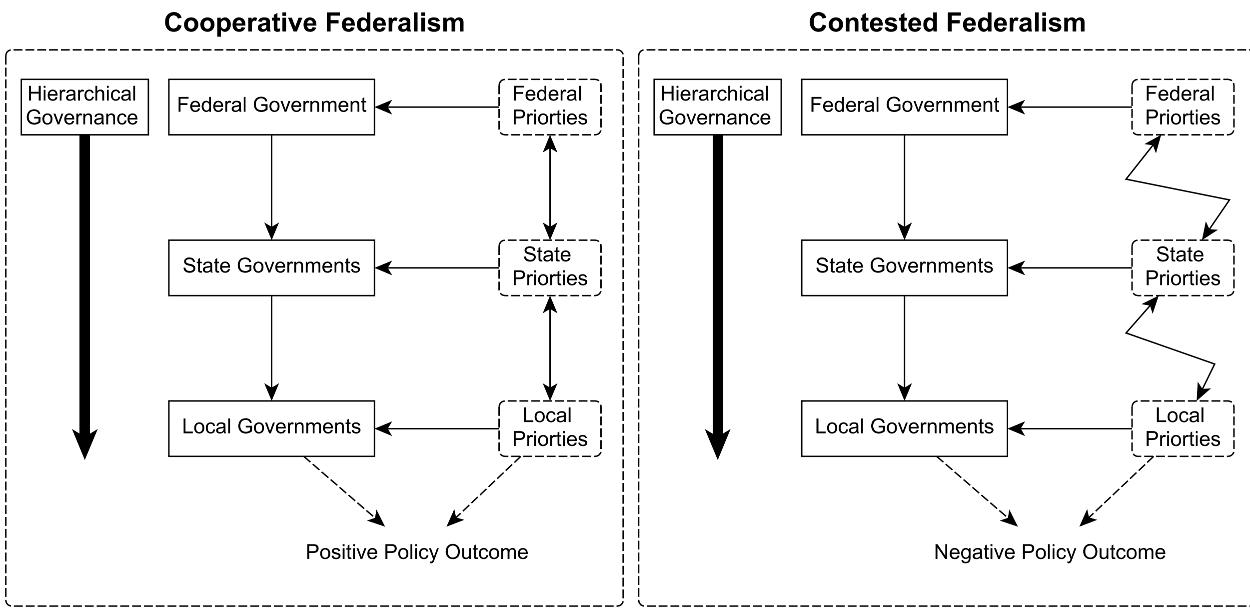
Transaction costs theory stems from rational choice and institutional scholarship. Rational choice scholarship assumes that individual actors make rationally bounded decisions to limit the costs of exchange, an economical approach to understanding decision-making (Williamson, 1981, 2010). The prevailing assumption behind the bounded rational choice theoretical approach is that actors or individuals make self-interested decisions to maximize benefits and reduce costs based on their understanding of a situation (Feiock, 2008; Neiman & Stambough, 1998; Ostrom, 1998). Elinor Ostrom and others argue the rational choice theory requires institutional context to help deduce the institutions mediating actor choices, particularly in governance systems (Ostrom, 1998). Douglass North defines institutions as "the humanly devised constraints that structure political, economic and social interaction" (North, 1990, p. 97). These social constructs or rules can include formal constructs (e.g., constitutions, laws) or informal constructs (e.g., traditions, customs) (North, 1990; Ostrom, 1998). The lack of institutional context in rational choice theory generated concern about the applicability of this theory beyond micro-market-focused inquiry (Neiman & Stambough, 1998). These competing areas of scholarship laid the foundation for transaction costs theory to emerge and proliferate because it combines rational choice theory with institutional theory to deduce transaction costs driving actor decisions in intergovernmental relations (Carr et al., 2008; Hindmoor, 1998).

2. Contested Federalism

Rabe (2011) conceptualizes the competitive interdependent relations between principal and agent governments as "Contested Federalism." From the perspective of contested federalism, all levels of government are highly involved and take actions to actualize their individual policy goals (e.g., executive rollback in environmental policy). Intergovernmental vertical dilemmas can emerge when principal governments have policy misalignments with their agent governments (Farmer, 2022a, 2022b; Farmer & Lombeida, 2021). Vertical dilemmas generate transaction costs that can negatively impact the implementation of federal policy at the local level (Youm & Feiock, 2019). Environmental policy implementation is a function of multilevel efforts. Since 2015 all tiers of government have become highly involved in managing environmental protection, but the tiers of government do not have the same implementation priorities (Karch, 2021; Rabe, 2011; Rabe, 2002). Contestation between tiers of government decreases mutually beneficial intergovernmental relations and thus can lead to inefficient policy outcomes at the local level (Farmer & Lombeida, 2021).

Figure 2 provides a visual depiction of the cooperative versus contested federalism concepts. The primary tenets of this framework suggest that principal rules that confer or restrict authority to agent governments shape policy implementation effectiveness, efficiency, and equity at the agent levels (Feiock, 2008). In contested federalism, policy misalignments and mandates from the higher levels of government place implementation burdens on state and local governments, leading to increased transaction costs. Misalignments in priorities lead to increased transaction costs across governmental tiers which negatively impacts policy outcomes at the local level. In this body of literature, the transaction costs of contestation between principal and agent governments are conceptualized as commitment, agency, and administrative costs.

Figure 2: Difference between cooperative and contested federalism



3. Transaction Costs of Contested Federalism Theory

Environmental policy implementation is a function of vertical intergovernmental institutional arrangements and efforts (Farmer & Lombeida, 2021; Feiock, 2008; Rabe, 2011). The transaction costs of contested federalism theory characterize the US multilevel governance system as a hierarchical principal-agent-based system (Feiock, 2008). In this system, principals are governments with authority over agent governments (i.e., subordinates). The federal government functions as a principal. States operate in both a principal and agent role. Local governments operate in an agent role. In this governance arrangement, local governments contend with both federal and state level institutions when implementing environmental policy (Homsy, 2020; Homsy et al., 2019; Homsy & Warner, 2014). Principal governments face a tradeoff between the costs of implementing a policy directly (i.e., centralized control) or delegating policy implementation discretion to agent governments (i.e., decentralized authority) (Feiock, 2008). Specific policy implementation transaction costs can emerge in federal systems that devolve federal implementation authority to state and local governments and are in a state of contestation (Farmer, 2022a, 2022b; Farmer & Lombeida, 2021). Transaction costs in a multilevel governance system can be defined as the amount of resources or effort (e.g., funds, workers, infrastructure, etc.) needed to implement a policy (Williamson, 1981). In a state of intergovernmental competition (i.e., contested federalism), these transaction costs can manifest in federal systems as political transaction costs brought on by misaligned principal government actions that increase the amount of effort and resources needed to implement policy effectively at the local level (Farmer & Lombeida, 2021). Given that drinking water service delivery is generally directly implemented by local governments, and local governments operate within both state and federal institutional arrangements, it is expected that hierarchical institutions at the federal, state, and local level generate or mitigate transaction costs for local governments trying to provide safe drinking water to their communities.

Overall, this theory contends that principal governments can effectively maintain agent compliance by reducing transaction costs on agent governments through a "stable structure of exchange," whereby agents are provided (1) clear directives that align with local goals (decreases agency costs on agents), (2) enough autonomy to implement the directives (decreases administrative costs on agents), and (3) resources (e.g., financial, technical) needed to implement the directives (decreases commitment costs on agents) (Feiock, 2008; Homsy & Warner, 2014;

North, 1990). Principal governments that compete with their encompassed agent governments commonly disrupt the stable structure of intergovernmental exchange by adopting mandates that increase the agency, administrative, or commitment costs on agent governments attempting to comply with principal demands (Feiock, 2008).

3.1. Agency Transaction Costs

Agency costs emerge when principal governments adopt policy that misaligns with agent governmental priorities (Farmer & Lombeida, 2021). Misaligned policy mandates can produce goal conflicts between principals and agents (Farmer, 2022a, 2022b). Vertically conflicting goals can lead to an agent government implementing policy in a way that defects from the principal government's intent (Feiock, 2008). Principal governments can decrease agency costs by mandating vertically consistent policies that align with agent goals. Principal governments that adopt a policy or stance that aligns vertically with agent interests are more likely to maintain policy implementation compliance from agent governments (Farmer, 2022a, 2022b; Farmer & Lombeida, 2021; Huang & Berry, 2022). Recent studies have applied the agency costs concept to identify linkages between intergovernmental policy decisions that align vertically with local priorities. Huang and Berry (2022) identify that local governments operating in states with energy efficiency standards adopt more local energy efficiency standards. Farmer (2022a) found similar results and contends that vertically consistent state level energy policies that align with local government priorities decrease agency costs on local governments. The decrease in agency costs leads to local governments adopting policy measures that align with state priorities.

SDWA implementation priorities generally align across federal, state, and local governments because safe drinking water is a concern for all levels of government, and it is not politicized (Switzer, 2019). However, states with primacy over CWA enforcement may not account for the SDWA when implementing relaxed compliance enforcement standards in their state to decrease EPA penalties on industry partners discharging waste to surface waters (Woods, 2021b, 2022). Typically, relaxed compliance entails state CWA administrators under-inspecting NPDES-permitted firms and under-penalizing non-compliant firms (Earnhart & Friesen, 2021, 2022; Grooms, 2015). Lax enforcement of the CWA is commonly associated with republican governed states, while democratically governed states commonly have higher CWA regulation (Konisky et al., 2021). For CWSs sourcing from surface waters, lax state enforcement does not align with local priorities for drinking water provision because increased pollutant discharges from NPDES-permitted firms could lead to contaminated drinking water. In this study, it is expected that states with lax CWA enforcement likely used the federal rollback to relax compliance enforcement further. Whereas it is expected that states with institutional structures already in place to maintain heightened CWA compliance would have been more prepared to maintain compliance within their state after the EPA rollback. Thus, one can expect that local government-owned CWSs sourcing from surface waters and operating under increased agency costs (i.e., operating in states with relaxed CWA enforcement) will experience more SDWA health violations in response to a temporary CWA rollback.

3.2. Administrative Transaction Costs

Administrative costs emerge when agent governments have limited authority or discretion over implementing top-down policy mandates (Farmer & Lombeida, 2021; Feiock, 2008; Lee & Feiock, 2021). Agent governments with increased policy implementation autonomy and discretion are more accountable to the community(ies) they govern because they are (1) closer to the voters they are governing and (2) can adapt to policy issues in more timely and specific ways. Agent governments operating under centralized governance arrangements have less policy implementation autonomy. While agent governments operating under decentralized governance arrangements have increased policy implementation autonomy. Generally, the transaction costs of contested federalism literature contend that agent governments operating under a decentralized governance approach have less administrative costs and are better able to implement policy according to principal expectations (Farmer & Lombeida, 2021).

In state and local government relations, centralized governance often exists within a context based upon the principle of Dillon's Rule (Richardson, 2011). In a Dillon's rule state, local governments are deemed "creatures of the state" where local governments are not afforded the autonomy to make governmental decisions without permission and guidance from the state (Farmer, 2022b; Feiock, 2008). Direct sub government coordination can become too costly for the principal government as the number of individual decisions and actions needed to implement a policy increase across agent governments. Subgovernment coordination in the American federalist system is particularly challenging for state governments because they both enforce policies made at the federal level and their local government affairs (Feiock, 2008). Environmental policy can be particularly challenging to manage in a centralized, hierarchical system because environmental conditions vary substantially across and within states (Fiorino & Weted, 2020).

A decentralized state governance approach between state and local governments is called home rule (Richardson, 2011). Home rule states allow their local governments the discretion and autonomy to make local decisions without permission from the state (Krane et al., 2001). In this system, agent governments are operating in a form of a competitive free market with the discretion to choose their governance structures, investments, and public service offerings (Feiock, 2002). Opponents of home rule suggest that regional issues that stretch across multiple local governments can cause inter-local dilemmas (e.g., depletion of watershed quality) and increased financial costs for individual local governments. However, proponents of home rule suggest that local governments with increased policy implementation discretion can and do join or create collaborative arrangements with neighboring local governments to mitigate regional issues (Youm & Feiock, 2019).

Furthermore, proponents suggest that increased local government autonomy allows local politicians and administrators the flexibility to increase their efficiency and responsiveness (Chen, 2022; Maser, 1985). The local level policy makers and administrators are closer to the community they civically serve, making these officials more knowledgeable and thus theoretically more capable of providing public goods and services than a state or federal politician or administrator (Polski & Ostrom, 1999). The literature generally contends that local government transaction costs decrease in home rule states because local governments do not need to lobby the state legislature for approval of a local government measure (Chen, 2022; Farmer, 2022a, 2022b). Overall, the decision to decentralize policy implementation is generally viewed as a way for principal governments to decrease their direct implementation responsibility and to increase the autonomy and responsibility of agent governments to implement policy in ways that meet the expectations of the principal government and the community served.

The CWA and SDWA are highly decentralized to states, but state governments can limit (i.e., Dillon's rule provisions) or broaden (i.e., home rule provisions) the discretion of local governments in their public service delivery abilities (Farmer, 2018; Richardson, 2011). State level decentralized authority has particular prevalence to the local government implementation of the SDWA. Local governments operating under a centralized governance system (i.e., Dillon's rule) lack the autonomy and discretion to innovate and adapt quickly to policy issues (Chen, 2022; Farmer, 2010a, 2018; Farmer & Lombeida, 2021; Richardson, 2011). Local governments in states with centralized control must seek state legislative approval to take policy actions (Farmer & Lombeida, 2021). Overall, local governments with increased autonomy over policy implementation are considered to have lower administrative costs and are thus expected to have more effective policy outcomes than governments with limited autonomy. Recent findings confirm these administrative cost expectations.

3.3. Commitment Transaction Costs

Prior research has frequently used commitment costs to denote the fiscal and technical costs of policy implementation (Farmer, 2022a, 2022b; Farmer & Lombeida, 2021; Feiock, 2008). Agent governments with limited resource capacities and uncertainty about whether principal government(s) will provide the resources needed to implement a policy effectively make it challenging for agent governments to commit to implementing a principal governmental mandate (Feiock, 2008). Agent governments with resource challenges either rely on principal governments for flows of resources to accomplish implementation goals or can forgo implementing principal policies altogether simply due to a lack of resources to implement the policy (Farmer & Lombeida, 2021; Feiock, 2008). Institutional factors that provide agent governments with increased access to financial and technical resources are expected to decrease policy implementation commitment costs (Youm & Feick, 2019).

Principal governments can reduce policy implementation commitment costs for agent governments by providing a stable flow of financial resources (Farmer, 2022a, 2022b; Farmer & Lombeida, 2021; Youm & Feiock, 2019a). Intergovernmental financial support not only decreases commitment costs on agent governments but can also incentivize agents to implement policy in accordance with principal expectations (Homsy & Warner, 2020b; North, 1990;

Shrestha & Feiock, 2010). Overall, the literature contends that increased commitment costs detrimentally impact intergovernmental policy implementation outcomes. Therefore, it is expected that high resource agent governments or agent governments receiving consistent flows of financial resources have decreased commitment costs and are better able to implement policy according to principal expectations.

4. Federal and State Water Policy Governance Arrangements

Overall, to analyze how transaction costs impact SDWA compliance at the local level, a thorough understanding of the governmental and institutional arrangements driving federal, state, and local SDWA policy implementation must be established. This section overviews the primary federal and state institutional governance factors controlling SDWA implementation.

US federal government-based attempts at standardizing environmental water quality controls began in the 1940s (Keiser & Shapiro, 2019). The passage of the 1948 Federal Water Pollution Control Act (FWPCA) was the first federal law to address water pollution and public health (Walsh & Ward, 2022). Environmental disasters and increased research on the impact of anthropogenic pollutants on the environment led the public to demand further federal environmental protection-based legislative action (Walsh & Ward, 2022). By 1970 the Nixon presidential administration ushered in a national administrative body to oversee environmental protection, the Environmental Protection Agency (EPA). The EPA administrative body was formed to consolidate federal environmental responsibilities into one agency and oversee state-level development of environmental pollution control initiatives. In 1972 the FWPCA was overhauled through a series of amendments transitioning the FWPCA to the CWA.

4.1. Clean Water Act

The CWA overhauled how the federal government protects surface waters in the US (Keiser & Shapiro, 2019). The CWA defined the waters the federal government regulates as navigable surface waters, commonly referred to as Waters of the United States (WOTUS) (Driggs et al., 2020; Walsh & Ward, 2022). The exact definition of WOTUS has garnered impassioned debate since the 1970s, but overall, this policy set maximum contaminant requirements on point source organizations (e.g., factories, farms, refineries) discharging pollutants into navigable waters (Jerch, 2019).

The CWA created the National Pollutant Elimination Discharge System (NPDES) permit program (Earnhart & Friesen, 2021, 2022). NPDES permits are required by all organizations that discharge wastewater to CWA-regulated surface waters. The EPA uses NPDES permits to set the maximum amount of pollutant a regulated entity can discharge into its watershed (Earnhart & Friesen, 2022). Permit levels are determined in conjunction with other local wastewater dischargers to ensure surface waters are not overly polluted to the point that environmental or public health issues emerge. The EPA administers the NPDES permitting program to manage water quality testing requirements and other compliance measures to control pollutant discharge into watersheds (Konisky & Teodoro, 2016; Teodoro et al., 2018). Failure to adhere to the criteria set in NPDES permits can result in federal penalties (e.g., fines) (Teodoro et al., 2018). Overall, the CWA set the foundation for the federal government to manage point-source pollutant discharges into surface water supplies, but much of the implementation authority and responsibility has devolved to state governments (Fowler & Birdsall, 2021b; Woods, 2021, 2022). The CWA stipulates that states can receive implementation authority over NPDES permitting upon approval from the EPA (Cherney & Wardzinski, 1985; Woods, 2021c). To receive implementation approval, states must provide evidence that they will enforce regulations that are at least as stringent as federal CWA requirements. The federal government delegates this authority to states to cut down on coordination and financial costs (Feiock, 2008). States assume environmental regulatory responsibility and thus assume increased economic and agency transaction costs associated with CWA responsibility (Woods, 2021; Woods, 2022a, 2022b).

A few recent studies analyzed why states would choose to assume the transaction costs associated with CWA primacy and found evidence that states assume primacy costs to either relax or enhance NPDES permit compliance requirements (Woods, 2021; Woods, 2022a, 2022b). This finding ties in with Fowler & Birdsall (2021), who found that transferring CWA primacy to states improved program outcomes in some states and not others. These studies suggest the perceived or realized benefits of states assuming CWA primacy have outweighed the economic and coordination costs of administering the CWA. The EPA issues and manages NPDES permits directly in four states (Idaho, Massachusetts, New Hampshire, and New Mexico). Otherwise, all other states have primacy over NPDES permitting (Fowler & Birdsall, 2021). The EPA tracks state NPDES compliance by focusing on the following State Review Framework criteria: data, enforcement, inspection, penalties, and violations (Fowler, 2020; GAO, 2021). However, it is key to note that state applications for primacy are rarely denied or revoked after approval (Chang et al., 2014; Woods, 2022). Therefore, it is unclear if the federal government would reassume control of a perpetually underperforming state government. Thus, it is unclear how accountable state governments are to the federal government over CWA enforcement.

4.2. Safe Drinking Water Act

In addition to CWA primacy, states can apply for and acquire primacy over SDWA authority (Ding et al., 2022). All US states but Wyoming have primacy over SDWA regulations.

To receive primacy approval from the EPA, states must have as stringent regulatory requirements as those outlined by the SDWA (Ding et al., 2022). Upon approval, states are empowered to track local CWS compliance of the SDWA. Unlike the CWA, local governments predominantly implement the SDWA directly through the management of CWSs. State governments directly implement CWA compliance because NPDES permits extend beyond local jurisdictional lines (Morris, 1999). Studies contend that the authority states have over CWA implementation may lead to increased moral hazard and thus underreporting (Switzer, 2019). Studies further contend that SDWA non-compliance is generally procedural and thus the chance of strategic CWS or state underreporting is unlikely (Konisky & Reenock, 2013). A 2011 GAO report found that SDWA violation misreporting was not due to nefarious underreporting or systematic biases (Switzer, 2019). The database housing SDWA compliance is the SDWIS database, as mentioned previously.

