WATER AFFORDABILITY DISPARITIES IN NORTH CAROLINA

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Undergraduate Honors Thesis

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April 14, 2021

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ABSTRACT

This thesis examines disparities in water affordability in North Carolina by racial and ethnic groups via a quantitative analysis of a nine-year water provider-level, panel data set. I utilize regression analyses to answer the question "after controlling for demographic and financial characteristics and year fixed-effects, what is the relationship between minority presence and water bill prices in North Carolina?" This analysis is motivated by the United States' water affordability crisis and its documented disproportionate impact on non-white communities. Given that there are no federal nor state protections from water shutoffs, possible affordability disparities mean that racial and/or ethnic minority North Carolinians are at greater risk of losing access to water.

From my regression models, I observe that one percentage point increases in a county's Black population increases the cost of both water and wastewater bills, while one percentage point increase in a county's Latine[1] residents decreases the price of water and wastewater bills, with the disparity being greater for wastewater bills. These results indicate that Black North Carolinians face disproportionate water affordability challenges due to systemic inequalities in wastewater infrastructure quality. These affordability disparities are augmented by Black North Carolinians' disproportionately lower median incomes, increasing water affordability challenges for these individuals. These findings motivate the need for shut-off protections, targeted affordability assistance, and infrastructure investment.

[1]"Latine" is a gender-neutral term for Latino/Latina

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ACKNOWLEDGEMENTS

I am very grateful to Dr. Evan Johnson of the UNC Public Policy Department for being a fantastic mentor, advisor, and boss for the past year. He has taught me a great deal about the research process, strengthened my technical skills, and encouraged me to be ambitious and confident in both my academic and professional pursuits. I have appreciated his support throughout the thesis process, the most rigorous academic task I have completed during my time at UNC, as well as the confidence he's shown in me throughout our work and research together.

A big thanks to Dr. Jeremy Moulton of the UNC Public Policy Department for first encouraging me during my junior year to pursue a thesis, and helping me see it through by being an involved second reader that pushed me to produce my best work. Thank you also to Kellen Kane of the UNC Public Policy department for providing valuable advice and encouragement during my junior year, when I was first developing my research aims.

Thank you to Dr. Casey Wichman, Assistant Professor in the School of Economics at the Georgia Institute of Technology, for meeting with me and providing valuable personal knowledge of water affordability research methods and insights into his own research. Thanks to Bailey DeBarmore of the UNC Odum Institute for Research in Social Science for providing statistical support on many occasions. I also appreciate the knowledge shared by Evan Kirk, Project Director of the Environmental Finance Center, and Shadi Eskaf, Research Director of the Environmental Finance Center. This project was also supported by the Alexandre Honors Carolina Expendable Fund administered by Honors Carolina.

Finally, thank you to both my biological and chosen family who have loved, cared for, and sustained me throughout this season of my life, believing in me even when I did not believe in myself. I am exceedingly grateful for you all.

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Chapter 1: Introduction

As the United States' water infrastructure is repaired, water providers increase consumers' bills. Because non-white individuals have access to lower-quality infrastructure than white individuals, their water-delivery systems are in greater need of repair. As a result, their water bills may be more unaffordable than white individuals' due both to infrastructure updates and lower median incomes. Due to the federal water policy prioritizing water sanitation over affordability and equity, non-white communities are left more vulnerable to water shut-offs than white households.

U.S. Water Affordability

To absorb the costs of water system maintenance and repairs, water providers incrementally increase consumers' water bills. While consumers may not see large absolute increases in their water bills, incremental increases are more detrimental to low-income households relative to high-income households, and even small increases to their monthly bills can create affordability challenges (Mack and Wrase, 2017). Because there are no federal polices to protect consumers from water shutoffs in the United States, providers address accounts unable to absorb increased costs by shutting off their water supply (Mack and Wrase, 2017; Jones and Moulton, 2016). Therefore, without federal protections, water access in the U.S. is linked to one's ability to pay rising water bills, leaving low-income populations vulnerable to shutoffs.

Shortcomings of Current Polices and Affordability Metrics

The current water policy context in the U.S. is primarily focused on compliance and sanitation, rather than affordability. The U.S. Environmental Protection Agency's (EPA) water affordability standards are based on a census tract's median household income (MHI). If a tract's water bills are below 4.5% of the tract's MHI, they are deemed "affordable." This measure is meant to determine if municipalities are financially burdened by complying with the Clean Water Act (CWA) and/or the Safe Drinking Water Act (SDWA), rather than consumer affordability. This measure does not capture household-level affordability, nor does it consider the ability of low-income households to pay their water bill (Cardoso and Wichman, 2020; Mack and Wrase, 2017; Jones and Moulton, 2016). A census tract's MHI may mask water affordability challenges faced by low-income populations, especially in highly-segregated areas with significant disparities in income and wealth due to housing segregation. In such areas that contain extremely low- and/or high-income households, the MHI may be skewed and disguise water affordability challenges that low-income households face (PolicyMap, 2020; Logan and Stults, 2014).