4.3. Funding for the CWA and SDWA

In the 1980s, there was a concerted effort at the federal level to delegate (i.e., devolve) policy responsibility and costs to state governments (Gerlak, 2006; Glendening, 2018). Reagan's administration pushed for new federalism, where federal regulations were downsized, and cost-sharing between government tiers increased (Gerlak, 2006). This push to devolve water policy implementation responsibility to states accelerated during the Reagan presidential administration, and this trend has persisted in the U.S., particularly for environmental and natural resource governance, ever since (Gerlak, 2006; Woods, 2021).

During the 1960s and 1970s, the federal government allocated approximately $1.9 trillion to fund state and local infrastructural and technological updates to drinking water treatment plants and sewage treatment plants across the country (Keiser et al., 2019; Keiser & Shapiro, 2019). EPA oversight, the passage of the CWA and SDWA, and the infrastructural overhaul in the mid-1970s significantly improved the quality of source waters across the country; however, surface water quality and quantity and federal grant funding for water infrastructure have steadily declined since the 1980s (Allaire et al., 2018, 2019; Keiser & Shapiro, 2019). Decreased funding and declining water resources, have placed locally owned CWSs in a position where the hierarchical authority over drinking water from federal and state governments persists, but the burden of cost to manage and maintain drinking water infrastructure predominantly falls on local governments and their community members (Knopman et al., 2017). Overall, devolution gives lower level governments more discretion to implement innovative policy decisions that meet the specific needs of the state or local government. Still, resource and information constraints make devolved policy implementation complex for state and local governments (Daley et al., 2014).

Greer (2020) provides the most recent review on public water infrastructure financing in the US, and notes that the financial burden of cost as of 2020 falls on state and local governments. In 1995 the EPA conducted the first 20-year economic infrastructure needs assessment for US water resources management. This initial evaluation indicated that water infrastructure maintenance costs in the US would amount to $256 billion by 2014 (2015 calculated inflation amount) (Greer, 2020). The second 20-year financial water infrastructure needs assessment conducted in 2015 indicated that water infrastructure financial needs would amount to $472.6 billion by 2034 (Greer, 2020). The federal government phased out direct grants in 1987 and replaced this system with state-managed revolving funds to finance CWA infrastructure upgrades within states. The 1996 amendments to the SDWA generated a similar state revolving fund to help states fund the development and maintenance of drinking water infrastructure (Greer, 2020). State revolving funds offer a perpetual loan-based funding approach. The federal legislature allocates a portion of funds to states and states loan portions of these funds to local governments that pay back the loans with interest. This economic model type aims to generate a perpetual funding system that grows as local governments pay back the interest and keeps funding responsibility off of the federal budget (Jerch, 2019; Mullin & Daley, 2018).

Overall, public CWS access to financial resources is limited, and the CWS compliance literature suggests resource capacity is the most significant deterrent to CWS compliance. Multiple studies find that smaller systems (i.e., CWSs serving small populations that are less than or equal to 10,000 people) experience SDWA violations more frequently than larger systems (Allaire et al., 2018; Fu et al., 2020; Marcillo & Krometis, 2019). Overall, the primary concern regarding smaller local government owned CWSs is that they cannot apply for state revolving funds and lack a large enough consumer base to cover aging infrastructure costs and declining water supplies (Allaire & Acquah, 2022; GAO, 2021). A recent Government Accountability Office (GAO) report published in 2021 reaffirms the size to compliance issue, and states that financial resource access is the primary issue for small systems:

> [S]mall systems are estimated to need $74.4 billion over the next 20 years—which is 16.5 percent of the total needs across all systems, although they serve about 8 percent of customers. Furthermore, small water utilities can face unique financial and operational challenges to consistently provide drinking water that meets EPA standards and requirements. According to a 2017 report, small water utilities have a small rate base and struggle to pay the cost of infrastructure projects, either to repair or replace aging infrastructure or to add treatments for new contaminants. (GAO, 2021, p. 9)

Overall, small local government owned systems are struggling to provide safe drinking water because they require financial resources to upgrade critical infrastructure, and they lack access to state and federal funding.

5. Temporary EPA COVID-19 Policy in the Context of Contested Federalism

Twelve days after President Donald Trump declared a national emergency in response to the COVID-19 pandemic, the EPA instituted the Temporary COVID-19 Enforcement Discretion Policy. The temporary policy was adopted on March 26, 2020 and ended on August 31, 2020. The EPA indicates it adopted this temporary policy in response to "consequences of the pandemic [that] may constrain the ability of regulated entities to perform routine compliance monitoring, integrity testing, sampling, laboratory analysis, training, reporting or certification" due to worker shortages or other related issues (Bodine, 2020). The memorandum furthers that while regulated entities may not have had the ability to meet compliance obligations, CWSs must maintain clean drinking water throughout the pandemic despite the temporary easing of CWA compliance requirements:

> water systems have a heightened responsibility to protect public health because unsafe drinking water can lead to serious illnesses and access to clean water for drinking and handwashing is critical during the COVID-19 pandemic. Accordingly, the EPA has heightened expectations for public water systems. The EPA expects operators of such systems to continue normal operations and maintenance as well as required sampling to ensure the safety of our drinking water supplies (Bodin 2020, p. 6).

In the context of wastewater discharges, this temporary policy directly impacts the CWA regulation on surface water supplies. The EPA maintains CWA compliance through NPDES permits and requires states with primacy over the CWA to enforce the minimum compliance stringency set at the federal level. The temporary policy temporarily lowered federal CWA compliance requirements, leaving it to the states to either maintain pre-March 26, 2020 NPDES compliance or temporarily ease compliance requirements.

Persico & Johnson (2021) suggest that regulated firms, including NPDES regulated firms, may have been incentivized to pollute more if the fines for surpassing standards were eliminated. The costs to firms to ensure they maintain compliance with their NPDES permits include paying staff and running the technology or equipment needed to maintain compliance. Essentially, firms take on this cost to eliminate the potential costs of government penalties, and this penalty system significantly helps maintain firm compliance with NPDES permits (Gray & Shimshack, 2020). A recent study shows state fines are more effective than federal fines at maintaining CWA compliance (Earnhart & Friesen, 2021). However, when penalty certainty and severity for NPDES compliance decreases, firms are opportunistic and cost-conscious and change their CWA compliance in response to changing regulatory compliance costs (Earnhart & Friesen, 2021, 2022). Furthermore, Persico and Johnson (2021) found that in response to the temporary COVID-19 policy, Clean Air Act regulated entities increased pollutant discharges into the atmosphere, and this led to increased respiratory deaths (i.e., COVID-19 deaths). Therefore, it is likely that CWA regulated entities, many of which are also regulated by the Clean Air Act, also increased pollutant discharges to surface waters as well.

Within the context of the transaction costs federalism theory, the temporary delegation of compliance authority to state governments represents a principal (federal government) choosing to delegate compliance costs to agent governments (i.e., states) with the expectation that state and local governments could continue to serve safe drinking water to the public with unclear federal guidance on CWA compliance. The temporary policy stated it would provide resources to help alleviate acute situations where safe drinking water quality could not be maintained, but otherwise, the financial responsibility to maintain safe drinking water was delegated to state and subsequently local governments.

Regarding the question of contested federalism, this policy is arguably misaligned with local government priorities. Many politicians and advocacy groups petitioned against the adoption of the temporary policy. Nine state attorney generals filed a lawsuit against the EPA in a New York District Court for adopting the temporary enforcement policy (Persico & Johnson, 2021; Rushton & Kirkland, 2020). Among multiple environmental concerns, the lawsuit alleged that the temporary deregulation of compliance and monitoring allowed regulated entities to discharge pollutants into the environment without reporting it to the local EPA authorities (Rushton & Kirkland, 2020). These nine states suggested that the EPA abdicated their responsibility to manage waste discharge into their environment, which endangers citizens, and transfers the burden of regulatory cost on states already exacerbated by the COVID-19 pandemic (Denton, n.d.). Overall, this policy was misaligned with state interests and was contested by many federal legislatures, state politicians, and advocacy coalitions (Feiock, 2008; Rabe, 2011).

6. Hypotheses

This dissertation uses the theoretical assumptions of transaction cost federalism to develop several testable hypotheses. The fundamental assumption and concern underlying this temporary policy is that it misaligns with local government SDWA implementation goals because it likely allowed NPDES permitted firms to discharge excess pollutants, leading to a temporary increase in surface water pollutant composition (Grooms, 2015). This study tests if this federal policy shift impacted CWSs sourcing from surface waters. Therefore, the first and primary hypothesis that was tested is as follows:

> Hypothesis 1 (H1): Local government owned CWSs sourcing from surface water experience more SDWA health violations after a federal CWA enforcement rollback.

6.1. Agency Cost Hypotheses

Agency costs emerge when state governments adopt a policy that misaligns with their encompassed local governments' priorities (Farmer, 2022a, 2022b; Farmer & Lombeida, 2021;

Youm & Feiock, 2019). Misaligned policy mandates can produce goal conflicts between states and their local governments (Farmer, 2022a, 2022b). Vertically conflicting goals can lead local governments to implement policy in a manner that defers from the state government's intent. States can decrease agency costs by adopting vertically consistent policies that align with local government goals. Vertically consistent policy measures that align with citizen priorities at the local level help ensure policy actions are consistent across governmental tiers (i.e., no policy uncertainty) (Farmer, 2022a, 2022b; Farmer & Lombeida, 2021; Feiock & Stream, 2001).

Recent studies have applied the agency costs concept to identify linkages between intergovernmental policy decisions that align vertically with local priorities. Huang and Berry (2022) identify that local governments operating in states with energy efficiency standards adopt more local energy efficiency standards. Farmer (2022a) found similar results and contends that vertically consistent state-level energy policies that align with local government priorities decrease agency costs on local governments. The decrease in agency costs leads to local governments adopting policy measures that align with state priorities.

In the context of CWA compliance, multiple studies indicate that state governments assume CWA primacy to either enforce more stringent standards or relax standards to suit industry interests, relaxing standards is commonly referred to as a "race to the bottom" (Elbakidze & Beeson, 2020, 2021; Konisky et al., 2021). Multiple studies find that states with increased interstate competition over the pollutant discharging industry seek primacy over the CWA and take policy actions to restrict and relax NPDES regulatory costs on industry firms in the state (Woods, 2021a, 2021b, 2022). Grooms (2015) finds that after states with a history of increased corruption (i.e., policy actions that favor industry firms) assume CWA primacy, NPDES violations decrease. Her study results suggest that firms underreport violations because they know their state regulators are lenient. This suggests that NPDES violation data may be systematically lower in states that are likely to have the highest rates of pollutant discharges to surface waters.

In the context of agency costs, the following institutional arrangements are expected to increase agency costs on local government CWSs. As discussed above, states acquire CWA primacy to enhance or decrease NPDES regulatory expectations. States with heightened CWA compliance expectations are implementing a vertically consistent policy that aligns with local drinking water interests. In contrast, states that have acquired CWA primacy and have relaxed CWA compliance enforcement standards are implementing vertically inconsistent policies relative to local SDWA implementation priorities. Overall, it is expected that an increase in surface water pollutants brought on by the temporary policy would exacerbate CWSs already burdened with increased agency costs from their state's misaligned CWA enforcement standards (Allaire et al., 2018). Given that CWA compliance and surface water quality are inextricably linked, it is expected that CWSs in states that enhance CWA compliance are better prepared to maintain compliance from NPDES regulated entities if a federal rollback like the temporary policy were to occur. Two measures are used to test the agency cost hypothesis, including a state's EPA CWA enforcement records and the political affiliation of each state's governor. The following agency cost moderator hypotheses are tested:

> Hypothesis 2a (H2a): Local government owned CWSs sourcing from surface water and operating in a state with a record of lowered administrative CWA enforcement experience more SDWA health violations after a federal CWA enforcement rollback.
>
> Hypothesis 2b (H2b): Local government owned CWSs sourcing from surface water and operating in a state with a republican governor experience more SDWA health violations after a federal CWA enforcement rollback.

6.2. Administrative Costs Hypotheses

Administrative costs refer to the costs of centralized governance structures on agent governments (Feiock, 2008; Farmer & Lombeida, 2021). Agent governments operating under a centralized governance system lack the autonomy and discretion to adapt quickly and innovatively to policy issues mandated by principal governments (Farmer, 2022; Farmer & Lombeida, 2021; Feiock, 2008). Between state and local governments, the primary state-to-local governmental institution driving SDWA compliance revolves around the level of authority and discretion state governments afford to their local governments (i.e., Home Rule or Dillon's Rule). Transaction costs federalism theory suggests that the level of autonomy delegated from principal to agent governments affects local level policy implementation outcomes (Feiock, 2008).

Recent findings corroborate the administrative cost expectations. Farmer (2022a) found that local governments operating in a state with functional decentralization of authority (i.e., home rule) were significantly more likely to enter interlocal collaborative arrangements on environmental sustainability. This finding suggests that local governments will take proactive measures to implement environmental policy when state governments grant a broad home authority structure to local governments. To date, there is a lack of research that empirically analyzes local government SDWA implementation compliance within the context of state functional decentralization (i.e., home rule). However, based on previous studies, it is expected local government owned CWSs operating in states with broad home rule would have increased flexibility and responsiveness to potential drinking water issues, such as increased pollutant loads in surface waters (Farmer, 2022a). Therefore, local government CWSs in states that provide less implementation autonomy to local governments would be expected to have increased agency costs for local public service delivery, including the provision of drinking water. Thus, it is expected that CWSs in states providing less discretion and authority would have less flexibility to respond to surface water contamination issues from point-source discharges. Therefore, the following hypothesis is tested:

> Hypothesis 3 (H3): As a state government's home rule provisions increase, the effect of a federal CWA enforcement rollback on the number of SDWA health violations experienced by local government CWSs sourcing from surface water decreases.

6.3. Commitment Cost Hypotheses

Commitment costs emerge when local governments are uncertain if they will have or receive the necessary resources (e.g., funds, technology, expertise, workforce) needed to implement a policy. Local governments that cannot commit to a policy, will in turn implement the policy in a way that deviates from state expectations. As a result, commitment costs is lower in communities that are better financially and technically equipped to implement a policy (Farmer, 2010b; Homsy & Warner, 2014). State governments often fail to provide the technical expertise and funds necessary to implement a policy in a contested federal system (Feiock, 2008). Commitment costs can lead to poor policy outcomes when local government resources are so limited that they cannot meet state policy implementation expectations (Farmer, 2022a, 2022b; Farmer & Lombeida, 2021).

Recent studies have applied the commitment costs concept to identify linkages between intergovernmental resource exchanges between local policy outcomes. Multiple studies identify a positive link between state fiscal support for environmental sustainability and local government sustainability actions (Farmer, 2022a, 2022b; Farmer & Lombeida, 2021; Youm & Feiock, 2021). Using data collected by the International City/County Management Association (ICMA) 2015 survey on *Local Government Sustainability Practices*, Farmer identified that municipalities that operate within states that commit more fiscal resources to environmental sustainability are more likely to take local environmental policy actions focused on sustainability (Farmer, 2022

Three). Similarly, using ICMA data, multiple studies find that state fiscal support for energy funding is positively associated with increased municipal commitments to energy efficiency incentive programs (Farmer 2022 energy; Huang & Berry, 2022). Farmer & Lombeida (2021) also identified a positive link between city commitments to internal energy efficiency-based operations and state energy program budgets. Additionally, Youm & Feiock (2019) found that local governments implement greater local climate and renewable energy-based sustainability initiatives (e.g., tax incentives for reductions in energy consumption) in states that provide increased financial support to local governments for these initiatives.

Though the US is considered to have one of the most robust national water management systems in the world, numerous US communities are exposed to unsafe tap water every year (20 million people annually), and studies predominantly attribute this SDWA compliance failure to local government commitment costs (Bae & Lynch, 2022). Scholarly analyses focused on SDWA implementation compliance have increased over the past two decades as access to governmental data on CWSs has increased. The national online EPA repository housing CWS compliance data is referred to as the Safe Drinking Water Information System (SDWIS). This database is used widely by both researchers and regulators to analyze CWS compliance (Beecher et al., 2020). From these studies, it is understood that a CWS's resource capacity increases when systems serve small populations, low-income communities, and rural communities (Allaire et al., 2018, 2019; Allaire & Acquah, 2022; Ding et al., 2022; K. B. Dobbin & Fencl, 2021; Fu et al., 2020; Goddard et al., 2022; Marcillo & Krometis, 2019; McDonald & Jones, 2018; Michielssen et al., 2020; Nigra et al., 2020; Oxenford & Barrett, 2016; Pennino et al., 2020; Rubin, 2013; Schaider et al., 2019; Sharma & Lyon-Colbert, 2020; Statman-Weil et al., 2020; Switzer & Teodoro, 2017; Teodoro et al., 2018). CWSs serving small populations have less ability to generate user fees or property taxes needed to make significant SDWA implementation-based policy changes (e.g., upgrade regional drinking water and wastewater infrastructure; hire highly trained operators) (Allaire et al., 2018; Fu et al., 2020). Low-income communities have a similar limitation: they have less user fee and regional tax resource access, making day-to-day management and infrastructure upgrades costly (Alaire & Acqua, 2021; Dobbin & Fencl, 2021; Michielssen et al., 2020). Furthermore, many of these studies also find that the rurality of a CWS may impact a CWS's ability to ascertain financial resources because they are isolated systems (i.e., limited opportunity to merge with larger systems) and generally serve small populations (Allaire et al., 2018, 2019; EPA, 2011; Rubin, 2013). Therefore, the following local level financial commitment cost hypotheses is tested**:**

> Hypothesis 4a (H4a): As a CWS's population served count increases, the effect of a federal CWA enforcement rollback on the number of SDWA health violations experienced by local government CWSs sourcing from surface water decreases.
>
> Hypothesis 4b (H4b): As a CWS's community income inequality increases, the effect of a federal CWA enforcement rollback on the number of SDWA health violations experienced by local government CWSs sourcing from surface water increases.
>
> Hypothesis 4c (H4c): Local government owned CWSs sourcing from surface water and that serve a rural community experience more SDWA health violations after a federal CWA enforcement rollback.

Commitment cost literature suggests that states can alleviate commitment costs on local governments by providing stable financial assistance (Feiock, 2008). Funding provided to local governments to manage drinking water comes from the Drinking Water State Revolving Loan Fund (DWSRF). The EPA funds each state's CWA state revolving funds (SRF) and DWSRFs. In this system, the federal EPA distributes grants to state governments that match 20% of this amount. States then annually distribute funds to local governments in the form of "low interest 20-year loans at an interest rate two to three points under market rates to local drinking water and wastewater systems" (Mullin & Daley, 2018, p.635 to 636). State governments have predominantly distributed CWA SRF loans to local government owned wastewater treatment plants for infrastructure upgrades and DWSRF loans to local government owned CWSs (Mullin & Daley, 2018). However, CWSRF funds have been used to fund other projects including nonpoint source pollution control, green infrastructure, and other water quality-based projects[1]. CWA and DWSRF loans are distributed to local governments that apply and are approved. Mullin & Daley (2018) found that state loan distributions from these funds have led to varying outcomes. The CWA SRF loans have positively associated with local wastewater infrastructure project funding. Wastewater projects have significant positive spillover effects because higher quality effluent discharges to surface waters from wastewater treatment plants benefit all CWSs sourcing from or downstream from those waters. Recent research finds that DWSRFs have not significantly increased CWS project funding; instead, DWSRF funds are used to supplement day-to-day maintenance and employee costs (Mullin & Daley, 2018). Given this, historic SRF funding is expected to likely decrease compliance costs on local governments to implement the SDWA. Therefore, the following state level funding-based commitment cost hypotheses are tested**:**

> Hypothesis 4d (H4d): As a state's DWSRF funding increases, the effect of a federal CWA enforcement rollback on the number of SDWA health violations experienced by local government CWSs sourcing from surface water decreases.

> Hypothesis 4e (H4e): As a state's CWSRF funding increases, the effect of a federal CWA enforcement rollback on the number of SDWA health violations experienced by local government CWSs sourcing from surface water decreases.

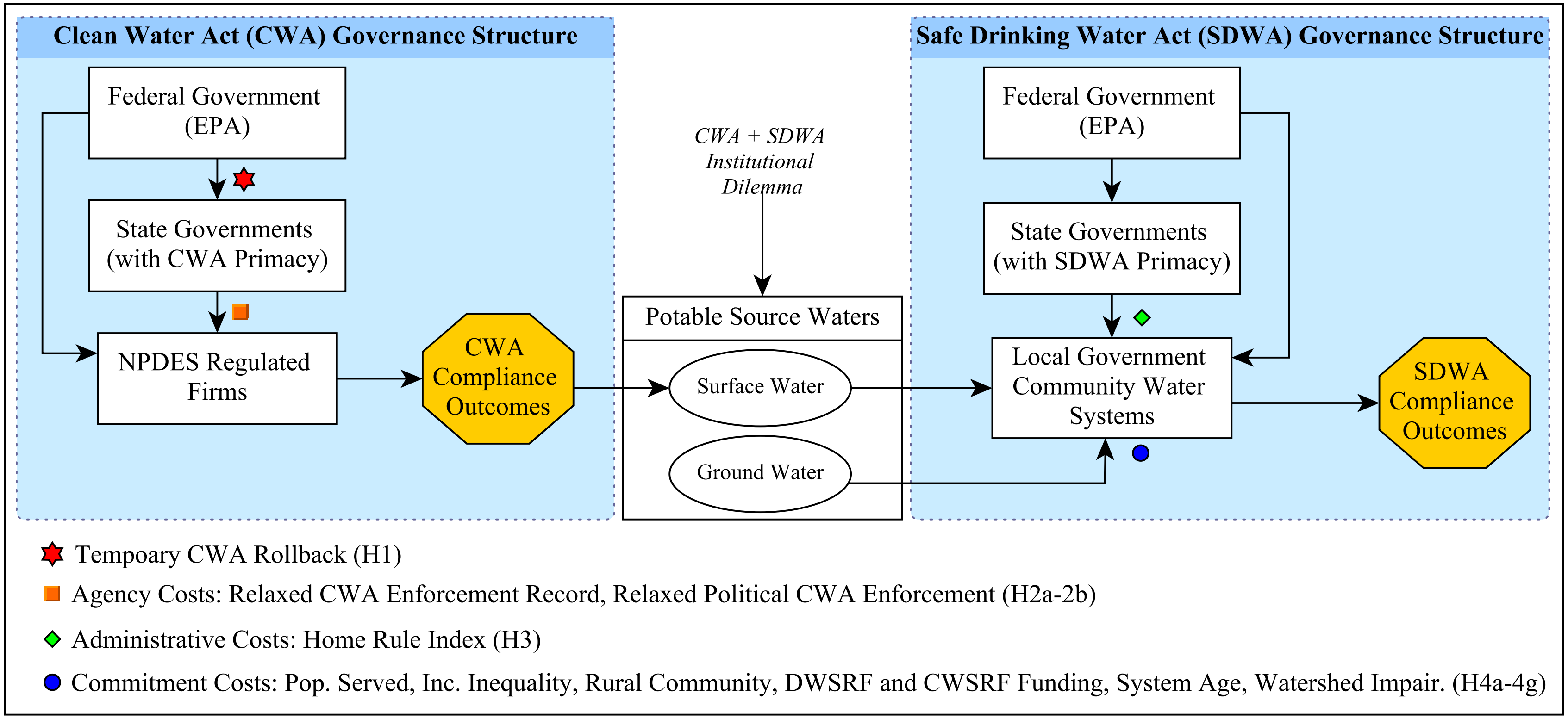
[1] Learn about the Clean Water State Revolving Fund (CWSRF): https://www.epa.gov/cwsrf/learn-about-clean-water-state-revolving-fund-cwsrf

Lastly, recent studies suggest that technical difficulties arise for older CWSs because they are the most likely to have failing infrastructure and antiquated treatment technology (Switzer, 2019). Furthermore, CWSs sourcing from consistently low quality waters have a heightened technical commitment cost to treat their source water to a level that is safe for consumption (Allaire & Acquah, 2022). Older CWSs and CWSs sourcing from low quality waters could be disproportionately affected by the CWA rollback because these systems may already have been on the verge of experiencing a health violation and thus even a minor increase in surface water pollutants could have pushed these systems to experience a health violation. Therefore, the following local level technical commitment cost hypotheses are tested**:**

> Hypothesis 4f (H4f): As a CWS's age increases, the effect of a federal CWA enforcement rollback on the number of SDWA health violations experienced by local government CWSs sourcing from surface water increases.
>
> Hypothesis 4g (H4g): As a watershed's surface water impairment increases, the effect of a federal CWA enforcement rollback on the number of SDWA health violations experienced by local government CWSs sourcing from surface water increases.

Figure 3 provides the conceptual diagram of this study. The conceptual diagram positions this study's hypotheses with the CWA-SDWA institutional dilemma to show where in the governance structure each hypothesis test is expected to impact the CWA-SDWA governance system.

Figure 3: Conceptual diagram



Chapter 3: Methods

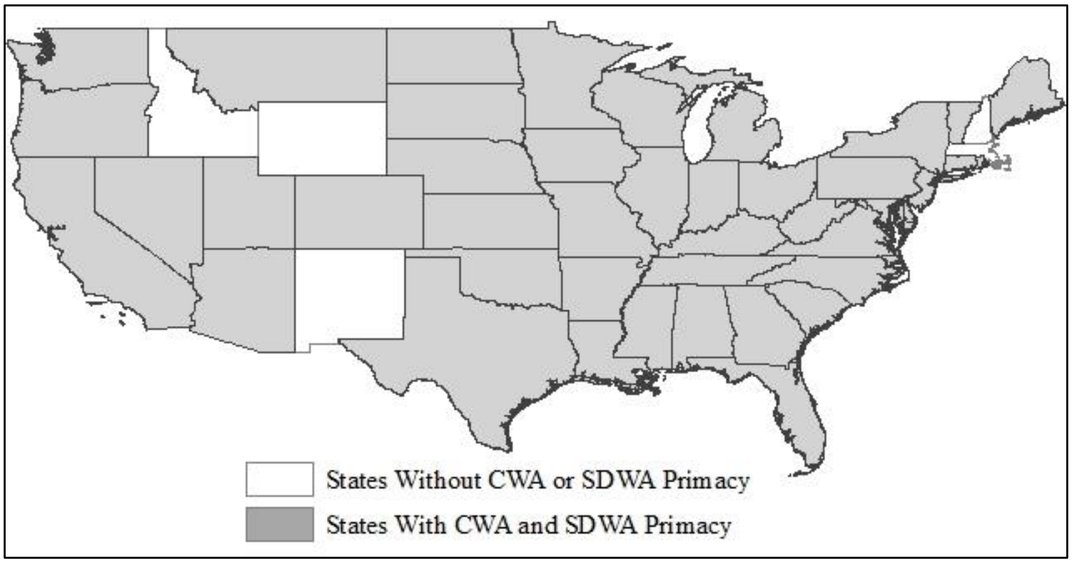
1. Data and Dependent Variable

Data for the dependent variable were drawn from the SDWIS data repository managed by the EPA Office of Ground Water and Drinking Water (Allaire et al., 2018). The data utilized includes local government owned CWS health violations data (i.e., number of health violations, health violation start date) provided in the SDWIS database. This is the same data the EPA and state governments use to determine if local governments are maintaining SDWA implementation compliance. Health violations occur when a CWS distributes water to the community that exceeds federal maximum contaminant levels, federal maximum residual disinfection levels, or when treatment techniques do not meet minimum federal requirements (ECHO EPA 2022). The EPA categorizes water systems into three types, including CWSs (serve the same population year-round), Non-Transient Non-Community Water Systems (serve at least 25 of the same people for at least six months out of the year), and Transient Non-Community Water Systems (serve water in a place where people do not spend long periods). This study focuses on community water systems only because their data are the most accurate, and they had to continue serving the public before and during the COVID-19 pandemic (Allaire et al., 2018; Bodine, 2020; GAO, 2021). Approximately 24,000 community water systems are local government owned and serve about 261 million people (nearly 87% of the public water consuming population) (Allaire et al., 2018; Fu et al., 2020).

The dependent variable is a measure of health-based non-compliance by local government CWSs. Local government CWSs report their compliance data to their state SDWA enforcement office, the state enforcement office then sends this compliance data to the EPA for review. The EPA releases CWS compliance data to the public in the online SDWIS repository after a three-month data review process.

This study's sample includes 16,042 CWSs. CWSs were excluded from this study if they (1) operate in Alaska or Hawaii, (2) operate in states without CWA or SDWA primacy, (3) serve less than 501 people, (4) are not local government owned, (5) source from ground water under the direct influence of surface water, or (6) were not in operation from 2018 to 2021. Figure 4 visualizes the states included in this study. Alaska and Hawaii were removed due to weather data limitations and because these states are not part of the contemporaneous US (Allaire et al., 2018). The following states were not included in this analysis because they did not have CWA primacy in 2020: Idaho, Massachusetts, New Hampshire, and New Mexico. Wyoming was also excluded from this study because it did not have SDWA enforcement primacy in 2020. The 16,042 systems included in this study serve approximately 246 million people, which is over 80% of the public drinking water consumer population (SDWIS). CWSs sourcing from surface water (i.e., treatment group) account for 42.0% (6,739) of the sample, while CWSs sourcing from ground water (i.e., control group) account for 58.0% (9,303). The CWSs sourcing from surface water (SW) in this study serve approximately 183 million people, and CWSs sourcing from ground water (GW) serve approximately 63.5 million people. Each CWS is observed at the daily level. This study uses data from the 365 days before and after March 26th, 2020 (731 days), thus the number of observations is 11,726,702 (i.e., 16,042*731).

Figure 4: Map of states with or without CWA or SDWA enforcement primacy in 2020



Note: Alaska and Hawaii (not visualized) were excluded from this study

2. Difference-in-Differences Empirical Approach

The DID approach is used to isolate the effect of the temporary EPA policy (i.e., effect on CWSs health violations) on CWSs operating within differing institutional arrangements with high commitment, agency, and administrative costs. The policy treatment group in this study includes local government CWSs sourcing from surface waters, whereas the control group includes local government CWSs sourcing from ground water that is not directly affected by surface water (see section eight below for empirical estimations).

3. Temporary EPA Policy DID Variables

To operationalize the EPA policy in a DID design, the following dichotomous measures were developed. First, a variable referred to as *T* (to denote the treatment group) takes on a value of 1 for CWSs sourcing from surface water, and 0 otherwise. Second, a variable referred to as *Post*, takes on a value of 1 for all observations that occurred on or after the adoption of the temporary policy (i.e., March 26th, 2020, to August 31st, 2020). The *Treat* and *Post* variables are interacted within DID Poisson regression models to identify the policy effect.

4. Agency Costs Moderator Variables

The agency cost measures to be used in this study focus on state stringency over CWA enforcement. The two agency cost measures focus on the administrative or political dimension of state level agency costs. The data used to capture the administrative agency costs measure, originates from the EPA's State Review Framework data provided online[2]. Every five years, the EPA conducts a review of state level implementation of CWA enforcement. The five elements reviewed in this framework focus on data (i.e., completeness, accuracy, and timeliness of data entry into national data systems), inspections (meeting inspection and coverage commitments, inspection report quality, and inspection report timeliness), violations (identification of violations, accuracy of compliance determinations, and determination of significant noncompliance or high priority violators), enforcement (timeliness and appropriateness of enforcement), and penalties (calculation including gravity and economic benefit components, assessment, and collection).[3] Each element is graded using a three-item scale. States are assigned one of the three following statements, "Meets or exceeds," "Area for Attention," and "Area for Improvement." Grooms (2015) suggests that states relax compliance by decreasing inspections and penalties on regulated firms. Therefore, the most recent state review results on each state's inspections and penalties grades is used to generate a dichotomous moderator variable, referred

[2] EPA State Review Framework: https://www.epa.gov/compliance/state-review-framework
[3] State Review Framework Information Key: https://www.epa.gov/sites/default/files/2019-11/documents/srf_key_information_publicsite.pdf

to as *Relaxed CWA Enforcement Record*, with 1 indicating a state received a grade of "Area for Improvement" in the inspections or penalties categories of their most recent EPA state review, and 0 otherwise. For the political dimension of agency costs in this study, online data sources were used to identify which states had a republican or democratic governor in 2020. This binary moderator variable is referred to as *Relaxed Political CWA Enforcement*, with 1 indicating a state had a republican governor in 2020 and 0 if a state had a democratic governor in 2020. These moderator variables is used to test if local government owned CWSs that source from surface waters and operate in states with relaxed CWA enforcement (i.e., low SRF score or republican governed states) experienced more SDWA health violations after the temporary CWA rollback.

5. Administrative Costs Moderator Variables

The administrative costs measure used in this study emphasizes a state's level of functional authority decentralized to local governments (i.e., home rule provisions). Wolman et al. (2008) built a Local Government Autonomy Index through a factor analysis procedure using twenty variables that "capture much of the differences in state local government systems" (p. 29). They built this index, and provide the index in their manuscript, to "be utilized as a test variable to model the effect of local government autonomy or its various dimensions on other fiscal or non-fiscal outcomes" (Woolman et al., 2008, p.29). The state level index from Woolman et al. (2008) was used to assign each state in this dissertation a home rule index score. This continuous measure was used to test if a state's home rule provisions negatively moderated the effect of the temporary CWA rollback. This continuous moderator variable is measured at the state level and is referred to as *Home Rule Index.*

6. Commitment Costs Moderator Variables

6.1. Population Served Measure

Hypothesis 4a focuses on a CWS's population served size. The SDWIS database provides a CWS's population served count. The population served by each CWS data was downloaded from SDWIS, and the natural log of a CWS's population served size is used to identify if local government CWSs sourcing from surface waters and that serve small populations were impacted disproportionality more by the CWA rollback than other CWSs serving larger populations. This continuous moderator variable is referred to as *Population Served*.

6.2. Income Inequality Measure

Hypothesis 4b focuses on a CWS's community income inequality level. The 2020 GINI Index of Income Inequality data provided by the US Census Bureau's American Community Survey (ACS) is used to capture this local financial commitment cost. The Gini index provides a standardized measure of income inequality for all US counties and is used as a continuous measure in this study. This variable is used identify if local government CWSs sourcing from surface waters and that serve communities with lower financial capacity were impacted disproportionality more than other CWSs serving higher income communities. This continuous moderator measure is referred to as *Income Inequality*.

6.3. Rural Community Measure

Hypothesis 4c focuses on a CWS's community rural status. The decennial Census categorizes counties based on their urban population sizes. County's lacking urban communities (i.e., urban centers with 10,000 people or more) are deemed rural. Census Bureau Decennial 2010 data on a county's urban-rural status is used to measure a community's rurality in this dissertation. Therefore, a binary measure is generated where counties meet the rurality threshold takes on a value of 1, and 0 otherwise. This measure helps identify if rural CWSs were impacted more by the temporary policy than non-rural systems. This binary moderator measure is referred to as, *Rural Community*.

6.4. State Revolving Fund Distribution Measures

Hypotheses 4d and 4e focus on SRF distributions to local governments. The EPA provides fiscal year CWA state revolving fund (CWSRF) allotments to state governments on the CWSRF allotment site[4]. Additionally, the EPA provides fiscal year SDWA state revolving fund (DWSRF) allotments on the DWSRF allotment site[5]. These reports provide the annual dollar amounts allotted to state revolving funds used to distribute loans and emergency funds to local governments to manage wastewater (CWSRF) and drinking water (DWRSF).

To capture the moderating effect of intergovernmental funding for the CWA and SDWA, individual per capita SRF allocation measures were generated for the years 2010 through 2019 for both the CWSRF and DWSRF. These ten SRF allocation measures were then averaged and treated as a continuous historical measure of SRF funding at the state level for CWSRF and DWSRF. These two continuous moderator variables are referred to as *DWSRF Funding* and C*WSRF Funding*.

6.5. Community Water System Age

Hypothesis 4f focuses on a CWS's age. The SDWIS database provides when a CWS first started reporting to the EPA. This is used as system age proxy variable. To generate this variable the year a CWS started reporting is subtracted from 2020 to produce a continuous age value of CWS measure. This continuous moderator variable is referred to as *System Age*.

6.6. System Source Water Quality

[4] Clean Water State Revolving Fund (CWSRF) Allotments of Federal Funds to States: https://www.epa.gov/cwsrf/clean-water-state-revolving-fund-cwsrf-allotments-federal-funds-states
[5] Drinking Water State Revolving Fund (DWSRF) Allotments of Federal Funds for States, Tribes, and Territories: https://www.epa.gov/dwsrf/annual-allotment-federal-funds-states-tribes-and-territories

Hypothesis 4g focuses on a system's source water quality. No data is available to identify what water source that every CWS is sourcing from. Therefore, as a proxy measure, this study uses data provided by states or collected directly by the EPA regarding which areas of surface water are on the Impaired Waters List in each state (https://www.epa.gov/ceam/303d-listed-impaired-waters#national). This data is provided as spatial GIS data. Therefore, in ArcGIS, the area of impaired surface waters in each US watershed (HUC 10) was divided by the total surface water area in each watershed to produce a watershed level fraction where a higher fraction means a larger percentage of waters in each watershed are on the EPA impaired list. CWSs were matched to their watershed using a zip code level georeferencing procedure. The impaired water data at the watershed level was then merged with the CWS data. This continuous variable is referred to as *Watershed Impairment*.

7. Controls

To isolate the temporary policy's effect on CWSs operating within differing institutional arrangements, this study's modeling design aims to further eliminate omitted variable bias using control variables and multi-way fixed effects. All models include weather controls to account for potential weather-based effects driving SDWA non-compliance. First, each model includes a precipitation control variable that captures average precipitation amounts per month at the county level. This data originates from the Centers for Disease Control Prevention's (CDC) National Environmental Public Health Tracking Network database.[6] Second, each model includes a flood control variable that captures the number of flood events per month at the county level. This data comes from the National Oceanic and Atmospheric Administration's (NOAA) National Centers

[6] CDC National Environmental Public Health Tracking Network online database: https://ephtracking.cdc.gov/DataExplorer/?c=36&i=108&m=-1

for Environmental Information database.[7] Third, it is expected that floods generally negatively affect CWSs sourcing from surface water more than CWSs sourcing from ground water therefore a third control variable is included in all models that interacts the treatment group variable (i.e., T_i=1) by the floods control to control for any surface water specific issues caused by floods. All model estimations also include (1) CWS level fixed effect to control for time-invariant CWS specific variables (e.g., administrative rules, employees), (2) a day level fixed effect to account for time shocks to the whole sample (e.g., COVID-19 state of emergency announcement) and (3) an interaction between weeks in the study and sub-region watersheds (i.e., HUC 8) to control for weekly changes at the watershed sub-region level. Floods and other weather-related events commonly occur and are recorded at the sub-basin level in the US (i.e., HUC 8) (Li et al., 2022). Essentially, the multi-way sub-region watershed by week fixed effect accounts for watershed differences overtime that could affect SDWA health compliance.