Disproportionate Effects of the Water Affordability Crisis

Water unaffordability disproportionately affects Black and Latine families, who are more likely to have their water shut off than their white counterparts, even after controlling for poverty (Cardoso and Wichman, 2020; Jones and Moulton, 2016). These disproportionate effects are well-documented by other researchers, who have noted that poverty and/or income alone do not explain affordability challenges, the shortcomings of the EPA's water affordability measure, and the need for federal protections from water shutoffs (Cardoso and Wichman, 2020; Mack and Wrase, 2017; Jones and Moulton, 2016; Mirosa, 2015; Baird, 2010).

Hypothesis

I anticipate that water bill costs in North Carolina will increase as the percentage of non-white residents increases, holding income constant. This positive relationship between the minority population size and water price is due to differences in infrastructure access. Black and Latine families are more likely to live in areas with lower-quality infrastructure than white individuals due to environmental, systemic racism, segregation and white flight (Jones and Armanios, 2020; Logan and Parman, 2017; Gasteyer et al., 2016; Mirosa, 2015; Carrera, 2014; Logan and Stults, 2011; Carrera and Gasteyer, 2008; Wilson et al., 2008; Pulido, 2000). Thus, the water infrastructure that services these households will be in greater need of repair, increasing the costs that are passed along to Black and Latine consumers, relative to white consumers, by their water providers. Further, because these populations have lower median incomes than white N.C. residents **(Table 3.1)**, even equal increases to their water bills due to infrastructure repairs will be more financially burdensome, as they will make up a greater proportion of their overall income than that of white households.

Potential Policy Significance

There are currently no federal protections from water shutoffs. However, the EPA has recently suggested affordability metrics meant to monitor affordability for low-income households, although they have not yet been adopted (EPA, 2020b). This research may bolster efforts of activists and other researchers to persuade the EPA to implement these proposed changes to water affordability standards, federal water subsidies, or other changes that support water affordability, and, importantly, implement federal protections from complete water shutoffs. By examining the relationship between minority presence and the cost of water and wastewater bills, controlling for a host of explanatory variables, this thesis seeks to document the disproportionate effects of the water affordability crisis in North Carolina. North-Carolina-specific findings of inequitable water affordability may inform state water affordability policy to compliment future federal laws, meeting needs that may be underserved by federal regulations, as well as extending water affordability protections set forth during the COVID-19 pandemic.

Organization

After discussing U.S. water policy and causes of water unaffordability, the disproportionate impacts of climate change on non-white communities, the systemic nature of environmental racism, and the disproportionate impact of the water affordability crisis on non-white households, I explore if there is a relationship between minority presence and increasing water bills in North Carolina and, if so, what factors explain this relationship. The thesis is organized as follows: Chapter two examines extant water affordability literature, related research on climate change and environmental racism, and the disproportionate impacts of water affordability challenges, and identifies opportunities to add to this research. Chapter three explains the data and methods, describing the key variables and their construction, data sources, and models utilized. Chapter four describes the main findings, including the primary variable relationships and differential impacts of minority populations on water and wastewater bills, and the impact of affordability disparities. Chapter five concludes with a discussion of the validity of my initial hypothesis, limitations and generalizability of my findings, alternative hypotheses, and recommendations for both policy and future research based on my findings.

Chapter 2: Literature Review

To assess water affordability challenges in North Carolina, it is necessary to first examine literature detailing the underlying causes of U.S. water (un)affordability generally, the current, fragmented water policy context, the disproportionate effects of climate change, the relationship between climate change and water (un)affordability, and the systemic nature of environmental racism that results in the U.S. water affordability crisis to disproportionately burden non-white communities. This literature review details recent EPA reports, articles by water finance experts, foundational and contemporary published texts and dissertations explaining and/or demonstrating the mechanisms and effects of environmental racism, and extant nation-wide quantitative examinations of water affordability.

U.S. Water (Un)Affordability

Literature related to U.S. water unaffordability identifies outdated infrastructure and climate change as the primary causes of water unaffordability in the U.S. Necessary updates to aging waste-water and drinking-water systems, most of which have not been updated since those completed by the Works Progress Administration following World War II, will be costly to providers (Mack and Wrase, 2017; Jones and Moulton, 2016). These necessary infrastructure investments will require at least $1-trillion over the next 20–25 years (Cardoso and Wichman, 2020). As providers shoulder the cost of system maintenance and repair, consumers experience incremental increases to their bills to offset their providers' financial burdens (Mack and Wrase, 2017).

Current Policy Context

First authored in 1997, EPA water affordability standards use a census tract's MHI to determine affordability. If the average water bill is below 4.5% of a census tract's MHI, they are considered “affordable” (Mack and Wrase, 2017; Mirosa, 2015). However, this measure does not consider the ability of low-income families or otherwise disadvantaged populations to meet this standard, as median measurements do not accurately represent households at extreme ends of a given community’s income distribution (Baird, 2020; EPA, 2020b; Mack and Wrase, 2017; Jones and Moulton, 2016; Mirosa, 2015; Baird, 2010). A low-income household’s water bill may far exceed 4.5% of their income, but the higher incomes of other households in their census tract will raise the tract’s MHI, and their bill will thus be incorrectly categorized as “affordable,” per EPA affordability standards. Furthermore, this measure does not fully capture the extent of water affordability challenges, as it views unaffordability through a binary lens, possibly underestimating the extent of water unaffordability in a given census tract. For example, although a water bill that comprises 4.6% of a household’s income would be less financially burdensome than a water bill that comprises 10% of that same household’s income, these bills would be similarly labeled “unaffordable.”

In addition to the shortcomings of the EPA’s affordability metric, water affordability also goes under-attended due to extant water policies focusing primarily on sanitation. The CWA and the SDWA were meant to regulate water pollution and health risks, and do not contain “affordability standards meant to ensure that low-income consumers don’t lose access to their water services” (Jones and Moulton, 2016). Although state and local governments incur CWA and SDWA compliance costs, the federal government does not provide financial assistance to these governing bodies (Cardoso and Wichman, 2020; Mirosa, 2015; Gerlak, 2006). These unfunded federal sanitation mandates result in even higher rates for consumers, who absorb providers’ costs (Mack and Wrase, 2017, and Jones and Moulton, 2016). As a result, consumers are left to pay rising water bills, and are left unprotected by the lack of federal affordability policies and protections from water shut-offs.

Devolution of Governmental Responsibility

In addition to a lack of federal affordability standards and water shutoff protections, the lack of consensus over which governing bodies have the responsibility to address water affordability compounds consumers' vulnerability to shut-offs due to inaction and competing interests. U.S. water policy has devolved since the 1980s, with greater responsibility falling to state and local governments (Gerlak, 2006). Localizing the control of water-delivery systems increases fragmentation of water affordability policies, decreases regulation, and leaves the responsibility of ensuring consumers' access to water to stakeholders whose interests do not align with water affordability (Mirosa, 2015; Baird, 2010; Gerlak, 2006).

Currently, "local governments are responsible for 98% of all water and wastewater expenditures to comply with federal and state unfunded mandates." (Baird, 2020; EPA, 2020). Lack of federal and/or state assistance means that addressing affordability challenges is left up to individual providers. This is a threat to consumer affordability, given that the priorities of water providers and local governments often does not align with consumer affordability (Mack and Wrase, 2017; Mirosa, 2015; Gerlak, 2006). While federal regulations are focused on environmental concerns such as water quality, local governments are often focused on cost minimization, and water providers are typically most concerned with technical aspects of water delivery. Further, these providers often do not have knowledge of, nor an interest in, water affordability, as the business interests of providers conflicts with consumer cost minimization (Mirosa, 2015; Gerlak, 2006). Although some aspects of water affordability may be better-handled by state or local bodies than the federal government due to variation in factors such as regional climate, income, and infrastructure quality, the federal government has the responsibility to ensure, at a minimum, that funds are properly allocated to state governments to meet federal sanitation guidelines (Christian-Smith, Gleick, & Cooley, 2012). The federal government also has the capacity to establish water affordability standards, as the current policy context leaves consumers who absorb providers' compliance costs with little to no affordability assistance or protection (Cardoso and Wichman, 2020; Mirosa, 2015; Gerlak, 2006).