8. Empirical Estimations

8.1. Common Trends Estimations

Firstly, a fundamental assumption behind the DID modeling procedure,[8] in the absence of treatment, the average outcomes for the treated and control group would have followed common trends over time (i.e., the common trends assumption). Given the count nature of this dissertation's dependent variable and the high number of zeros (i.e., days CWSs did not experience a health violation), a pseudo-likelihood regression model is used for all regressions estimations as opposed to a linear regression. The following common trends specification is used to identify if the health violations experienced by local government CWSs sourcing from surface

[7] NOAA National Centers for Environmental Information database: https://www.ncdc.noaa.gov/stormevents/choosedates.jsp?statefips=-999%2CALL#

[8] See Appendix A for an in-depth discussion about the Difference-in-Differences (DD) modeling approach and its usage in this study.

waters was significantly divergent than CWSs sourcing from ground water in the pre-period leading up the temporary policy adoption date. The specification takes the following form in equation 1 and is tested strictly on the 365 days of data leading up to the temporary policy adoption date:

Equation 1: Common trends

$$\mathrm{E}(Y_{it}) = \exp\left(\beta_0 + \beta_1 T_i + \beta_2 D_t + \beta_3 T_i \times D_t + \beta_4 P_{it} + \beta_5 F_{it} + \beta_6 T_i \times F_t + \delta_1 X_{it} + \varepsilon_{it}\right)$$

Where Y_{it} represents an individual CWS's (i) SDWA health violation count per day (t), referred to as $Health\ Violations_{it}$. T_i is a binary variable coded as 1 for CWSs that source their water from surface water sources (treatment group), and 0 for CWSs that source from groundwater (control group). D_t is a continuous variable representing each day. $T_i \times D_t$ is an interaction term between the treatment group and day, which tests if health violations grew at common rates in the treatment and control groups before the temporary policy adoption. A significant β_3 coefficient would indicate health violations grew in different rates in the two groups. A significant test would suggest the common trends assumption is not met. P_{it} is a control variable capturing average monthly-county level precipitation. F_{it} is a control variable capturing average monthly-county level flood events. $T_i \times F_t$ control specifically for the effect of flood events on the treatment group's violation rate. X_{it} represents a vector of fixed effects including a CWS level fixed effect to control for time-invariant CWS specific variables (e.g., administrative procedures, employee expertise), a day level fixed effect to account for time shocks to the whole sample, and an interaction between weeks in the study and watershed geographical areas (i.e., HUC 8) to control for weekly changes at the watershed level.

Equation 1 was estimated for the pre-period six additional times for the sub-group moderator variables. The six additional common trend models took the following form:

- *Relaxed CWA Enforcement Record =1:*

$$E(Y_{it}) = \exp(\beta_0 + \beta_1 T_i + \beta_2 D_t + \beta_3 T_i \times D_t + \beta_4 P_{it} + \beta_5 F_{it} + \beta_6 T_i \times F_t + \delta_1 X_{it} + \varepsilon_{it})$$

- *Relaxed CWA Enforcement Record =0:*

$$E(Y_{it}) = \exp(\beta_0 + \beta_1 T_i + \beta_2 D_t + \beta_3 T_i \times D_t + \beta_4 P_{it} + \beta_5 F_{it} + \beta_6 T_i \times F_t + \delta_1 X_{it} + \varepsilon_{it})$$

- *Relaxed Political CWA Enforcement =1:*

$$E(Y_{it}) = \exp(\beta_0 + \beta_1 T_i + \beta_2 D_t + \beta_3 T_i \times D_t + \beta_4 P_{it} + \beta_5 F_{it} + \beta_6 T_i \times F_t + \delta_1 X_{it} + \varepsilon_{it})$$

- *Relaxed Political CWA Enforcement =0:*

$$E(Y_{it}) = \exp(\beta_0 + \beta_1 T_i + \beta_2 D_t + \beta_3 T_i \times D_t + \beta_4 P_{it} + \beta_5 F_{it} + \beta_6 T_i \times F_t + \delta_1 X_{it} + \varepsilon_{it})$$

- *Rural Community=1:*

$$E(Y_{it}) = \exp(\beta_0 + \beta_1 T_i + \beta_2 D_t + \beta_3 T_i \times D_t + \beta_4 P_{it} + \beta_5 F_{it} + \beta_6 T_i \times F_t + \delta_1 X_{it} + \varepsilon_{it})$$

- *Rural Community =0:*

$$E(Y_{it}) = \exp(\beta_0 + \beta_1 T_i + \beta_2 D_t + \beta_3 T_i \times D_t + \beta_4 P_{it} + \beta_5 F_{it} + \beta_6 T_i \times F_t + \delta_1 X_{it} + \varepsilon_{it})$$

8.2. DID Empirical Estimations

The DID estimations in this study are conducted using a 365 day pre-period and either a 158 day post period to represent the exact time the temporary policy was legally in effect and 365 day post period to capture the full year after the policy went into effect. Hypotheses are tested using the 365 day post period because this post period accounts for potential seasonal or administrative cycles that occur within the span of a year that could drive CWS health violations. Additionally, the 365 day post period helps account for any lagged effects of point source discharges. For example, NPDES regulated entities may have discharged excess pollutants to ephemeral streams that flow after August 31st each year. An additional example could be that CWSs downstream from multiple point source discharges may be negatively affected by pollutants that accumulate due to multiple upstream discharges. This accumulation could take days, weeks, or months (Chien and Pierce, 2018). Overall, it is expected that the effect of point source discharges is likely lagged due to variations in stream flow, surface water dilution, non-point source pollutants, geology, land use, and more (Chien and Pierce, 2018).

The first DID model used in this study takes the following form in equation 2:

Equation 2: DID equation for hypothesis 1 and the subgroup moderator tests

$$\mathrm{E}(Y_{it}) = \exp\left(\beta_0 + \beta_1 T_i + \beta_2 PP_t + \beta_3 T_i \times PP_t + \beta_4 P_{it} + \beta_5 F_{it} + \beta_6 T_i \times F_t + \delta_1 X_{it} + \varepsilon_{it}\right)$$

Where Y_{it} represents an individual CWS's (i) SDWA health violation count per day (t), referred to as $Health\ Violations_{it}$. T_i is a binary variable coded as 1 for CWSs that source their water from surface water sources (treatment group), and 0 for CWSs that source from groundwater (control group). PP_t is a binary variable coded as 1 for the time period on and after March 26th, 2020. $T_i \times PP_t$ is an interaction term between the treatment group and the post period, which tests if the health violations experienced by CWSs in the treatment group increased significantly more in the after the temporary policy adoption relative to the control group. This interaction term provides the temporary policy treatment effect (i.e., DID estimate). P_{it} is a control variable capturing average monthly-county level precipitation. P_{it} is a control variable capturing average monthly-county level flood events. $T_i \times F_t$ control specifically for the effect of flood events on the treatment group's violation rate. X_{it} represents a vector of fixed effects including a CWS level fixed effect to control for time-invariant CWS specific variables (e.g., administrative rules, employees), a day level fixed effect to account for time shocks to the whole sample, and an interaction between weeks in the study and watershed geographical areas (i.e., HUC 8) to control for weekly changes at the watershed level.

Equation 2 was estimated seven times (for both a 158 day and 365 day post period), once for the whole sample and six times for the sub-group moderator tests. The six additional DID models took the following form:

- *Relaxed CWA Enforcement Record =1:*

$$\mathrm{E}(Y_{it}) = \exp\left(\beta_0 + \beta_1 T_i + \beta_2 PP_t + \beta_3 T_i \times PP_t + \beta_4 P_{it} + \beta_5 F_{it} + \beta_6 T_i \times F_t + \delta_1 X_{it} + \varepsilon_{it}\right)$$

- *Relaxed CWA Enforcement Record =0:*

$$\mathrm{E}(Y_{it}) = \exp\left(\beta_0 + \beta_1 T_i + \beta_2 PP_t + \beta_3 T_i \times PP_t + \beta_4 P_{it} + \beta_5 F_{it} + \beta_6 T_i \times F_t + \delta_1 X_{it} + \varepsilon_{it}\right)$$

- *Relaxed Political CWA Enforcement =1:*

$$\mathrm{E}(Y_{it}) = \exp\left(\beta_0 + \beta_1 T_i + \beta_2 PP_t + \beta_3 T_i \times PP_t + \beta_4 P_{it} + \beta_5 F_{it} + \beta_6 T_i \times F_t + \delta_1 X_{it} + \varepsilon_{it}\right)$$

- *Relaxed Political CWA Enforcement =0:*

$$\mathrm{E}(Y_{it}) = \exp\left(\beta_0 + \beta_1 T_i + \beta_2 PP_t + \beta_3 T_i \times PP_t + \beta_4 P_{it} + \beta_5 F_{it} + \beta_6 T_i \times F_t + \delta_1 X_{it} + \varepsilon_{it}\right)$$

- *Rural Community=1:*

$$\mathrm{E}(Y_{it}) = \exp\left(\beta_0 + \beta_1 T_i + \beta_2 PP_t + \beta_3 T_i \times PP_t + \beta_4 P_{it} + \beta_5 F_{it} + \beta_6 T_i \times F_t + \delta_1 X_{it} + \varepsilon_{it}\right)$$

- *Rural Community =0:*

$$\mathrm{E}(Y_{it}) = \exp\left(\beta_0 + \beta_1 T_i + \beta_2 PP_t + \beta_3 T_i \times PP_t + \beta_4 P_{it} + \beta_5 F_{it} + \beta_6 T_i \times F_t + \delta_1 X_{it} + \varepsilon_{it}\right)$$

To identify if the CWA rollback impacted CWSs operating in differing state and local institutional arrangements differently, a series of individual DID models were conducted whereby the DID model in equation 2 is conducted but includes a three-way interaction term to capture the moderating effect of the continuous moderator variables in this study. This moderator equation takes the following form:

Equation 3: DID equation for the continuous moderator tests

$$\mathrm{E}(Y_{it}) = \exp\left(\beta_0 + \beta_1 T_i + \beta_2 PP_t + \beta_3 T_i \times PP_t + \beta_4 M_i + \beta_5 T_i \times PP_t \times M_i + \beta_6 P_{it} + \beta_7 F_{it} + \beta_8 T_i \times F_t + \delta_1 X_{it} + \varepsilon_{it}\right)$$

This model is the same as the DID model in equation 2 above, but M_{it} represents the continuous moderator variable, and β_5 in this equation provides the effect of the continuous moderator variables. The model in equation three was run seven times and took the following forms:

- $E(Y_{it}) = \exp(\beta_0 + \beta_1 T_i + \beta_2 PP_t + \beta_3 T_i \times PP_t + \beta_4 Home\ Rule\ Index_i + \beta_5 T_i \times PP_t \times Home\ Rule\ Index_i + \beta_6 P_{it} + \beta_7 F_{it} + \beta_8 T_i \times F_t + \delta_1 X_{it} + \varepsilon_{it})$
- $E(Y_{it}) = \exp(\beta_0 + \beta_1 T_i + \beta_2 PP_t + \beta_3 T_i \times PP_t + \beta_4 \ln(Population\ Served_i) + \beta_5 T_i \times PP_t \times Population\ Served_i + \beta_6 P_{it} + \beta_7 F_{it} + \beta_8 T_i \times F_t + \delta_1 X_{it} + \varepsilon_{it})$
- $E(Y_{it}) = \exp(\beta_0 + \beta_1 T_i + \beta_2 PP_t + \beta_3 T_i \times PP_t + \beta_4 Income\ Inequality_i + \beta_5 T_i \times PP_t \times Income\ Inequality_i + \beta_6 P_{it} + \beta_7 F_{it} + \beta_8 T_i \times F_t + \delta_1 X_{it} + \varepsilon_{it})$
- $E(Y_{it}) = \exp(\beta_0 + \beta_1 T_i + \beta_2 PP_t + \beta_3 T_i \times PP_t + \beta_4 DWSRF\ Funding_i + \beta_5 T_i \times PP_t \times DWSRF\ Funding_i + \beta_6 P_{it} + \beta_7 F_{it} + \beta_8 T_i \times F_t + \delta_1 X_{it} + \varepsilon_{it})$
- $E(Y_{it}) = \exp(\beta_0 + \beta_1 T_i + \beta_2 PP_t + \beta_3 T_i \times PP_t + \beta_4 CWSRF\ Funding_i + \beta_5 T_i \times PP_t \times CWSRF\ Funding_i + \beta_6 P_{it} + \beta_7 F_{it} + \beta_8 T_i \times F_t + \delta_1 X_{it} + \varepsilon_{it})$
- $E(Y_{it}) = \exp(\beta_0 + \beta_1 T_i + \beta_2 PP_t + \beta_3 T_i \times PP_t + \beta_4 System\ Age_i + \beta_5 T_i \times PP_t \times System\ Age_i + \beta_6 P_{it} + \beta_7 F_{it} + \beta_8 T_i \times F_t + \delta_1 X_{it} + \varepsilon_{it})$
- $E(Y_{it}) = \exp(\beta_0 + \beta_1 T_i + \beta_2 PP_t + \beta_3 T_i \times PP_t + \beta_4 Watershed\ Impairment_i + \beta_5 T_i \times PP_t \times Watershed\ Impairment_i + \beta_6 P_{it} + \beta_7 F_{it} + \beta_8 T_i \times F_t + \delta_1 X_{it} + \varepsilon_{it})$

All models are estimated in STATA SE 16.1 using the *ppmlhdfe* STATA package, the recommended package for Poisson linear models with multi-way fixed effects and dependent variables with a majority of zeros, in STATA (Correia, 2020). The *ppmlhdfe* package absorbs multi-way fixed effects and drops CWSs that are either perfectly explained by fixed effects or had zero SDWA health violations in the entire study period (i.e., singletons). Dropping singletons is preferred because they do not contribute to the model coefficients and keeping singletons in the model estimation leads to artificially higher degrees-of-freedom inflating the significance of model coefficients.

Lastly, several robustness DID estimations were conducted using the date, March 26, 2019, as a placebo policy rollback date to identify if health violation rates in the treatment group (CWSs sourcing from surface water) exhibit significant changes in the 158 and 365 days after March 26 in a non-treatment year. Additionally, multiple weather-based robustness checks were conducted to ensure that precipitation and floods are not driving the temporary policy effect. All model coefficients were converted to incident rate ratios for interpretation.

Chapter 4: Results

1. Summary Statistics

Table 1 provides descriptive statistics for the dependent variable, the transaction costs moderator variables, and the weather control variables. Health violations has a particularly low mean value but ranges from 0 to 12, indicating the dataset has a high proportion of zero values and that health violations generally occur infrequently. Approximately 28% of the observations fall in states with relaxed enforcement, 52% fall within states that had republican governors in 2020, and nearly 17% of observations fall within rural counties. The average state level home rule index value is 0.183 on a scale of -1 to 1. The average CWS population served size is 15,363 people. The average community income inequality measure is 0.448 on a scale of 0 to 1. The average annual per capita federal CWSRF Funding is $9.86 and the average annual per capita DWSRF Funding is $8.69. The average CWSs system age is 38 years. The average surface area watershed impairment percentage is 1.87, and ranges from 0 to 91.20%. The average monthly precipitation per county in this dataset is 0.12 inches. Lastly, the average monthly number of flood events per county is 0.34.

Table 1: Descriptive statistics

Variable	Obs.	Mean	Std. Dev.	Min	Max
Health Violations	11726702	.0004	.0302	0	12
Record of Relaxed CWA Enforcement	11726702	.282	.45	0	1
Relaxed Political CWA Enforcement	11726702	.521	.5	0	1
Home Rule Index	11726702	.183	.353	-.982	.845
Population Served Size	11726702	15362.598	100981.13	501	8271000
GINI Index	11726702	.448	.034	.316	.652
Rural County	11726702	.1661264	.3721941	0	1
CWSRF Funding	11726702	$9.864	7.411	0	28.453
DWSRF Funding	11726702	$8.685	14.498	.966	86.161
System Age	11726702	38.077	6.125	3	41
Watershed Impairment	11726702	1.874	7.329	0	91.197
Precipitation	11726702	.1216909	.08319	0	.75
Floods	11726702	.3397469	1.405324	0	73

Table 2 provides the average SDWA health violations experienced by CWSs in the pre- and post-period of the study. Interestingly, other than the Rural Community=1 sub-group in the Treatment group, all average violations decreased in the post-period. It is also interesting to note that on average CWSs sourcing from surface waters tend to have higher average health violations, but CWSs in the control group have the widest range of maximum daily health violations experienced at a local government CWS. Lastly, it is clear from the low average values that health violations are generally experienced extremely infrequently across all CWS groupings.

Table 2: Pre and post period SDWA health violation summary statistics

		Pre-Period Health Violations				Post-Period Health Violations (365 days)			
Experimental Group	**Variable**	**Obs.**	**Mean**	**Min**	**Max**	**Obs.**	**Mean**	**Min**	**Max**
Treatment Group (SW)	All	2,459,735	.0007623	0	8	2,466,474	.000671	0	7
	Relaxed CWA Enforcement Record=1	612,470	.0005159	0	3	614,148	.0003664	0	3
	Relaxed CWA Enforcement Record=0	1,847,265	.000844	0	8	1,852,326	.000772	0	7
	Relaxed Political CWA Enforcement=1	1,194,280	.0011924	0	8	1,197,552	.001053	0	7
	Relaxed Political CWA Enforcement=0	1,265,455	.0003564	0	5	1,268,922	.0003105	0	7
	Rural Community=1	329,960	.0010668	0	4	330,864	.0013032	0	5
	Rural Community=0	2,129,775	.0007151	0	8	2,129,775	.0005752	0	7
Control Group (GW)	All	3,395,595	.0003083	0	12	3,404,898	.0002214	0	12
	Relaxed CWA Enforcement Record=1	1,040,615	.0004075	0	6	1,043,466	.0002338	0	3
	Relaxed CWA Enforcement Record=0	2,354,980	.0002645	0	12	2,361,432	.0002160	0	12
	Relaxed Political CWA Enforcement=1	1,853,470	.0003081	0	12	1,858,548	.0002502	0	12
	Relaxed Political CWA Enforcement=0	1,542,125	.0003087	0	6	1,546,350	.0001869	0	6
	Rural Community=1	642,765	.0003874	0	12	644,526	.0003274	0	12
	Rural Community=0	2,752,830	.0002899	0	6	2,760,372	.0001967	0	6

2. Common Trend Test Results

Table 3 provides the common trend test results. First, the estimated Treat Date IRRs for the 365-day pre-period across both the full sample (Column 1 Table 3) and the sub-groups (Columns 2-7) are insignificant and close or equal to one, suggesting health violation rates in the pre-period did not exhibit significantly different trends. Therefore, the common trend assumption that CWSs sourcing from surface water would have followed the same trajectory as CWSs sourcing from ground water is accepted in this study.

Table 3: Common trend test results

VARIABLES	(1) All CWSs Y_{it}	(2) Relaxed CWA Enforcement Record=1 Y_{it}	(3) Relaxed CWA Enforcement Record=0 Y_{it}	(4) Relaxed Political CWA Enforcement=1 Y_{it}	(5) Relaxed Political CWA Enforcement=0 Y_{it}	(6) Rural Community=1 Y_{it}	(7) Rural Community=0 Y_{it}
Treat × Day	1.000	1.003	0.999	1.000	1.001	1.001	1.000
	(0.00102)	(0.00223)	(0.00119)	(0.00115)	(0.00238)	(0.00237)	(0.00129)
Precipitation	0.00191***	1.91e-07***	0.131	0.0533	8.25e-06***	0.0158	0.000551***
	(0.00336)	(6.31e-07)	(0.263)	(0.103)	(2.60e-05)	(0.0844)	(0.00109)
Floods	0.946	0.917	0.969	0.944	0.983	0.928	0.904
	(0.0570)	(0.0647)	(0.0837)	(0.0681)	(0.132)	(0.293)	(0.0626)
Treat × Floods	1.027	1.105	0.947	1.011	1.035	1.470	1.025
	(0.0585)	(0.0742)	(0.100)	(0.0564)	(0.144)	(0.576)	(0.0633)
Constant	2.278*	4.872**	2.462	1.791	3.356	1.484	2.781*
	(0.979)	(3.375)	(1.394)	(0.982)	(2.533)	(1.437)	(1.534)
Observations	10,662	2,020	5,097	4,393	2,691	961	7,138
Pseudo R^2	0.56	0.38	0.54	0.54	0.41	0.49	0.53
CWS FE	Y	Y	Y	Y	Y	Y	Y
Day FE	Y	Y	Y	Y	Y	Y	Y
Sub-Basin × Week FE	Y	Y	Y	Y	Y	Y	Y

Robust standard errors in parentheses clustered at the CWS level
*** p<0.01, ** p<0.05, * p<0.1
Note: Y_{it} represents $Health\ Violations_{it}$

3. Primary Results

3.1. DID Estimates Using 158 Day Post Period

Tables 4 and 5 provide the DID estimates for the 158 days that the temporary policy was legally in effect. Table 4 provides DID estimates for the whole sample (Column 1 in Table 4) and all moderator sub-groups. Table 4 results indicate that during the 158 days in which the temporary policy was in effect, the percent of health violations experienced by CWSs sourcing from surface water and operating in states with democratic governors significantly increased by 152% (IRR=2.52) in the post period. Lastly, CWSs sourcing from surface water and operating in rural counties experienced 152% (IRR=2.52) more health violations in the post period.

Table 5 results provide DID treatment estimates for the 158 day post period when including moderator variable tests as a three-way interaction term. These results indicate that when analyzing the 158 day post period, only one of the continuous moderator variables shows signs of significantly moderating the effect of the temporary rollback. CWSRF Funding has a significant negative moderating effect on the CWA rollback. When holding the moderating effect of CWSRF Funding constant, local government CWSs sourcing from surface waters reported 189% (IRR=2.89) more health violations in the 158d post period.

Table 4: DID tests results and subgroup results 158 day post period

VARIABLES	(1) All CWSs Y_{it}	(2) Relaxed CWA Enforcement Record=1 Y_{it}	(3) Relaxed CWA Enforcement Record=0 Y_{it}	(4) Relaxed Political CWA Enforcement=1 Y_{it}	(5) Relaxed Political CWA Enforcement=0 Y_{it}	(6) Rural Community=1 Y_{it}	(7) Rural Community=0 Y_{it}
Treat × Post	1.339	1.913	1.141	1.121	2.522**	2.516**	1.251
	(0.271)	(1.000)	(0.242)	(0.244)	(1.116)	(1.182)	(0.324)
Precipitation	0.0378**	5.73e-06***	1.206	1.051	2.44e-05***	0.0106	0.0267**
	(0.0533)	(1.55e-05)	(1.770)	(1.594)	(6.28e-05)	(0.0496)	(0.0447)
Floods	0.968	0.994	0.958	0.968	1.026	1.653**	0.929
	(0.0530)	(0.0724)	(0.0785)	(0.0640)	(0.0805)	(0.374)	(0.0589)
Treat × Floods	1.018	1.036	0.968	1.002	0.993	0.620*	1.043
	(0.0496)	(0.0524)	(0.0912)	(0.0564)	(0.0718)	(0.169)	(0.0574)
Constant	1.656***	4.787***	1.277	1.334	2.957***	1.744	1.804**
	(0.321)	(2.058)	(0.252)	(0.287)	(1.048)	(1.030)	(0.426)
Observations	15,108	3,197	7,226	6,319	4,094	1,328	10,300
Pseudo R^2	0.54	0.38	0.53	0.53	0.41	0.45	0.52
CWS FE	Y	Y	Y	Y	Y	Y	Y
Day FE	Y	Y	Y	Y	Y	Y	Y
Sub-Basin × Week FE	Y	Y	Y	Y	Y	Y	Y

Robust standard errors in parentheses clustered at the CWS level
*** p<0.01, ** p<0.05, * p<0.1
Note: Y_{it} represents $Health\ Violations_{it}$

Table 5: Continuous moderator DID tests results 158 day post period

VARIABLES	(1) Y_{it}	(2) Y_{it}	(3) Y_{it}	(4) Y_{it}	(5) Y_{it}	(6) Y_{it}	(7) Y_{it}
Treat × Post	1.639**	2.344	2.613	2.886**	1.452*	0.758	1.319
	(0.413)	(1.382)	(3.571)	(1.293)	(0.328)	(0.368)	(0.269)
Treat × Post × Home Rule Index	0.502						
	(0.276)						
Treat × Post × ln(Population Served)		0.934					
		(0.0613)					
Treat × Post × GINI Index			0.233				
			(0.687)				
Treat × Post × CWSRF Funding				0.939**			
				(0.0286)			
Treat × Post × DWSRF Funding					0.986		
					(0.0164)		
Treat × Post × System Age						1.015	
						(0.0116)	
Treat × Post × Watershed Impairment							1.018
							(0.0126)
Precipitation	0.0372**	0.0388**	0.0369**	0.0348**	0.0380**	0.0365**	0.0399**
	(0.0525)	(0.0548)	(0.0520)	(0.0492)	(0.0535)	(0.0514)	(0.0565)
Floods	0.965	0.970	0.968	0.959	0.968	0.968	0.968
	(0.0528)	(0.0532)	(0.0530)	(0.0533)	(0.0532)	(0.0530)	(0.0530)
Treat × Floods	1.018	1.015	1.018	1.025	1.018	1.018	1.016
	(0.0495)	(0.0497)	(0.0496)	(0.0512)	(0.0497)	(0.0496)	(0.0495)
Constant	1.611**	1.641**	1.659***	1.564**	1.645**	1.667***	1.636**
	(0.314)	(0.320)	(0.321)	(0.307)	(0.320)	(0.323)	(0.319)
Observations	15,108	15,108	15,108	15,108	15,108	15,108	15,108
Pseudo R^2	0.55	0.55	0.55	0.55	0.55	0.55	0.55
CWS FE	Y	Y	Y	Y	Y	Y	Y
Day FE	Y	Y	Y	Y	Y	Y	Y
Sub-Basin × Week FE	Y	Y	Y	Y	Y	Y	Y

Robust standard errors in parentheses clustered at the CWS level
*** p<0.01, ** p<0.05, * p<0.1
Note: Y_{it} represents $Health\ Violations_{it}$

The DID results provided in Tables 4 and 5 provide evidence that two commitment cost measures significantly moderated the policy treatment effect in the 158 days that the temporary policy was legally in effect. The DID treatment effect on the whole sample (Table 4, Column 1) was insignificant at the 5% level indicating the null cannot be rejected for H1 when analyzing the 158d post period. Regarding agency costs hypotheses, the sub-group tests in Table 4 indicate that CWSs operating in states with democratic governors in 2020 were affected by the rollback indicating the null cannot be rejected for H2b. Focusing on the commitment costs hypotheses, results in Table 4 and 5 provide evidence that community rurality and CWSRF historic funding significantly moderate the temporary policy effect. Thus, using the 158 day post period, for H4c and H4d, the null can be rejected, and the alternative can be favored that community rurality and historic intergovernmental CWA funding moderate the temporary policy effect in 2020.

Overall, the 158 day post period tests do not lend evidence in support of H1, H2a, H2b, H3, H4a, H4b, H4e, H4f, and H4g. However, the 158 day post period tests have two potential concerns that make interpretating the DID estimates potentially unreliable. Firstly, only analyzing the 158 days that the policy was in effect assumes there was no lag in human behavior (i.e., all NPDES dischargers immediately adhered to the end of the temporary rollback on August 31st, 2020) or surface water contamination (i.e., accumulation of contaminants downstream, faster or slower flows due to shifts in weather). Furthermore, the 158-day post period does not encapsulate a full year. Both natural and social systems undergo cycles over the course of a year that could impact health violations. For example, seasonal shifts can impact violation rates due to changes in source water quantity. Furthermore, organizations and people operate according to annual cycles including budgeting cycles, monthly water sampling cycles, and more. Therefore, it is possible that estimates identified using a 158 post period may be biased and not accurately reflect the temporary rollback's actual effect on the CWS population. To account for potential annual shifts in natural and social systems in the US, the same DID estimates conducted for the 158 day post period are conducted again using a 365 day post period.

3.2. DID Estimates Using 365 Day Post Period

Tables 6 and 7 provide the DID estimates for the 365 days after the temporary policy went into effect. Table 6 results indicate that in the 365 days after the temporary policy went into effect, the total study sample, and four sub-groups exhibited significant increases in health violations. Focusing on the whole sample, the estimate in Table 6 (Column 1) indicates that CWSs sourcing from surface water experienced an average of 57% (IRR=1.57) more health violations after the CWA rollback. CWSs sourcing from surface water and operating in states without relaxed CWA enforcement stringency (Table 6, Column 3) experienced 52% (IRR=1.52) more health violations in the post-period. CWSs sourcing from surface water and operating in states with republican governors in 2020 experienced 54% (IRR=1.54) more health violations after the rollback. CWSs sourcing from surface water and operating in states with democratic governors in 2020 experienced 108% (IRR=2.08) more health violations after the rollback. Lastly, CWSs sourcing from surface water and operating in rural counties experienced 291% (IRR=3.911) more health violations in the post period.

Table 6: DID tests results and subgroup results 365 day post period

VARIABLES	(1) All CWSs Y_{it}	(2) Relaxed CWA Enforcement Record=1 Y_{it}	(3) Relaxed CWA Enforcement Record=0 Y_{it}	(4) Relaxed Political CWA Enforcement=1 Y_{it}	(5) Relaxed Political CWA Enforcement=0 Y_{it}	(6) Rural Community=1 Y_{it}	(7) Rural Community=0 Y_{it}
Treat × Day	1.574**	1.769	1.517**	1.537**	2.083**	3.911***	1.365
	(0.288)	(0.779)	(0.303)	(0.324)	(0.757)	(1.880)	(0.312)
Precipitation	0.137	0.000176***	3.119	2.657	0.000387***	1.119	0.0636*
	(0.166)	(0.000442)	(3.825)	(3.382)	(0.000908)	(4.201)	(0.0937)
Floods	1.010	1.033	1.000	0.967	1.087	1.389	1.015
	(0.0447)	(0.0689)	(0.0530)	(0.0617)	(0.0592)	(0.348)	(0.0474)
Treat × Floods	0.972	1.002	0.909*	0.952	0.953	0.657	0.980
	(0.0389)	(0.0548)	(0.0479)	(0.0573)	(0.0479)	(0.192)	(0.0413)
Constant	1.199	2.187**	0.977	1.020	1.627	0.772	1.374
	(0.193)	(0.838)	(0.158)	(0.180)	(0.500)	(0.371)	(0.274)
Observations	21,670	4,505	10,825	9,849	5,650	1,858	15,058
Pseudo R^2	0.55	0.38	0.53	0.54	0.39	0.46	0.52
CWS FE	Y	Y	Y	Y	Y	Y	Y
Day FE	Y	Y	Y	Y	Y	Y	Y
Sub-Basin × Week FE	Y	Y	Y	Y	Y	Y	Y

Robust standard errors in parentheses clustered at the CWS level

*** p<0.01, ** p<0.05, * p<0.1

Note: Y_{it} represents $Health\ Violations_{it}$

Table 7 results show that when analyzing the 365-day post period, two of the continuous moderator variables significantly moderate the effect of the temporary rollback. A state's home rule status (Column 1, Table 7) has a significant negative moderating effect on the CWA rollback. When holding the moderating effect of home rule index constant, the temporary rollback effect on CWSs sourcing from surface waters is estimated to be 109% (IRR=2.09). As a state's home rule status increases the temporary policy treatment effect decreases. Secondly, CWSRF funding (Column 4, Table 7) also has a significant negative moderating effect on the CWA rollback. When holding the moderating effect of CWA SRF Funding constant, the temporary rollback effect on CWSs sourcing from surface waters is estimated to be 277% (IRR=3.77). States that have received higher rates of CWA funding from 2010 to 2019 were impacted less by the temporary CWA rollback.

Table 7: Continuous moderator DID tests results 365 day post period

VARIABLES	(1) Y_{it}	(2) Y_{it}	(3) Y_{it}	(4) Y_{it}	(5) Y_{it}	(6) Y_{it}	(7) Y_{it}
Treat × Post	2.089***	1.538	5.447	3.765***	1.883***	0.819	1.543**
	(0.455)	(0.858)	(7.928)	(1.509)	(0.414)	(0.396)	(0.284)
Treat × Post × Home Rule Index	0.345**						
	(0.173)						
Treat × Post × ln(Population Served)		1.003					
		(0.0622)					
Treat × Post × GINI Index			0.0666				
			(0.210)				
Treat × Post × CWSRF Funding				0.930***			
				(0.0248)			
Treat × Post × DWSRF Funding					0.968		
					(0.0212)		
Treat × Post × System Age						1.017	
						(0.0118)	
Treat × Post × Watershed Impairment							1.023*
							(0.0121)
Precipitation	0.129*	0.137	0.133*	0.129*	0.139	0.136*	0.144
	(0.156)	(0.166)	(0.161)	(0.157)	(0.169)	(0.165)	(0.175)
Floods	1.011	1.010	1.010	1.000	1.010	1.009	1.010
	(0.0446)	(0.0448)	(0.0446)	(0.0448)	(0.0449)	(0.0445)	(0.0445)
Treat × Floods	0.970	0.973	0.973	0.984	0.972	0.974	0.972
	(0.0389)	(0.0389)	(0.0389)	(0.0397)	(0.0390)	(0.0387)	(0.0386)
Constant	1.129	1.199	1.201	1.078	1.175	1.207	1.181
	(0.184)	(0.194)	(0.193)	(0.182)	(0.190)	(0.194)	(0.191)
Observations	21,670	21,670	21,670	21,670	21,670	21,670	21,670
Pseudo R^2	0.55	0.55	0.55	0.55	0.55	0.55	0.55
CWS FE	Y	Y	Y	Y	Y	Y	Y
Day FE	Y	Y	Y	Y	Y	Y	Y
Sub-Basin × Week FE	Y	Y	Y	Y	Y	Y	Y

Robust standard errors in parentheses clustered at the CWS level

*** p<0.01, ** p<0.05, * p<0.1

Note: Y_{it} represents $Health\ Violations_{it}$

The DID results provided in Tables 6 and 7 provide evidence that the temporary policy significantly impacted CWSs sourcing from surface waters, and multiple agency, administrative, and commitment cost measures significantly moderated the effect of the temporary rollback. The DID treatment effect on the whole sample (Table 6, Column 1) lends evidence to Hypothesis 1 that the temporary CWA rollback likely led CWSs sourcing from surface water to experience significantly more health violations after the temporary policy went into effect. Regarding the agency costs hypotheses, results in Table 6 and 7 lend some evidence in support of Hypothesis 2b that CWSs sourcing from surface waters and operating in states with republican governors experienced more health violations after the temporary rollback. However, opposite to expectations, CWSs (1) operating in states with heightened CWA stringency or (2) operating in states with democratic governors in 2020 also experienced significantly more health violations after the temporary policy went into effect. These results suggest that the null on Hypothesis 2a and 2b cannot be rejected. Regarding the administrative costs moderator (Hypothesis 3), results suggest that home rule negatively moderates the temporary policy rollback effect. Focusing on the commitment costs hypotheses, results in Table 6 and 7 show evidence that community rurality and CWSRF historic funding significantly moderated the temporary policy effect. Thus, for H4c and H4d, the null can be rejected, and the alternative can be favored that community rurality and past intergovernmental CWA funding moderated the temporary policy effect.

Overall, for the purposes of this study, models run using the 365-day post period are the author's preferred models because the post period represents an entire year of data rather than five months. Analyzing one full year's worth of data to another one full year ensures that annual cycles driving organizational behavior, weather, or other phenomenon that occur systematically over the course of a year that could impact SDWA compliance outcomes are controlled for in the

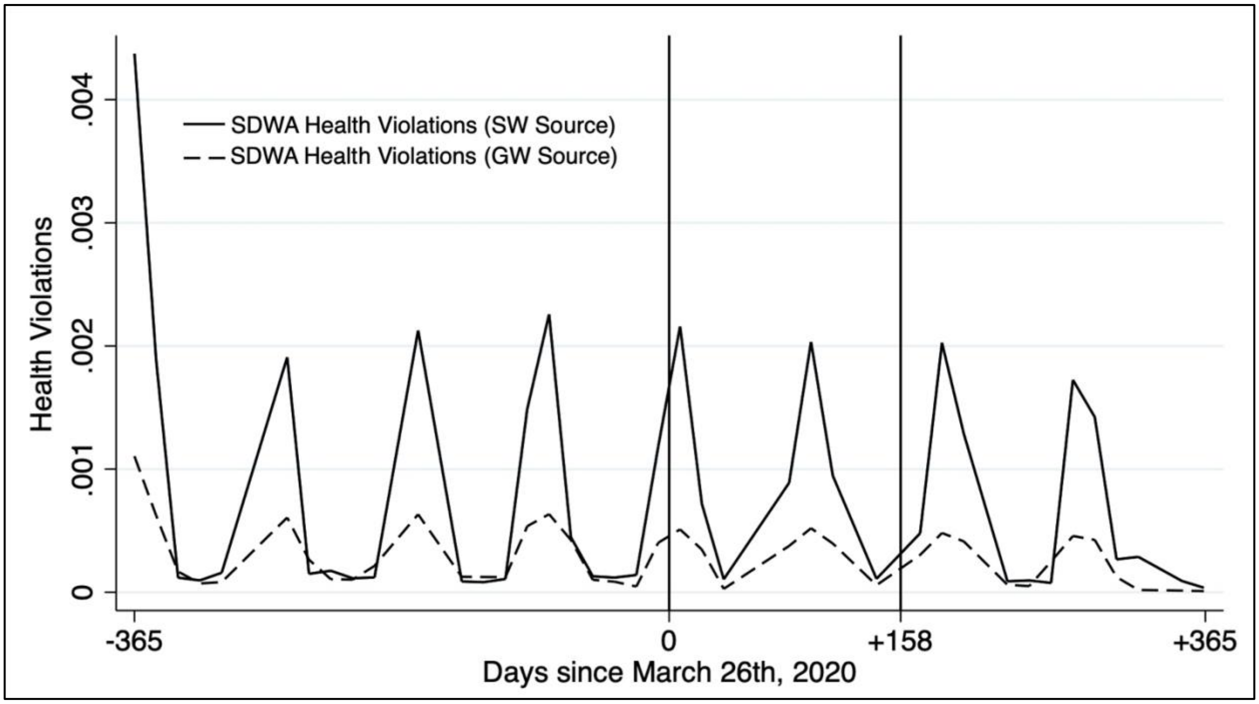
DID estimation procedures. Furthermore, analyzing the months following the formal end to the temporary policy helps ensure any lagged effects are captured in the DID analysis.