Proposed Federal Reforms

Changes to the EPA Affordability Metric

The federal government has signaled potential efforts to address water affordability challenges for low-income households. In September 2020, the EPA released their proposed 2020 Financial Capability Assessment, which included changes meant to support local governments' compliance with the CWA (EPA, 2020b; George and Pugh, 2020). Of particular importance to consumer affordability, the report recommended changes to the current affordability metric that relies on MHI to determine community water affordability. To address the shortcomings of this measure, the EPA suggested examining a community's Lowest Quintile Income (LQI) along with its MHI when determining water affordability, as LQI households spend a larger percentage of their income on water services relative to high-income households (EPA, 2020b). The EPA also proposed adjusting their LQI residential indicator by house size as a proxy for differences in water usage between median and LQI households (EPA, 2020b). These changes may alleviate the existing regressive nature of water bills, as the Water Research Foundation and the EPA found in 2010 that a third of LQI households experienced water shut-offs due to inability to pay their water bills on time. This rate of service disconnection was three times greater than the average, demonstrating the disproportionate burden of the water affordability crisis on low-income populations (Jones and Moulton, 2016).

Infrastructure Investment

Additionally, the Environment and Public Works Committee voted unanimously on March 24, 2021 in support of the amended Drinking Water and Wastewater Infrastructure Act. This legislation will invest more than $35 billion in U.S. water infrastructure (EPWCmte, 2021). If the Drinking Water and Wastewater Infrastructure Act is passed by Congress, this funding may minimize the costs water providers offset via increases to consumer water bills.

The Disproportionate Impact of Climate Change

Social groups are differentially affected by climate change due to social and economic factors, rather than simply different levels of exposure to climate hazards (Thomas, Hardy, Lazrus, et al., 2019). For example, income and resultant access to resources affects groups' ability to prepare for, protect themselves from, and recover from the hazards of climate change, such as hurricanes, tornados, and droughts, as those with greater resources can secure higher-quality housing that is less exposed to climate hazards, is more durable in the event of storms, and can recover lost housing and other resources more quickly (Thomas, Hardy, Lazrus, et al., 2019). Further, resource access influences social groups' ability to adapt to a changing climate. The unequal distribution of economic, institutional, and political resources enables highly-resourced individuals and groups to more readily adapt to changing climatic conditions than those who are less highly-resourced (Thomas, Hardy, Lazrus, et al., 2019). In the U.S., structural racism and the inequities that result increase the vulnerability of non-white individuals to the effects of climate change.

For example, racial, ethnic, and economic segregation in the U.S. have resulted in differential exposure to the effects of climate change, increasing the vulnerability of non-white individuals to the detrimental health and safety risks of climate change (Mitchell and Chakraborty, 2018). In a survey of twenty U.S. cities, Mitchell and Chakraborty (2018) found that U.S. urban-dwellers face higher temperatures than individuals who live in suburban or rural areas. This increased heat exposure is due, in part, to urban landscapes, which store and emit heat, and urban industrial processes that emit greenhouse gasses, increasing the temperature (Mitchell and Chakraborty, 2018). Mitchell and Chakraborty (2018) note that this "landscape of thermal inequity" results from segregation and economic inequality that leave minority and/or low-income individuals consistently exposed to higher temperatures, and the resultant health effects of this ongoing exposure.

The disproportionate effects of climate change are not limited to urban centers, however. There are many predominantly-Black communities along the eastern coast of the U.S., formed as a result of the enslavement and exploitation of West African people for their knowledge of rice cultivation on plantations along the coast (Hardy, Milligan, and Heynen, 2017). Contemporarily, these communities are located on the coast to support their livelihoods of fishery and agriculture. In turn, they are more vulnerable to the dangers of climate change due to rising sea levels (Miller Hesed and Paolisso, 2015). The implementation of "color-blind" environmental policies that do not account for non-white communities' increased differential risk and exposure only worsens existing inequities in access to resources that facilitates adaptation to climate change and relative protection from harm (Thomas, Hardy, Lazrus, et al., 2019).

Climate Change and Water (Un)Affordability

In addition to age-related wear, costs water providers incur due to the growing pressures of climate change present challenges for water affordability. Wastewater systems endure an increased frequency and intensity of weather events as a result of climate change, which causes costly strain to these systems (Mack and Wrase, 2017; Jones and Moulton, 2016; Christian-Smith, Gleick, & Cooley, 2012). While providers cannot postpone costs incurred through federal mandate compliance, those incurred via climate change-related damage may not be as highly-prioritized, and deferred in favor of keeping costs low to both providers and consumers. However, these repairs to water-delivery systems will soon become inevitable as non-renewable forms of energy are depleted, increasing reliance on water-delivery systems as hydrologic forms of energy are more heavily-utilized (Christian-Smith, Gleick, & Cooley, 2012). Consequently, consumers' bills will further increase to absorb these maintenance and repair costs of wastewater systems. The effects of climate change and water unaffordability are not experienced equally, but are instead exacerbated by existing societal inequalities such that marginalized communities experience disproportionate effects of both climate change and rising water bills (Schmeltz, 2021; Kaiisera and Kronsellb, 2014).

"The Spatiality of Racism"

The U.S. water affordability crisis disproportionately affects non-white communities across the nation (Cardoso and Wichman, 2020; Mack and Wrase, 2017; Jones and Moulton, 2016). These disproportionate effects demonstrate that water (un)affordability should be examined in a larger context that considers historical patterns of exclusion, contemporary housing segregation, and inequitable access to quality infrastructure and environments free of toxins (Jones and Armanios, 2020; Gasteyer et al., 2016; Mirosa, 2015; Pulido, 2000). Rather than a direct causal relationship between race and disproportionate water affordability concerns, these inequalities result from the impact of race on one's built, natural, and sociopolitical environments (Thomas, Hardy, Lazrus, et al., 2019; Mitchell and Chakraborty, 2018; Miller Hesed and Paolisso, 2015; Balazas and Ray, 2014).

The term "environmental racism," a concept that first emerged in the late 1980s, is most often associated with the disproportionate impact of toxins on non-white communities, as well as the discriminatory development and/or implementation of environmental policies (Wright, 2018; Pulido, 2000). However, Pulido (2000) argues that this definition does not fully explain how and why environmental racism manifests, as the effects of environmental racism do not result only from conscious, malicious intentions of individuals on an interpersonal level, but also from systemic injustice and the exploitation of space as a resource and tool of white privilege. Previous understandings of environmental racism did not include discussions of what Pulido (2000) calls "the spatiality of racism." Pulido (2000) explains that "homogeneous white spaces are necessary for the full exploitation of whiteness" and the creation of a social system that benefits white individuals. That is, systemic racism and white privilege result in white individuals holding disproportionate amounts of wealth and benefitting from laws that enable and prioritize their upward economic mobility, while non-white individuals do not benefit, and are harmed, from this system.

Therefore, white individuals can act to secure cleaner environments than their non-white counterparts through processes such as suburbanization and decentralization (Pulido, 2000). Recent literature confirms Pulido's (2000) previous research on suburbanization, as Mack and Wrase (2017) noted that suburbanization has decreased water providers' customer base in central cities. Consequently, households located in urban centers may face higher absolute water bills due to the decreased number of accounts for providers to divide maintenance and compliance costs between. Recent literature also confirms Pulido's (2000) assertions of the destructive effects of "the spatially of racism" by illustrating the negative effects of segregation, and explains that although there may appear to be progress towards residential integration in the U.S., it is due to an increase in the Hispanic population and integration between non-white racial groups, rather than integration between white individuals and racial minorities (Logan, 2014).

Segregation in metropolitan areas remains high due to white-flight that occurs in reaction to the growth of minority populations in a neighborhood. So, despite formerly-white neighborhoods across the U.S. diversifying, segregation persists because white residents often move from these diversifying areas, and rarely move into neighborhoods in which non-white individuals make up the majority of the neighborhood's population (Logan and Stults, 2011). Racial segregation is one underlying cause of the water affordability crisis, as residence location may determine access to and quality of infrastructure (Logan and Parman, 2017; Logan and Stults, 2011). Extant literature documents inequitable access to quality infrastructure and basic services, which affects the mobility, environment, and health outcomes of non-white communities (Jones and Armanios, 2020; Gasteyer et al., 2016). For example, the percentage of non-white residents in a county has a negative relationship with access to nonrestrictive infrastructure, adversely affecting their mobility (Jones and Armanios, 2020). Further, majority non-white communities are more likely to be subjected to disproportionate amounts of toxins, and lack access to adequate basic plumbing services (Gasteyer et al., 2016).

For example, the town of Mebane, North Carolina placed landfills, hazardous waste sites, and underground storage tanks in areas of the town containing majority-Black neighborhoods.

Moreover, majority-Black neighborhoods in Mebane are systematically denied access to water and sanitation services through discriminatory zoning practices (Wilson et al., 2008). Systemic exclusion of Black residents from water and wastewater services is not unique to the South, however, as other studies have documented similar situations of racialized exclusion from essential utility services across the Midwest as well (Carrera, 2014; Carrera and Gasteyer, 2008).

The Disproportionate Impact of Water (Un)Affordability

Water affordability literature documents the widespread nature of the affordability crisis, and its disproportionate impact on non-white communities. This literature also shows us the shortcomings and strengths of previous research methods. While some literature is weakened by limited generalizability and utilizing MHI affordability metrics, other literature is strengthened by examining affordability across income distributions and finer geographic scales.