3.3. Robustness Checks

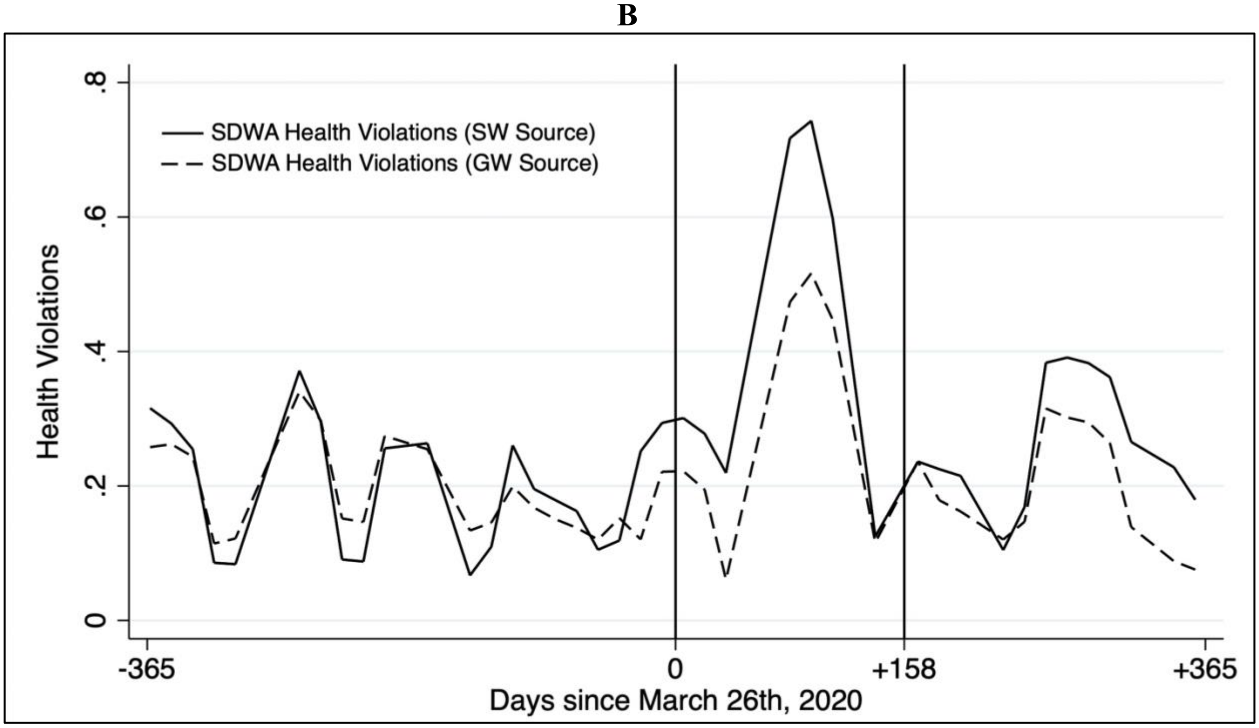
Figure 5 provides the smoothed values of kernel-weighted local polynomial regression graphs of the raw CWS health violation trends (A) and fitted CWS health violation trends (B) for the treatment (SW Source) and control (GW Source) groups. The fitted health violation trends of the predicted average values from the model used to test Hypothesis 1 (i.e., Column 1, Table 6) were used to graph Figure 5B. The fitted average values represent the DID model's fitted values. Fitted values account for fixed effects, control variables, and singletons dropped from the estimation. Visually Figure 5A does not show that violations visibly changed after the temporary policy went into effect. However, the fitted health violation trends show a relatively common trend between the treatment and control group in the pre-period and a large increase in the post period particularly in the treatment group. The spike in both groups suggests other factors (e.g., COVID-19 pandemic) led CWSs in both groups to experience more health violations overall. Figure 5, in conjunction with the common trend tests above, provides visual evidence that the modeling procedure and empirical design in this study is valid. This fitted visualization helps deduce why modeling is necessary when conducting the DID estimate to ensure confounding variables do not wash out treatment effects.

Figure 5: Health violation trends

A



B



Lastly, several robustness DID tests were conducted using the date, March 26, 2019, as a placebo policy rollback date to identify if health violation rates in the treatment group (CWSs sourcing from surface water) exhibit significant changes in the 158 and 365 days after March 26 in a non-treatment year. Table 8 provides the placebo DID estimates for the whole sample and the sub-group moderator tests using the 158 day post-period. Table 9 provides the placebo DID estimates for the whole sample and the sub-group moderators using 365 day post period. Tables 10 and 11 provide the interaction moderator tests for the 158 post period and the 365 day post-period, respectively. Overall, none of the DID estimates (i.e., Treat × Post_2019) emerged as significant in the placebo tests. Furthermore, most of the DID estimates were either close to the value one (i.e., IRR values close to one indicates no effect) or less than one. These tests provide further validation for the 2020 empirical design used to test this study's hypotheses.

Table 8: Placebo DID test results and subgroup results 158 day post period

VARIABLES	(1) All CWSs Y_{it}	(2) Relaxed CWA Enforcement Record=1 Y_{it}	(3) Relaxed CWA Enforcement Record=0 Y_{it}	(4) Relaxed Political CWA Enforcement=1 Y_{it}	(5) Relaxed Political CWA Enforcement=0 Y_{it}	(6) Rural Community=1 Y_{it}	(7) Rural Community=0 Y_{it}
Treat × Post_2019	0.896	0.710	1.061	1.066	0.673	0.965	1.000
	(0.160)	(0.300)	(0.208)	(0.228)	(0.222)	(0.438)	(0.208)
Precipitation	0.606	0.0144*	1.701	0.562	0.496	0.237	0.447
	(0.529)	(0.0334)	(1.627)	(0.546)	(1.129)	(0.384)	(0.508)
Floods	0.992	0.991	0.974	1.024	0.999	1.179	0.974
	(0.0657)	(0.197)	(0.0654)	(0.0864)	(0.101)	(0.365)	(0.0714)
Treat × Floods	1.007	1.114	0.952	0.930	1.065	1.338	1.009
	(0.0687)	(0.220)	(0.0681)	(0.0958)	(0.0973)	(0.420)	(0.0740)
Constant	1.157	1.475	1.121	1.280*	0.888	1.455*	1.146
	(0.135)	(0.597)	(0.135)	(0.167)	(0.290)	(0.327)	(0.176)
Observations	13,615	2,046	8,342	6,468	3,120	1,356	9,010
Pseudo R^2	0.51	0.31	0.51	0.49	0.34	0.44	0.48
CWS FE	Y	Y	Y	Y	Y	Y	Y
Day FE	Y	Y	Y	Y	Y	Y	Y
Sub-Basin × Week FE	Y	Y	Y	Y	Y	Y	Y

Robust standard errors in parentheses clustered at the CWS level

*** p<0.01, ** p<0.05, * p<0.1

Note: Y_{it} represents $Health\ Violations_{it}$

Table 9: Placebo DID test results and subgroup results 365 day post period

VARIABLES	(1) All CWSs Y_{it}	(2) Relaxed CWA Enforcement Record=1 Y_{it}	(3) Relaxed CWA Enforcement Record=0 Y_{it}	(4) Relaxed Political CWA Enforcement=1 Y_{it}	(5) Relaxed Political CWA Enforcement=0 Y_{it}	(6) Rural Community=1 Y_{it}	(7) Rural Community=0 Y_{it}
Treat × Post_2019	0.975	0.855	1.101	1.143	0.743	1.276	0.979
	(0.156)	(0.297)	(0.201)	(0.223)	(0.217)	(0.505)	(0.189)
Precipitation	0.123**	0.00139***	0.682	0.209	0.0260*	0.215	0.0429**
	(0.118)	(0.00318)	(0.664)	(0.200)	(0.0561)	(0.334)	(0.0561)
Floods	0.951	0.899	0.948	0.996	0.900	1.031	0.937
	(0.0512)	(0.0873)	(0.0603)	(0.0592)	(0.104)	(0.230)	(0.0577)
Treat × Floods	1.033	1.135	0.988	0.983	1.118	1.727**	1.024
	(0.0543)	(0.104)	(0.0703)	(0.0596)	(0.125)	(0.415)	(0.0581)
Constant	1.329**	2.010*	1.171	1.364**	1.260	1.316	1.517**
	(0.179)	(0.749)	(0.157)	(0.193)	(0.384)	(0.306)	(0.281)
Observations	23,368	4,024	12,770	10,112	5,925	2,196	15,224
Pseudo R^2	0.53	0.35	0.52	0.51	0.38	0.47	0.49
CWS FE	Y	Y	Y	Y	Y	Y	Y
Day FE	Y	Y	Y	Y	Y	Y	Y
Sub-Basin × Week FE	Y	Y	Y	Y	Y	Y	Y

Robust standard errors in parentheses clustered at the CWS level
*** p<0.01, ** p<0.05, * p<0.1
Note: Y_{it} represents $Health\ Violations_{it}$

Table 10: Placebo DID Test results and subgroup results 158 day post period

VARIABLES	(1) Y_{it}	(2) Y_{it}	(3) Y_{it}	(4) Y_{it}	(5) Y_{it}	(6) Y_{it}	(7) Y_{it}
Treat × Post_2019	0.701	0.761	2.499	0.834	0.783	0.758	0.884
	(0.164)	(0.379)	(2.548)	(0.310)	(0.155)	(0.316)	(0.158)
Treat × Post_2019 × Home Rule Index	2.412*						
	(1.252)						
Treat × Post_2019 × ln(Population Served)		1.020					
		(0.0576)					
Treat × Post_2019 × GINI Index			0.106				
			(0.234)				
Treat × Post_2019 × CWSRF Funding				1.006			
				(0.0262)			
Treat × Post_2019 × DWSRF Funding					1.028		
					(0.0182)		
Treat × Post_2019 × System Age						1.004	
						(0.00955)	
Treat × Post_2019 × Watershed Impairment							1.014*
							(0.00823)
Precipitation	0.603	0.606	0.593	0.606	0.598	0.604	0.618
	(0.529)	(0.529)	(0.519)	(0.529)	(0.522)	(0.527)	(0.541)
Floods	0.996	0.993	0.993	0.992	0.992	0.993	0.992
	(0.0653)	(0.0657)	(0.0656)	(0.0659)	(0.0657)	(0.0657)	(0.0657)
Treat × Floods	1.000	1.007	1.005	1.007	1.007	1.006	1.008
	(0.0678)	(0.0688)	(0.0687)	(0.0689)	(0.0690)	(0.0687)	(0.0688)
Constant	1.199	1.159	1.160	1.164	1.166	1.158	1.151
	(0.142)	(0.135)	(0.136)	(0.142)	(0.137)	(0.136)	(0.135)
Observations	13,615	13,615	13,615	13,615	13,615	13,615	13,615
Pseudo R^2	0.51	0.51	0.51	0.51	0.51	0.51	0.51
CWS FE	Y	Y	Y	Y	Y	Y	Y
Day FE	Y	Y	Y	Y	Y	Y	Y
Sub-Basin × Week FE	Y	Y	Y	Y	Y	Y	Y

Robust standard errors in parentheses clustered at the CWS level
*** p<0.01, ** p<0.05, * p<0.1
Note: Y_{it} represents $Health\ Violations_{it}$

Table 11: Placebo DID tests results and subgroup results 365 day post period

VARIABLES	(1) Y_{it}	(2) Y_{it}	(3) Y_{it}	(4) Y_{it}	(5) Y_{it}	(6) Y_{it}	(7) Y_{it}
Treat × Post_2019	0.756	1.087	3.638	0.731	0.860	0.584	0.956
	(0.151)	(0.550)	(3.703)	(0.248)	(0.155)	(0.223)	(0.154)
Treat × Post_2019 × Home Rule Index	2.561**						
	(1.154)						
Treat × Post_2019 × ln(Population Served)		0.987					
		(0.0565)					
Treat × Post_2019 × GINI Index			0.0559				
			(0.123)				
Treat × Post_2019 × CWSRF Funding				1.024			
				(0.0240)			
Treat × Post_2019 × DWSRF Funding					1.024		
					(0.0163)		
Treat × Post_2019 × System Age						1.013	
						(0.00894)	
Treat × Post_2019 × Watershed Impairment							1.022*
							(0.0123)
Precipitation	0.119**	0.122**	0.121**	0.123**	0.123**	0.123**	0.125**
	(0.115)	(0.117)	(0.116)	(0.118)	(0.118)	(0.119)	(0.120)
Floods	0.954	0.951	0.951	0.948	0.951	0.952	0.951
	(0.0512)	(0.0513)	(0.0512)	(0.0513)	(0.0512)	(0.0512)	(0.0513)
Treat × Floods	1.028	1.033	1.033	1.035	1.033	1.032	1.034
	(0.0536)	(0.0544)	(0.0543)	(0.0543)	(0.0544)	(0.0542)	(0.0544)
Constant	1.410**	1.328**	1.329**	1.380**	1.342**	1.330**	1.319**
	(0.192)	(0.179)	(0.179)	(0.195)	(0.181)	(0.179)	(0.178)
Observations	23,368	23,368	23,368	23,368	23,368	23,368	23,368
Pseudo R^2	0.53	0.53	0.53	0.53	0.53	0.53	0.53
CWS FE	Y	Y	Y	Y	Y	Y	Y
Day FE	Y	Y	Y	Y	Y	Y	Y
Sub-Basin × Week FE	Y	Y	Y	Y	Y	Y	Y

Robust standard errors in parentheses clustered at the CWS level
*** p<0.01, ** p<0.05, * p<0.1
Note: Y_{it} represents $Health\ Violations_{it}$

Given that this dissertation analyzes two years' worth of data, there is a potential concern that weather variables such as floods or precipitation could bias the effect of the temporary CWA rollback. Therefore, as a precautionary measure several tests were conducted to identify if floods or precipitation moderate the treatment effect of the CWA rollback or if floods or precipitation change significantly in the treatment group in the post policy rollback time period. Table 12 provides the weather moderator test results. Using a 158-day post period, model 1 and 2 tested if the policy treatment effect is moderated by precipitation (Treat × Post × Precipitation) or floods (Treat × Post × Floods). Similarly, models 3 and 4 also tested if precipitation and floods moderate the treatment effect in this study using a 365-day post period. None of the moderator tests in Table 12 show signs of significance, suggesting precipitation and floods do not moderate the treatment effect of the temporary CWA rollback.

Table 12: Weather moderator test results

VARIABLES	(1) Y_{it} 158d	(2) Y_{it} 365d	(3) Y_{it} 158d	(4) Y_{it} 365d
Treat × Post	0.993	1.303	1.414*	1.611***
	(0.302)	(0.301)	(0.284)	(0.291)
Treat × Post × Precipitation	14.98	5.898		
	(25.66)	(7.842)		
Precipitation	0.0172***	0.0869*		
	(0.0244)	(0.110)		
Treat × Post × Floods			1.074	0.986
			(0.0741)	(0.0410)
Floods			0.948	0.979
			(0.0328)	(0.0271)
Constant	1.770***	1.239	1.045	0.920
	(0.339)	(0.203)	(0.0396)	(0.0508)
Observations	15,896	22,779	15,896	22,779
CWS FE	Y	Y	Y	Y
Day FE	Y	Y	Y	Y
Sub-Basin × Week FE	Y	Y	Y	Y

Robust standard errors in parentheses clustered at the CWS level
*** p<0.01, ** p<0.05, * p<0.1
Note: Y_{it} represents $Health\ Violations_{it}$

Table 13 provides DID estimates identifying if precipitation or flood events changed significantly in the treatment group after the temporary policy was adopted. This study's precipitation data are reported at the monthly level and this study's dataset is measured at the daily level, thus measures of precipitation will correlate within months in the models. Models 1 and 3 cluster standard errors at the CWS level and models 2 and 4 cluster at the CWS level and the monthly level to account for within monthly correlations. Model 3 estimates suggest that precipitation levels were 0.03% lower in the treatment group in the post period; however, after clustering standard error calculations at the monthly level in model 4, the change in precipitation in the treatment group in the post period becomes insignificant. The drop in significance after clustering at the monthly level and since the calculated IRR in column 3 is extremely close to the value one, it is expected that precipitation and floods do not significantly change in the treatment group after the temporary policy adoption in 2020.

Table 13: Weather dependent variable test (precipitation)

VARIABLES	(1) Precipitation 158d	(2) Precipitation^{M} 158d	(3) Precipitation 365d	(4) Precipitation^{M} 365d
Treat × Post	0.998	0.998	0.997**	0.997
	(0.00204)	(0.00281)	(0.00170)	(0.00260)
Constant	0.150***	0.150***	0.143***	0.143***
	(3.90e-05)	(4.80e-05)	(4.83e-05)	(6.96e-05)
Observations	8,167,796	8,167,796	11,415,348	11,415,348
CWS FE	Y	Y	Y	Y
Day FE	Y	Y	Y	Y
Sub-Basin × Week FE	Y	Y	Y	Y

Robust standard errors in parentheses clustered at the CWS level
*** p<0.01, ** p<0.05, * p<0.1
Note: M indicates robust standard errors in parentheses clustered at the CWS and month level

Table 14 provides DID estimates when using floods as the dependent variable. This study's flood data are reported at the monthly level and this study's dataset is measured at the daily level, thus flood counts will correlate within months. Models 1 and 3 cluster standard errors at the CWS level and Models 2 and 4 cluster at the CWS level and the monthly level to account for within monthly correlations. None of the models in Table 14 indicate that floods increase in the post period in the treatment group after the temporary policy adoption.

Table 14: Weather dependent variable (floods)

VARIABLES	(1) Floods 158d	(2) Floods^{M} 158d	(3) Floods 365d	(4) Floods^{M} 365d
Treat × Post	0.999	0.999	1.000	1.000
	(0.0206)	(0.0359)	(0.0164)	(0.0294)
Constant	2.595***	2.595***	2.543***	2.543***
	(0.00805)	(0.0136)	(0.00796)	(0.0138)
Observations	2,475,715	2,475,715	2,969,305	2,969,305
CWS FE	Y	Y	Y	Y
Day FE	Y	Y	Y	Y
Sub-Basin × Week FE	Y	Y	Y	Y

Robust standard errors in parentheses clustered at the CWS level
*** p<0.01, ** p<0.05, * p<0.1
Note: M indicates robust standard errors in parentheses clustered at the CWS and month level

Chapter 5: Discussion

Analyzing the CWA-SDWA institutional dilemma provides an opportunity to better understand the complexities of contested federalism in the multilevel implementation of environmental policy in the United States. This analysis demonstrates how a federal rollback in CWA enforcement requirements could impact local government SDWA policy outcomes and how state and local SDWA institutional arrangements amplify or buffer a CWA rollback effect. This chapter is broken into five sections. Sections one through four overview the findings within the context of this study's four hypotheses. Section five provides the study implications.

1. Hypothesis One: CWA-SDWA Institutional Dilemma

First, this study establishes a link between federal CWA enforcement and local SDWA compliance. The findings suggest that local government CWSs sourcing from surface waters in the forty-three states with both CWA and SDWA enforcement primacy did experience significantly more SDWA health violations after the federal rollback in CWA enforcement requirements in 2020, affirming Hypothesis 1. Previous scholarship suggested that CWA enforcement and SDWA compliance are linked (e.g., Allaire et al., 2018); however, this study establishes one of the first empirical links between CWA enforcement and local SDWA compliance outcomes. These findings have key implications for US water policy and environmental federalism literature.

The CWA-SDWA institutional dilemma poses a serious concern for public tap water consumers being served by CWSs sourcing from surface waters. This study provides an empirical example of how politically motivated executive attempts to change federal CWA enforcement can affect SDWA compliance. Executive attempts to change federal environmental policy have generally become normalized; therefore, future presidential administrations could use executive means to roll back federal CWA enforcement again (Rabe, 2022). The consequences of a CWA rollback on SDWA compliance make it imperative that the CWA and SDWA be formally linked to ensure future changes to federal CWA enforcement are considered within the context of both CWA and SDWA compliance.

Furthermore, in the context of environmental federalism, the CWA-SDWA conundrum is particularly problematic because the CWA, like many other environmental policies, is highly politicized at the federal and state level and falls within the administrative purview of the executive branch. Legislative gridlock due to political polarization over the CWA, and other environmental policies, suggests presidential administrations will continue to use executive authority to make politically motivated changes to the CWA. In January 2023 the Biden administration introduced an executive action redefining Waters of the United States (WOTUS) to essentially match the Clean Water Rule put forward by the Obama administration in 2015. The same day the Biden administration's WOTUS amendments were uploaded to the federal registry, multiple state attorney generals, including Texas, sued the EPA to stall the administration's attempt to enhance federal CWA enforcement. This pattern of executive attempts to change federal EPA policy enforcement, followed by state-level attempts to stall the executive action in court, is another form of political polarization that stalls environmental policy updates at the federal level (Rabe, 2022).

Overall, CWA enforcement relies on shared responsibilities at the federal, state, and local levels. However, in the current state of contested federalism, where environmental policy gridlock ensues at the federal level, it is unlikely that local governments can rely on consistent federal environmental policy enforcement in the near future. Therefore, similar to other studies, state and local institutional governance factors may offer more reliable leverage points to safeguard local governments from federal CWA rollbacks or other environmental issues (e.g., Climate change) (Lee & Koski, 2015).