Jones and Moulton (2016)

The report "The Invisible Crisis: Water Unaffordability in the United States," by Jones and Moulton (2016) highlights the disproportionate effects of the U.S. water affordability crisis on non-white communities. The report compiles relevant U.S. water affordability literature to frame the committee's policy recommendations to water providers and federal and local government stakeholders. The authors state that Black and Latine families are ten times more likely than white families to have their water shut off, with race alone being a stronger predictor of shutoffs than average income. According to the authors, this disproportionate impact of the water crisis is in conflict with the EPA's commitment to environmental justice, which includes the fair treatment of people "regardless of race, color, national origin, or income with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies" (EPA, 2020a). Jones and Moulton (2016) identify the racialized impacts of the U.S.

water affordability crisis by using multiple cities and states throughout the nation as case-studies in water affordability. The cities and states utilized provide a fairly good representation of the U.S., bolstering the validity of their findings and demonstrating that water affordability is a wide-spread issue throughout the county.

However, the data used to demonstrate that Black and Latine individuals' race is a better predictor of their vulnerability to shutoffs than their income is only from Massachusetts. The report heavily references a study by Massachusetts Global Action (MGA) to demonstrate the disproportionate impact of the U.S. water affordability crisis on people of color and bolster the researchers' policy recommendations. The MGA study utilized demographic and land use data from the 2010 U.S. Census and Geographic Information System, then conducted OLS regressions with the variables: average income, percentage of people of color, vacancy rates, median property value, percentage of multifamily parcels, shutoffs per 100 residential parcels, and shutoffs per 1,000 residential parcels (Foltz-Diaz, Kelleher-Calnan, and Moodliar, 2010). From this regression, MGA identified that for each 1% increase in the number of people of color in a city ward in Massachusetts, the city's likelihood of a water shutoff increased by 2-3% (Foltz-Diaz, Kelleher-Calnan, and Moodliar, 2010).

By using only the MGA study to illustrate the relationship between percent of people of color in a city ward and the likelihood of a water shutoff, Jones and Moulton (2016) introduce selection bias. Water affordability, MHI, housing segregation, and other relevant dimensions may differ systematically in Massachusetts than other regions of the nation. Noting this shortcoming, the authors explain that this limited analysis is due to the lack of a national water affordability database, and recommend the creation of one in order to more easily track water affordability and conduct research. Nevertheless, the findings Jones and Moulton (2016) reference from the MGA study are significant, as they demonstrate that the disproportionate burden of the water affordability crisis is not solely due to differences in income, and the need to identify the mechanisms responsible for the disproportionate financial burden placed in non-white communities. This article also highlights the injurious consequences of not having access to water beyond health and sanitation, as being subject to a water shut-off can result in losing custody of one's children, criminalization, and/or losing your home (Jones and Moulton, 2016). Given that the water affordability crisis disproportionately affects people with disabilities, Black, and/or Latine households, these extremely adverse consequences of water-shutoffs further demonstrate the necessity of federal protections.

Mack and Wrase (2017)

Other research has built upon that of Jones and Moulton (2016), not only confirming the disproportionate impact of the water affordability crisis on non-white communities, but also utilizing quantitative methods that provide greater generalizability than that of the MGA study. Mack and Wrase (2017) examined the characteristics of U.S. counties where residents are most vulnerable to "unaffordable" water bills under the EPA's affordability criteria, and are therefore subject to shutoffs. The authors sought to convey the importance and urgency of the water affordability crisis to protect vulnerable populations from shutoffs, as low-income individuals will be more greatly impacted from even incremental increases in their water bills due to climate change and infrastructure updates. Assuming recent upward trends in water bills remains constant, the researchers estimated that over a third of American households could face unaffordable water bills, per EPA standards, by 2022.

Mack and Wrase (2017) compare the average annual water bill of a census tract to its MHI to assess affordability, and find that "at-risk" households, those whose tract's average water bill is greater than 4.5% of its MHI, are clustered in “pockets of water poverty” throughout the nation. They identify these “pockets” by computing which census tracts are facing “unaffordable” water bills, and modeling that such tracts are clustered together. The authors identify that disabled individuals, Black, and/or Hispanic households are more likely to experience unaffordable water bills. Mack and Wrase (2017) attribute the disproportionate impact these communities are facing to what they call “compounding economic factors,” such as lower rates of health insurance coverage, and higher rates of unemployment relative to non-disabled and/or white households, as these factors negatively affect their ability to pay rising water bills. In addition to evidencing the disproportionate impact of water unaffordability on marginalized populations in the U.S., Mack and Wrase (2017) also highlight that non-essential water use, such as swimming pools and lawn watering, make it difficult to measure water affordability. They note that such water uses may inflate a household’s water bill, deeming it “unaffordable,” despite the family facing no economic burden to pay for their essential water use.

However, the researchers’ utilization of MHI measures and the EPA affordability threshold disguise important features of the affordability crisis and leave room for future research. The researchers calculate water affordability by examining if the average water bill of a census tract exceeds 4.5% of the tract’s MHI. However, this measure does not account for the ability of low-income households to pay their water bills, and therefore their projections of future water unaffordability are likely underestimates. By utilizing only North Carolina data, I hope to limit the challenge of measuring what may be non-essential water use, as climate, weather, and possibly even lifestyle factors that influence non-essential water use and, consequently, water bill costs, may vary less within a state as compared to nation-wide comparisons such as that which

Mack and Wrase (2017) conducted. Additionally, my thesis will examine affordability in a more complete manner, as my regression analyses will examine the relationship between minority presence and water bill cost, rather than using the binary threshold of the EPA affordability measure that may underestimate unaffordability and does not accurately reflect the ability of low-income consumers to pay their water bill.

Cardoso and Wichman (2020)

In their nation-wide survey of water affordability, Cardoso and Wichman (2020) model the disproportionate burden of the water affordability crisis that falls to Black Americans. They found that the number of households in a Census-block group "facing affordability concerns is positively associated with water and sewer prices, impoverished residents, and the proportion of Black residents, even after conditioning for poverty" (Cardoso and Wichman, 2020). These findings are particularly important given the methodological strengths of the paper, as Cardoso and Wichman (2020) provide a strong example for my own methodology. Noting the limitations of the EPA's affordability metric, Cardoso and Wichman (2020) instead examine affordability across a full income distribution, rather than evaluating affordability at 4.5% MHI. The researchers' outcome variable was proportion of households paying more than 4.5% of their income, rather than MHI. They then applied this metric to sixteen different income distributions within Census block groups. This methodology enabled the authors to demonstrate affordability challenges that would not be captured by median income measurements. Although the researchers use 4.5% of a household's income as an arbitrary measure of "affordable" water bills, they explicitly note that their work is not meant to prove nor disprove the efficacy of the

EPA measure, and that their model could be applied to any threshold of household-level affordability.

Improving upon Mack and Wrase's (2017) methodology, Cardoso and Wichman (2020) examined affordability at the county level, and approximate rate structures. While Mack and Wrase (2017) conducted a nation-wide examination to draw attention to geographic aspects of the water affordability crisis, Cardoso and Wichman (2020) note that this survey did not account for "differences in water prices and consumption levels," instead evaluating water prices and consumption at a constant rate across the nation. This study demonstrates the benefits of examining affordability using a full income distribution, rather than the EPA measure of affordability. Cardoso and Wichman (2020) found that "households in the lowest income decile spend, on average, 8.1% of their annual income to water and sewer services," an important finding demonstrating the disproportionate financial burden shouldered by low-income households that may have not been captured by binary affordability measures based on a census tract's MHI.

Summary and Literature Contributions

The disproportionate burden of water unaffordability is driven by water infrastructure repairs due to providers' compliance with non-funded federal mandates, the devolution of water affordability to local water authorities whose expertise nor institutional mission does not align with ensuring affordable water access, age, climate change, persistent segregation, and systemic infrastructure disparities that disproportionately affect non-white Americans (Cardoso and Wichman, 2020; Jones and Armanios, 2020; Wright, 2018; Mack and Wrase, 2017; Jones and Moulton, 2016; Mirosa, 2015; Carrera, 2014; Logan, 2014; Christian-Smith, Gleick, & Cooley, 2012; Logan and Stults, 2011; Foltz-Diaz, Kelleher-Calnan, and Moodliar, 2010; Carrera and Gasteyer, 2008; Baird, 2010; Gerlak, 2006; Pulido, 2000). Given the lack of federal protections against water shutoffs, minority populations are more vulnerable than their white counterparts to lose access to water (Gasteyer et. al, 2016; Mack and Wrase, 2017; Mirosa, 2015; Baird, 2010).