2. **Hypothesis Two: Agency Costs**

Agency costs emerge when principal governments adopt a policy that misaligns with agent governmental priorities (Farmer, 2022a, 2022b; Farmer & Lombeida, 2021; Youm & Feiock, 2019). Analyzing the moderating effect of state and local institutional arrangements driving or curbing agency costs on CWSs within the context of the CWA-SDWA dilemma helps identify if state-level enforcement stringency over the CWA functions as an institutional buffer against the negative externalities brought on by a federal CWA rollback. The primary agency cost hypothesis was that the temporary rollback would affect CWSs operating in states with relaxed CWA enforcement. Two measures were used to capture CWA enforcement stringency, including each state's CWA SRF enforcement record and the governor's political affiliation. This study found that states with a record of enhanced CWA enforcement experienced significantly more health violations, but states with a record of relaxed CWA enforcement were not shown to be significantly impacted by the rollback. Furthermore, though local governments in states with republican governors experienced approximately 50% more health violations, states with democratic governors experienced approximately 100% more health violations after the CWA rollback. These findings run counter to this study's agency costs hypothesis.

Following the literature on federal and state CWA implementation, state governments acquire CWA enforcement primacy to enforce more stringent standards or relax standards to accommodate industry interests (Elbakidze & Beeson, 2020, 2021; Woods, 2022). The key assumption driving this study's agency cost hypothesis was that state governments interested in relaxing CWA enforcement to support industry interests would use the temporary CWA rollback to further relax enforcement within their state (Woods, 2022). On the contrary, the two agency costs moderator tests suggest state-level CWA enforcement stringency did not function as a buffer against the federal CWA rollback.

One explanation for these findings could be that states already relaxing CWA enforcement within their legal jurisdictions were impacted less by a federal enforcement rollback simply because enforcement minimums have already been met within these states (Fowler & Birdsall, 2021c; Haider & Teodoro, 2021; Woods, 2006, 2021b). For example, NPDES-regulated entities in a state that already push the limits of CWA enforcement by under-inspecting or penalizing, likely already operate under relaxed regulations and do not need a federal enforcement rollback to relax CWA compliance (Grooms, 2015). Though these findings contradict this study's hypothetical expectations, the agency cost moderators provide interesting results that can inform future contested federalism scholarship. Overall, the agency cost findings suggest that both federal and state-level enforcement of the CWA affect SDWA implementation outcomes for local government CWSs sourcing from surface waters; however, enhanced state-level CWA enforcement is likely reliant on supportive and stringent federal CWA enforcement. These findings suggest that federal rollbacks in CWA enforcement can undermine state-level efforts to enhance CWA enforcement. Following these findings, this study does not identify evidence that state-level CWA enforcement stringency is a viable institutional leverage point to buffer against future CWA enforcement rollbacks. Therefore, future research is needed to identify how state-level CWA enforcement can be enhanced to safeguard against federal CWA rollbacks.

3. Hypothesis Three: Administrative Costs

Hypothesis Three focuses on administrative costs, which refer to the costs of state-centralized governance structures on local governments (Feiock, 2008; Farmer & Lombeida, 2021). Analyzing the moderating effect of a state's home rule provision in the context of the CWA rollback helps identify if local governments with increased autonomy over local fiscal and functional affairs functioned as an institutional buffer against the CWA rollback. As hypothesized, a state's home rule provisions negatively moderated the CWA treatment effect. This finding indicates that local government CWSs sourcing from surface waters and operating in states with heightened home rule provisions were affected less by the CWA rollback.

The primary explanation for this finding is that local governments with administrative autonomy had the flexibility or the resources (e.g., advanced water treatment technology) to proactively maintain safe drinking water for their communities while the temporary CWA rollback was in effect (Chen, 2022; Farmer & Lombeida, 2021). As it stands, no empirical research exists that has analyzed local government SDWA implementation compliance within the context of state fiscal and functional decentralization (i.e., home rule provisions); however, the findings concur with other studies analyzing the relationship between local environmental policy outcomes and state level home rule provisions. Previous findings generally find that localities operating in states that grant broad home rule take more sustainable actions to adapt to changing local environmental conditions than localities operating under Dillon's rule states (Chen, 2022; Feiock, 2008; Richardson, 2011). Overall, the administrative costs moderator results suggest that a state government's provision of autonomy and authority to its respective local governments functions as a potential leverage point for local governments to safeguard against point source pollutants in surface water supplies brought on by a federal CWA rollback. Future scholarship is needed to deduce more specific functional or fiscal variables that link to

SDWA compliance. This future work will help identify more specific leverage points for states to support local SDWA implementation. Furthermore, future studies will need to explore if functional autonomy, financial autonomy, or both are needed to provide local governments with the administrative resources needed to safeguard against surface water contamination.

4. **Hypothesis Four: Commitment Costs**

Commitment costs emerge when local governments are uncertain if they will have or will receive the necessary resources (e.g., funds, technology, expertise, workforce) needed to implement a policy. Commitment costs can lead to poor policy outcomes when local government resources are so limited that they cannot meet state and federal policy implementation expectations (Farmer, 2022a, 2022b; Farmer & Lombeida, 2021). Analyzing the moderating effect of local government commitment costs helps identify potential leverage points for state and local governments to safeguard against a future federal CWA rollback or other related issues. Two of the seven commitment cost measures, including (1) a CWS's community rurality status and (2) historical (2010-2019) CWA intergovernmental funding, significantly moderated the CWA rollback effect.

First, regarding community rurality, local government CWSs sourcing from surface waters and operating in rural counties experienced significantly more health violations after the CWA rollback. This finding suggests that local government CWSs sourcing from surface waters and operating in rural counties were more vulnerable to the CWA rollback, while CWSs operating in urban counties were potentially less vulnerable. This finding aligns with previous studies analyzing SDWA non-compliance (Allaire et al., 2018, 2019; EPA, 2011; Rubin, 2013). Rural CWSs tend to serve not only small populations but are also more isolated from other larger systems (Marcillo & Krometis, 2019). Small systems can commonly incorporate with nearby systems in urban communities, while rural systems essentially fend for themselves. Furthermore, rural systems serve small populations, making it challenging for these CWSs to qualify for a DWSRF state revolving fund loan or collect enough funds to update drinking water treatment technology or practices (Daley et al., 2014; Mullin & Daley, 2018). Rural CWSs have historically violated SDWA compliance requirements more than urban CWSs, and in the context of this study, these systems were also more vulnerable to spikes in surface water contaminants brought on by the CWA enforcement rollback. Overall, rural CWSs suffer from financial and technical commitment costs, and as expected, these systems were likely more vulnerable to the CWA rollback.

Second, average per capita CWSRF funding (i.e., intergovernmental SRF funding for CWA compliance) negatively moderated the effect of the CWA rollback. This finding suggests that increased federal financial support specifically for projects related to CWA compliance potentially functioned as a buffer against the federal CWA enforcement rollback for local government CWSs sourcing from surface waters. Local government CWSs operating in states with higher per capita CWSRF loan distributions were impacted less by the CWA rollback than systems with lower CWSRF support. This finding provides evidence that there is a positive link between top-down fiscal support for local governments and local environmental policy outcomes (Farmer, 2022a, 2022b; Farmer & Lombeida, 2021; Youm & Feiock, 2021). This finding is particularly interesting within the context of the CWA-SDWA dilemma because it links federal CWA enforcement and funding to local SDWA compliance outcomes. Future studies should explore if different types of CWA-funded projects, such as wetland restorations, ultimately functioned as buffers against the CWA rollback (Stave, 2001). Once it is more clear what type of

CWA compliance projects safeguarded local government SDWA compliance, states can take actions to implement these projects within their respective jurisdictions.

5. Implications

This study's results provide key practical and theoretical implications that should be considered when understanding environmental policy implementation in the US multilevel governance system. First, this study is the second to analyze the impact of the temporary policy on local environmental compliance. Persico & Johnson (2021) analyzed the temporary policy's effect in the context of the Clean Air Act and found that the rollback led to an increase in point-source air pollution and COVID-19 respiratory deaths. This dissertation investigated the policy within the context of the CWA and found that the policy likely led to an increase in SDWA health violations by local government CWSs sourcing from surface water. Together these studies provide evidence that delegating enforcement authority to state governments within the context of the temporary EPA policy did not enhance local environmental policy outcomes. Instead, easing federal environmental policy enforcement worsened local environmental compliance outcomes and threatened the health of communities across the continental US.

Analysis of the temporary policy’s effect on local environmental policy implementation outcomes suggests that federal environmental policy enforcement is the backbone on which state and local governments base their environmental policy enforcement and implementation. The CWA and SDWA overhauled water resources management in the US in the 1970s, leading to drastic improvements in surface water quality and drinking water quality (Jerch, 2019; Keiser et al., 2019). However, due to political polarization, most federal environmental protection-based policies, including the CWA, have not been substantially changed or updated since the 1980s and 1990s (Rabe,2022). Since the George W. Bush administration, presidential administrations have attempted to use executive authority to change environmental policy. However, many executive actions never went into effect due to state governments suing the federal government and staying the executive action in court (Rabe, 2022). The temporary EPA rollback provided a glimpse into what may occur if the federal government chooses to delegate environmental policy enforcement to state governments and it goes into effect without being stayed in court. Given the findings in this study and other recent studies, the two key policy implications at the federal level include (1) federal delegation of environmental policy enforcement to state governments can lead to poor local implementation outcomes and (2) federal environmental policy actions in one sector can negatively affect implementation outcomes in another sector (e.g., CWA-SDWA institutional dilemma).

In the context of state and local institutional factors, two measures emerged as potential leverage points to mitigate the adverse effect of a federal CWA enforcement rollback. First, local governments sourcing from surface waters and operating in a state that grants broad fiscal and functional autonomy (i.e., home rule) were affected less by the temporary CWA rollback than local governments with limited fiscal and functional autonomy. This finding suggests that state political officials that have broadened local autonomy within their jurisdictions provided their encompassed local governments the ability to take innovative and locally necessary steps to maintain SDWA compliance after the temporary policy was adopted. Second, local governments sourcing from surface waters and operating in states that received the highest per capita CWSRF funding between 2010 to 2019 were affected less by the CWA rollback than those that received lower CWSRF funding. This study's finding suggests that federal CWSRF financial support may function as a buffer against pollutant discharges to surface waters and reduces local government SDWA commitment costs. Overall, local autonomy and federal financial support are two potential avenues to safeguard CWSs sourcing from surface waters against future CWA rollbacks or other issues driving surface water quality declines.

On the other hand, several institutional factors, including (1) states with a record of enhanced CWA enforcement stringency, (2) states governed by democratic governors, and (3) rural communities, made local governments sourcing from surface waters potentially more vulnerable to the CWA rollback. This study's findings suggest that a federal rollback essentially undermined the ability of states to maintain enhanced CWA enforcement within the state. Additionally, multiple commitment cost measures in this study did not significantly moderate the temporary policy effect. Given the mixed commitment cost-based findings, the link between local government SDWA compliance and commitment costs should be explored further in future studies.

Overall, this study identified key implications regarding the enforcement and implementation of environmental policy that also provide key implications for the Contested federalism literature more broadly. The transaction costs of contested federalism literature contend that contestation between the tiers of government leads to policy misalignment and poor implementation outcomes at the local level. Key transaction costs emerge, particularly at the state and local level, when political contestation plagues the federal system. Overall, this theory suggests that increased financial and functional support from principal governments to agent governments alleviates transaction costs at the local level and ultimately promotes better implementation outcomes (Feiock, 2008). This study contributes to the contested federalism literature by providing additional evidence that political contestation over environmental policy enforcement associated with poor implementation outcomes at the local level.

Interestingly, local functional autonomy (i.e., home rule provisions) and intergovernmental financial support emerged as the two variables that may have decreased the effect of the CWA rollback on local governments. This indicates that increased top-down financial and functional support may have led to more effective, efficient, and equitable policy implementation outcomes. This study was one of the first to use the transaction costs of contested federalism theory to guide a study that analyzes state-to-local policy outcomes within the context of a federal environmental policy shift. Additionally, to the author's knowledge, this is the first study to analyze SDWA compliance within multilevel governance and contested federalism. Given the results, further research is needed to identify how transaction costs brought on by both federal and state institutional factors drive local environmental policy implementation outcomes. A specific look at how this rollback impacted the economic systems driving CWA and SDWA compliance enforcement at all levels of the federal governance system may provide further insight into potential financial mechanisms driving or moderating the effect of the temporary CWA rollback on SDWA compliance. Local governments are nested within both state and federal institutional arrangements; therefore, local environmental policy decisions and outcomes should be considered within this nested institutional context in future scholarship.

Chapter 6: Conclusion

The temporary EPA COVID-19 policy provided an example of how a federal CWA enforcement rollback can impact local SDWA compliance. This study aimed to answer two research questions (1) Do federal CWA compliance enforcement rollbacks lead to increased SDWA non-compliance by local government owned CWSs sourcing from surface waters? (2) Do state and local institutional governance arrangements buffer against the potential adverse effects of federal CWA rollbacks on surface water quality? While this dissertation attempted to answer these questions within the context of this temporary federal policy, further analyses are warranted before we can concretely validate any findings.

1. Summary

This dissertation identified empirical evidence that a decrease in federal CWA enforcement likely led to an increase in local SDWA non-compliance, suggesting that the CWA-SDWA institutional dilemma is a policy area of concern, particularly for CWSs sourcing from surface waters. Furthermore, guided by the transaction costs of contested federalism theory, multiple state and local level transaction cost measures showed signs of significant moderation of the CWA rollback effect, including state-level CWA administrative enforcement, state-level CWA political enforcement, state delegation of authority to their encompassed local governments (i.e., home rule provisions), CWS community rurality status, and CWSRF funding for CWA related projects. Overall, this theory helped explain why some institutional factors at the state and local levels made local governments more vulnerable to misaligned federal CWA policy. These findings indicate that federal funding and local fiscal and functional autonomy are the two primary institutional factors in this study that potentially buffered against the CWA rollback. Scholars can explore these two factors further to identify if scaling up federal CWA funding and local autonomy will help buffer against future federal CWA rollbacks or other issues that could decrease surface water quality in the US. Furthermore, this study found that some institutional factors made CWSs sourcing from surface waters more vulnerable to the federal CWA rollback. Contrary to expectations, local government CWSs sourcing from surface waters and operating in states with enhanced administrative and political CWA enforcement stringency experienced significantly more health violations after the rollback. Additionally, local government systems operating in rural communities experienced significantly more health violations after the CWA rollback. These three institutional factors should be explored further to identify why these systems showed signs of increased vulnerability to the rollback and how to safeguard these systems from future rollbacks or other issues negatively impacting surface water quality. Though these are the key takeaways, limitations in this study suggest the findings may not be causal. Thus, all findings should be considered associations that require further validation in future studies.

2. Study Limitations and Future Research

This study has multiple limitations that provide avenues for future research. Firstly, as a case study, this dissertation can only draw concrete conclusions within the context of the temporary policy. However, given the findings from this policy case study, future studies are needed to explore the effect of other federal CWA changes on local SDWA compliance. Furthermore, future studies should not only explore the CWA and SDWA but should also explore how shifts in other US environmental policy areas that rely on vertically shared responsibilities (e.g., Resource Conservation and Recovery Act) affect local policy outcomes. Identifying patterned effects of federal environmental policy changes will provide a more nuanced understanding of how these changes impact local implementation outcomes. Ultimately, the goal of this future work would be to identify solutions to environmental policy implementation problems in the US multilevel governance system.

Second, the authors caution against interpreting this dissertation's results as causal due to SDWIS data limitations. Though this dissertation used the same data that the EPA uses to track state and local SDWA compliance, these data are potentially underreported or misreported. Multiple studies suggest that small CWSs consistently underreport violations, but these are also the systems most likely to experience a violation; therefore, the SDWIS data used in this study may be missing health violation data that was not reported (Allaire et al., 2018). To mitigate this issue, following previous studies, systems serving less than 501 people were excluded from the analysis because these are the systems most likely to underreport violations, especially during the COVID-19 pandemic when financial and functional resources were strained and state and local governments had to take on increased responsibility (Allaire et al., 2018; Greer et al., 2022a; Greer et al., 2022b). Additionally, Beecher (2020) analyzed a sample of CWSs from the Great Lakes region and found that a small percentage of CWSs miscode their ownership status; therefore, it is possible some of the CWSs included in this analysis were miscoded as local government owned and some CWSs that are local government owned but miscoded as privately owned, were not included in this analysis. Overall, this data limitation is an issue that the EPA, states, and local governments have tried to remediate, but until all data are reliably recorded and coded, any study using SDWIS violation data would be hard-pressed to prove their data is 100% coded and reported correctly (Beecher, 2020).

Third, also relating to the SDWIS data, this dissertation focused solely on local government owned CWSs. The SDWIS data repository does not provide granular information on the type of local government that owns a CWS. CWSs can be owned by cities, counties, and special districts, each of which is institutionally unique and likely to operate CWSs heterogeneously, but this information is not available in the SDWIS database (Dobbin & Fencl, 2021; Lubell et al., 2002). Additionally, local governments and CWSs are particularly institutionally diverse; therefore, it is likely that additional local institutional factors that impact SDWA compliance were not considered in this dissertation (Bell et al., 2023). Therefore, future studies should consider analyzing if SDWA compliance varies systematically depending on local government types or other locally relevant institutional factors. This study took the first step of identifying a link between federal CWA policy enforcement and local SDWA compliance. Future studies are needed to identify more nuanced variables that practitioners and policy makers can utilize to safeguard local SDWA implementation, particularly for systems sourcing from surface waters.

Fourth, the temporary EPA policy rollback was the Trump administration's response to the COVID-19 pandemic. The COVID-19 pandemic strained the resource capacity of all levels of government, likely making it more challenging for all levels of government to implement any policy, including the CWA and SDWA. This dissertation utilizes a control group to account for the potential increase in SDWA violations due to common resource capacity concerns brought on by the pandemic (e.g., worker shortages). However, it is possible that the US multilevel governance system would have responded differently to a CWA enforcement rollback if it was not operating in a pandemic or other society-level issue (e.g., economic recession, world war) that affects all levels of government. For example, similar to other executive attempts to shift environmental policy, had the country not been in a state of emergency, state attorney generals may have successfully stayed the temporary policy in federal court by suing the EPA (Rabe, 2022). Furthermore, it is widely cited that upon entering office, President Trump and his administration made multiple concerted efforts to weaken the EPA and federal oversight of environmental protection more generally (Rabe, 2022). Therefore, it is possible that state and local governments were already contending with lowered federal oversight and regulatory consistency and were thus already in a vulnerable position leading up to the temporary COVID-19 rollback. This potential "all of society" limitation indicates that future studies should also analyze how shifts in federal CWA responsibility impact(ed) SDWA compliance when the nation's resource capacity is/was not strained from a societal issue and when the EPA is not administratively weakened. Future analysis will help deduce if CWA rollbacks lead to similar SDWA compliance effects in non-pandemic times and will provide insight into how the federal government can manage CWA regulatory compliance both during and outside of a pandemic. Lastly, this study only focused on health based violations as the outcome variable in this study. This study does not definitively measure surface water pollutant compositions, nor the types of pollutants discharged into surface waters. However, specific types of wastewater discharges could have led to more health violations than other types of discharges (e.g., industrial discharges, agricultural discharges). Additionally, this study did not analyze the environmental impact of the temporary policy. Future studies are needed to explore what types of discharges were the most detrimental to public health and environmental health and where after the temporary CWA rollback or other CWA shifts at the federal level. This dissertation did not consider location-based spillover effects from one state jurisdiction to another; therefore, future studies are needed to understand how state enforcement heterogeneity of the CWA impacts SDWA compliance in neighboring states when surface waters flow across state lines. Similarly, future studies are needed to explore other outcome variables that are expected to be directly or indirectly affected by an increase in point-source discharges, including surface water contaminant concentrations, waterborne diseases, health care costs, governmental financial expenditures, and likely more.

3. Final Note

Despite the limitations of this study, our findings suggest that local drinking water administration can be adversely affected by rollbacks in CWA enforcement, but states and local governments can take preventative measures to overcome these effects. This dissertation argues that “Contested Federalism” over environmental policy at the federal level likely led to misaligned executive policy (i.e., temporary policy) that likely negatively impacted local SDWA compliance outcomes. It further argues that some state and local institutional factors likely made local governments more or less vulnerable to a federal CWA rollback. These arguments are supported both theoretically and empirically. This study’s findings bring insight regarding the degree to which policy responsibility should remain federally centralized rather than devolving responsibilities down to the local levels. This dissertation provides a new avenue for scholarly investigation by providing some of the first empirical evidence that CWA enforcement and local SDWA implementation compliance are linked. While this dissertation’s contributions require validation in future studies, they help pave the way for future research on US drinking water administration, contested federalism, environmental policy, and multilevel governance.

Appendix

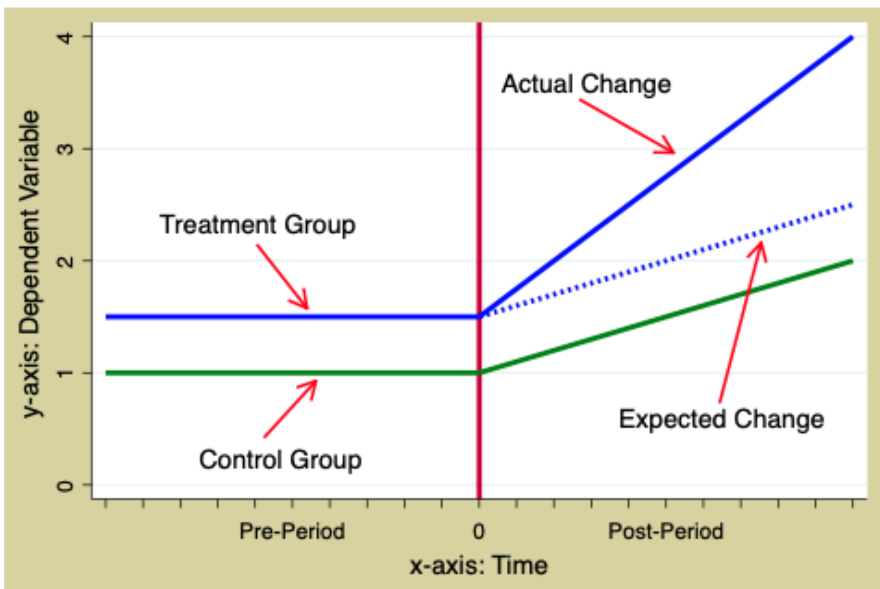
Appendix A: Difference-in-Differences Empirical Framework

Proving causality in social inquiry has historically proven difficult when analyzing observational data (King et al., 1994). In experiments, researchers control the experimental environment and the study participants; however, determining the impact of a program or policy implementation on a subset of the population, for example, commonly requires the use of nonexperimental or observational data (Dague & Lahey, 2019). When data permits and a researcher provides evidence that a natural experiment occurred, then the difference-in-differences framework can be employed to include a quasi-control group (Irwin et al., 2021). Natural or quasi experiments theoretically provide social science researchers the ability to use observational data to deduce causal results (Cárdenas & Ramírez de la Cruz, 2017; Schiozer et al., 2021).

The DID quasi-experimental design first requires a researcher to identify the occurrence of a natural experiment, and then provide a justification that the control and treatment groups are indeed similar. To do this, researchers must satisfy the common trends assumption (Schiozer et al., 2021). The common trends assumption relates to the pre trends of the dependent variable in the treatment and control groups. The DID estimation assumes that in the absence of treatment the difference between the treatment and control groups would remain constant over time. To back this assumption, the researcher must provide evidence that the treatment and control group exhibit common trends leading up to the treatment time.

Appendix Figure 1 visualizes the common trend assumption. The pre-period in Appendix Figure 1 depicts the treatment and control groups' dependent variable time trend leading up to the treatment event (e.g., policy implementation date, program start date, etc.). Pre-trends must be common leading up to the treatment time to validate the usage of the control group in a DID model. Furthermore, the post-period time trends show the change in the two groups after the event began. The blue dotted line shows the expected change in the treatment group if the event never occurred. The expected change is based on the control group change (i.e., counterfactual change).

Figure 6: Visual depiction of a theoretical difference-in-differences design



Once the common trends assumption is satisfied the researcher can move forward with deducing if an event caused a change in the treatment group that was significantly different from the control group. Appendix Table 1 shows the simple mechanics of DD. The mean differences (post-pre) are calculated for the treatment (Treat Diff) and control (Control Diff) groups, and then those mean differences are calculated between the treatment difference and control difference (Treat Diff – Control Diff). However, simply relying on the pre-post differences of the treatment group would not provide an accurate estimate of the impact of the event because other variables could have impacted the observations in the treatment group. Thus, a control group from the same population as the treatment group must be analyzed to understand the change that would have theoretically happened to the treatment group if the treatment event never occurred. Hence the final difference in Table 1 (Treat Diff) – (Control Diff) = DID estimate).

Table 15: Simplified form of the difference-in-differences empirical estimation

	Pre-Event Time Period	**Post-Event Time Period**	**Differences**
Treatment Group	Mean Treat Outcome Value in pre-period	Mean Treat Outcome Value in post-period	(Post Mean) – (Pre Mean) = Treat Diff
Control Group	Mean Control Outcome Value in pre-period	Mean Control Outcome Value in post-period	(Post Mean) – (Pre Mean) = Control Diff
DD Estimate			(Treat Diff) – (Control Diff) = DID estimate

To produce a more reliable estimate, the DID design can be modeled in a regression model. In a regression model, the significance of the DID effect estimate can be calculated, and the power of a panel dataset can also be exploited (Dague & Lahey, 2019). Panel datasets represent repeated time measures of the same individual (e.g., person, organization) over time. Therefore, DID fixed effect models can address the issue of fixed unobservable omitted variable bias. Fixed effect models can difference out unobserved heterogeneity that is constant at the level of a fixed effect. Spatial fixed effects difference out unobserved omitted variables that do not vary over time (Dague & Lahey, 2019). For example, a model with county fixed effects can control for all variables that do not vary at the county level (e.g., county policies). Additionally, time fixed effects can also be included to eliminate unobserved variables that impact the entire population over a given time period (Dague & Lahey, 2019). So long as the common trends assumption is met, the DID fixed effects design produces a reliable isolated estimate of the treatment effect.

The DID approach lends well to policy analysts aiming to understand the causal impact of policy implementations because policies often only impact a subset of the population (Dague & Lahey, 2019). Card & Krueger (1994) was one of the first studies to implement the differences-in-differences approach to determine the impact of New Jersey's April 1st, 1992 minimum wage increase policy on new hire rates. Many political entities suggested the minimum wage increase would force businesses to hire fewer employees, which Card & Krueger (1994) later proved wrong by comparing employment levels before and after the April 1st, 1992, date to a control group. They used Pennsylvania hiring data as the control group because the state did not increase the minimum wage in 1992, and the state's composition was quite similar to New Jersey's composition. Overall, this method of isolating policy effects has been widely used across the social sciences and is implemented in this dissertation (Dague and Lahey, 2019).

Appendix B: Study Variables Table

Table 16: Study variables

	Variable Name	Description
Dependent Variable		
SDWA Health Compliance measure	*Health Violation*$_{it}$	Continuous count of SDWA health violations per day at the CWS level
Independent Variables		
Temporary Policy Measures	*Treat*$_i$	Binary variable that takes on the value of 1 if a CWS(*i*) sources from surface waters, and 0 otherwise.
	Post$_t$	Binary variable that takes on the value of 1 if an observation occurred on or after the temporary policy adoption date(*t*), and 0 otherwise.
Agency Cost Measures	*Relaxed CWA Compliance Record*$_i$	Binary variable that takes on the value of 1 if a state was assigned "Area for Improvement" on their most recent EPA state review of inspection or penalty enforcement on NPDES regulated firms, and 0 otherwise.
	Relaxed Political CWA Compliance$_i$	Binary variable that takes on the value of 1 if a state was governed by a republican in 2020, and 0 otherwise.
Administrative Cost Measure	*Home Rule Index*$_i$	Continuous home rule index variable measured between -1 and 1. States with broader home rule provisions have a index value closer to 1.
Commitment Cost Measures	*Population Served*$_i$	Continuous count of CWS population size served
	Community Income Inequality$_i$	Continuous variable providing a county's income inequality Gini index value.
	Rural Community$_i$	Binary variable that takes on the value of 1 if a CWSs is in a rural county (i.e., counties with less than 10,000 people), and 0 otherwise.
	DWSRF Funding$_i$	Continuous measure of average state level per capita funding to from the DWSRF for years 2010 to 2019
	CWSRF Funding$_i$	Continuous measure of average state level per capita funding to from the DWSRF for years 2010 to 2019
	System Age$_i$	Continuous measure of a CWS's years in operation.
	Watershed Impairment$_i$	Continuous ratio value of the area of impaired surface waters within a watershed (i.e., HUC 10) over the total surface water area in a watershed.
Controls		
Weather Controls	*Precipitation*$_{it}$	Continuous measure of average monthly precipitation in inches at the county level.
	Floods$_{it}$	Continuous measure of monthly flood event counts at the county level.
Fixed Effects	*CWS FE*	Unique value for all individual CWSs included in the study
	Date FE	Unique value for all individual days included in the study.

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Curriculum Vitae

Jesse L. Barnes
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EDUCATION

AUGUST 2019 – MAY 2023
DOCTOR OF PHILOSOPHY, UNIVERSITY OF NEVADA, LAS VEGAS
School of Public Policy and Leadership: Public Affairs

JANUARY 2018 – AUGUST 2019
MASTER OF SCIENCE, UNIVERSITY OF NEVADA, LAS VEGAS
College of Sciences: Water Resources Management

AUGUST 2012 – MAY 2016
BACHELOR OF ARTS, UNIVERSITY OF CALIFORNIA, BERKELEY
College of Letters and Sciences: Political Science

RESEARCH APPOINTMENTS

AUGUST 2022 – DECEMBER 2022
Public Affairs Department, Graduate Research Assistant — LAS VEGAS, NV
Analyzing local government collaborations on climate change mitigation and local government readiness for the diffusion of electric vehicles in the US with Dr. Jayce Farmer at the University of Nevada, Las Vegas (UNLV).

NOVEMBER 2021 – MAY 2023
Nevada Health Workforce Research Center (NHWRC), Research Analyst — RENO, NV
Analyzing and reporting on health workforce supply and demand in Nevada at the NHWRC housed within the Office of Statewide Initiatives (OSI) with Dr. John Packham and Dr. Tabor Griswold at the University of Nevada, Reno.

DECEMBER 2021 – JANUARY 2022
Life Sciences Department, Research Assistant — LAS VEGAS, NV
Analyzed and visualized gene data using R and STATA for the Robleto Lab with Dr. Eduardo Robleto at UNLV.

JUNE 2021 – OCTOBER 2021
Marketing Department, Research Assistant — LAS VEGAS, NV
Analyzed survey and secondary data on residential solar panel adoption in Nevada with the marketing Department Chair Dr. Anjala Krishen in partnership with NV Energy at UNLV. Grant funded through the Department of Energy.

AUGUST 2019 – MAY 2021
Public Affairs Department, Graduate Research Assistant — LAS VEGAS, NV
Analyzed rural farmer survey data using topic modeling and semantic analysis and worked on other research projects with Dr. Krystyna Stave at UNLV.

JANUARY 2020 – MAY 2020
Public Affairs Department, Research Assistant — LAS VEGAS, NV
Processed survey respondent data for the Nevada *State of the State* survey with Dr. Lee Bernick at UNLV.

JANUARY 2019 – AUGUST 2019
Civil Engineering Department, Graduate Research Assistant — LAS VEGAS, NV
Developed a system dynamics model of Las Vegas Valley urban point source and non-point source wastewater flow to Lake Mead with Dr. Daniel Gerrity. National Science Foundation grant funded position.

JUNE 2018 – JANUARY 2019

Civil Engineering Department, Research Assistant — LAS VEGAS, NV

Managed greenhouse tasks, lab tasks, and literature reviews for Dr. Daniel Gerrity. Tasks included tracking plant growth and contaminant uptake in plant tissue and lab-based testing of wastewater contaminant composition at UNLV.

TEACHING APPOINTMENTS

AUGUST 2020 – DECEMBER 2022

Public Affairs Department, Part-Time Instructor — LAS VEGAS, NV

1. Course: *URST 241 Urban Governance in the United States*
   Semesters Taught: Fall 2020, Spring 2021, Summer 2021, Spring 2022
2. Course: *ENV 101 Introduction to Environmental Science*
   Semesters Taught: Fall 2021, Spring 2022, Fall 2022
3. Course: *URST 410 Environmental Policy in Urban Settings*
   Semesters Taught: Fall 2021, Spring 2022
4. Course: *ENV 206 Introduction to Climate Change*
   Semester Taught: Fall 2021

PROFESSIONAL APPOINTMENTS

JANUARY 2018 – JANUARY 2019

Academic Success Center, Graduate Assistant — LAS VEGAS, NV

Planned, marketed, and managed large academic events including UNLV Pride and Math Bridge. Emphasis was on increasing retention rates and average GPAs for first-generation freshman college students.

MAY 2016 – AUGUST 2017

Cyber Security Account Executive, DARKTRACE—SAN FRANCISCO, CA

Performed 3-6 month outside sales role with 250+ employee sized companies, presented presales demonstrations at conferences to crowds of 100 to 500 people, and acquired new accounts from Nevada, Arizona, and California.

JUNE 2015 – JUNE 2016

Senior Business Development Intern, MORGAN STANLEY—SAN FRANCISCO, CA

Conducted extensive research on and reached out to potential clients and private companies for new business opportunities in multiple market segments in the California, Bay Area.

APRIL 2013 – JUNE 2015

Manager and Student Fundraising Trainer — BERKELEY, CA

Hired and trained students to fundraise over the phone, directed and managed shifts, and fundraised high-profile donors at the Cal Calling Center at UC Berkeley.

PUBLICATIONS

Published

1. Hu, H. F., Krishen, A. S., & **Barnes, J.** (2023). Through narratives we learn: Exploring knowledge-building as a marketing strategy for prosocial water reuse. *Journal of Business Research*, *158*, 113655. https://www.sciencedirect.com/science/article/abs/pii/S0148296323000139

2. **Barnes, J. L.**, Krishen, A. S., & Chan, A. (2022). Passive and active peer effects in the spatial diffusion of residential solar panels: A case study of the Las Vegas Valley. *Journal of Cleaner Production*, 132634. https://doi.org/10.1016/j.jclepro.2022.132634

3. **Barnes, J. L.**, Krishen, A. S., & Hu, H. F., (2021). *Untapped Knowledge about Water Reuse: the Roles of Direct and Indirect Educational Messaging.* Water Resources Management, 1-15. https://link.springer.com/article/10.1007/s11269-021-02853-z

4. **Barnes, J. L.**, & Nicholl, M. J., (2020). *Mildly hydrophobic biobased mulch: A sustainable approach to controlling bare soil evaporation*. Vadose Zone Journal, 19(1), e20047. https://acsess.onlinelibrary.wiley.com/doi/full/10.1002/vzj2.20047

Non-Peer Reviewed Research Report

1. **Barnes, J.,** Griswold, T., & Packham, J., (2022). *Primary Care Practice Patterns of UNR Med Graduates – 2005 to 2018.* Nevada Health Workforce Research Center. Reno, NV. https://med.unr.edu/statewide/reports-and-publications

Under Review

1. Krishen, A.S., **Barnes, J.L.**, Petrescu, M., Janjuha-Jivraj, S. *Social Media Narratives Tweeting for Change: Recognizing Responsible and Sustainable Service*.

2. Krishen, A.S., **Barnes, J.L.**, Chan, A. *Knowledge and energy storage intention: A mixed-method interdisciplinary inquiry exploring the role of trust*.

3. **Barnes, J. L.**, Krishen, A. S., & Hu, H. F., *Overcoming the Yuck Factor: Consumer Acceptance of Potable and De Facto Wastewater Reuse.*

In-Preparation

1. Farmer, J.L., **Barnes, J.L.**, *Regional Institutions and Interlocal Climate Change Partnerships*.

ACADEMIC PRESENTATIONS AND CONFERENCE PAPERS

1. Heron, R., **Barnes, J.L.**, Leyva-Sanchez, H.C., Robleto, E., (2022). *The effect of Mfd on expression of sporulation genes in B. subtilis*. Poster Presentation at the Wind River Conference on Prokaryotic Biology. Estes Park, CO. June 2022.

2. Farmer, J.L., **Barnes, J.L.**, (2022). *Regional Institutions and Interlocal Climate Change Partnerships*. Paper Presentation at the Midwest Political Science Association Conference. Chicago, IL. April 2022.

3. **Barnes, J.L.**, (2021). *Federal Environmental Policies & Local Level Implementation*. Rebel Grad Slam 3-minute Presentation Competition. University of Nevada, Las Vegas. November 2021. **[Top 10 Finalist Award]**

4. Hu, H., Krishen A., **Barnes, J.L.**, (2020). *Building Knowledge Through Trust: Exploring the Relationships of Political Ideology, Message Characteristics, and Water Reuse*. Paper Presentation at the AMA Winter Academic Conference, Virtual. February 2021.

5. Krishen A., Hu, H., **Barnes, J.L.**, (2020). *Untapped Education: Exploring the Relationship Between Political Ideology and Water Reuse*. AMA Marketing + Public Policy Conference. Marina Del Rey, CA. May 2020. **[Best Conference Paper Runner Up]**

6. **Barnes, J.L.**, (2019). *Application of Hydrophobic Layers to Reduce Bare Soil Evaporation*. Thesis Defense. Lilly Fong Geoscience Building, Las Vegas (UNLV), NV. July 2019. **[2020 Outstanding Thesis Award]**

AWARDS & ACHIEVEMENTS

1. ***Top 10 Finalist Award,*** from the 2021, 3-Minute Rebel Grad Slam Presentation Competition with 100+ graduate student competitors across all graduate departments, UNLV Graduate College, November 2021
2. ***2020 Outstanding Thesis Award***, from UNLV Department of Geoscience, October 2020
3. ***Best Conference Paper Runner Up***, from 2020 AMA MPPC Conference Peer-Reviewers, May 2020

4. **Selection of Media Responses to Barnes and Nicholl (2020)**:
   (1) "Plastic-Free 'Sustainable' Mulch is Useful to the Nursery," *Technology Times*, 16-Oct-2020 Link
   (2) "Researchers invent plastic-free 'sustainable' mulch," *Capital Press*, 15-Oct-2020 Link
   (3) "Sustainable mulch studied*," American Society of Agronomy*, 15-Oct-2020 Link
   (4) "First Look at a Sustainable Agricultural Mulch," *Soil Science Society of America*, 28-Sept-2020 Link

LEADERSHIP & PROFESSIONAL SERVICE

AUGUST 2021 – MAY 2022

Grad Rebel Ambassador — LAS VEGAS, NV

Ambassadors are highly visible members of the Graduate College team helping to build a strong graduate student rebel community and strengthen ties between the Graduate College and alumni and community members.

AUGUST 2020 – MAY 2021

Grad Rebel Advantage Program Mentor — LAS VEGAS, NV

Mentored and helped a cohort of undergrad students apply to graduate school during the 2021-2022 academic year.

JANUARY 2019

Help Hope Home—LAS VEGAS, NV

Data collection volunteer for the 2019 Southern Nevada Homeless Census.

PEER REVIEWER (ad hoc)

1. Journal AWWA (American Water Works Association)
2. Journal Energy Efficiency
3. Journal of Business Research

OTHER EDUCATION AND PROFESSIONAL EXPERIENCES

1. Conference Attendance: Western Region Flex Conference, Portland, OR. June 2022.

2. Three-Day Summer School: System Dynamics Modeling Using STELLA software. *International Conference of the System Dynamics Society.* Virtual. July 2020.