My thesis seeks to further previous water affordability literature by matching provider-level water and wastewater rate data with county income and demographic characteristics, and examine the relationship between minority presence and average residential water and wastewater bill costs in North Carolina, allowing for an analysis of each bills' affordability. Rather than utilizing binary measures of unaffordability, such as the EPA's binary 4.5% MHI threshold, I will examine any difference in providers' water bill prices across service areas. Utilizing the knowledge set forth by Cardoso and Wichman (2020) that county-level comparisons "mask important heterogeneity at a finer geographic scale," I instead conduct a provider-level analysis of water affordability, which allows for a more in-depth examination of the water affordability landscape within and across N.C. counties with varying percentages of Black and Latine populations.

Chapter 3: Data and Methods

Quantitative Method

I conducted an observational study with pooled, cross-sectional data. To protect against endogeneity, I controlled for an urban indicator variable, median income at the county level, weighted by the number of water providers, and year fixed-effects. These regressions examine the relationship between minority presence, defined as the percentage of the population that identifies as either Black or Latine/Hispanic[2], and water bill cost, defined as cost of an average residential water or wastewater bill. I construct two models, incorporating different explanatory variables to examine variation in water affordability. The dependent variable of the first model is the price of average residential water bills, and the outcome variable of the second model is the cost of average residential wastewater bills. This construction of water and wastewater prices alone as outcome variables is meant to demonstrate possible differential affordability outcomes minority populations face with water and wastewater bills.

My models contain multiple explanatory variables to evaluate if increases in a county's minority population is correlated with relative increases to household water bills, even if they are considered "affordable," per EPA standards, as well as exploring heterogeneity effects for Black Latine residents on the costs of average residential water and wastewater bills. While this approach does not allow me to make causal claims about the determinants of water (un)affordability, it yields evidence on the direction, magnitude, and which variables explain the most variation in the relationship between minority presence and water affordability.

[2] While the term "Latine" refers to people who are from, or are descendants of, Latin America, the term "Hispanic" refers to individuals who are from, or are descendants of, Spanish-speaking countries. Although these are two differing populations, they are grouped together by the Census and used interchangeably throughout water affordability and environmental racism literature. Although I use the label "Latine" throughout my thesis, due to inconsistencies in data collection and storage by the sources from which I gathered my demographic data, it is likely that both Latine and Hispanic individuals are included in the data and analysis that follows.

Sample

I examine the relationship between water affordability and minority presence in North Carolina using data from the North Carolina League of Municipalities and the UNC School of Government's Environmental Finance Center (EFC). I select my sample based on the availability and congruity of data, and take a state-level approach in order to ensure consistency of the panel data across years. While I had first planned to take a regional approach, the data collected from providers in the Southeast were not consistent between years. Additionally, my sample being North Carolina-specific may increase the internal validity of my research, as important characteristics that affect water affordability, such as climate, population, and median income may be systematically different in other states. Because the income distribution of smaller geographic regions, such as a state, affects water affordability, this state-specific analysis may strengthen my findings (Cardoso and Wichman, 2020).

Data Sources

I utilize data from the Environmental Finance Center (EFC), American Community Survey (ACS), PolicyMap, and the Economic Research Service (ERS).

Environmental Finance Center (EFC)

The Environmental Finance Center (EFC) is a program of the University of North Carolina at Chapel Hill's School of Government. The group conducts a variety of projects, such as promoting efficient management of drinking and wastewater by partnering with utilities across the nation, and designing energy finance systems to promote clean energy (EFC, 2021b). This promotion of efficient water and wastewater system management is supported by the EFC's nation-wide financial research, and accomplished by contacting local governments and water providers to collect pertinent data. I utilize North Carolina data that is available for download on the EFC website. This data contains provider information, such as water and wastewater rates at multiple consumption tiers, service population, and monthly gallons provided with base charge.[3] These data from the EFC provide a fairly uniform data set, as well as a set of providers with relatively consistent data generations.

The EFC has North Carolina water provider data dating back to 2005, but data prior to 2010 is not as readily utilized, as it is only available in .pdf format. The EFC's 2010 data collection and storage methods were not cohesive with the following nine years, and did not contain the variables important to my analysis. For these reasons, I limit my analysis to 2011-2019 to increase continuity between EFC data.

American Community Survey (ACS)

The American Community Survey (ACS) is an ongoing survey, conducted monthly. It is sent to a smaller sample of the American population than the Census, and collects data not captured by the Census, such as employment, transportation access, and education (U.S. Census Bureau, 2020). I utilize five-year ACS data, which compiles data from the previous five years to form a single-year observation, to calculate the percentage of Black or Latine residents of a given county in the years 2011-2019. Although the ACS does not list counties' population breakdowns by racial and/or ethnic groups, the survey does collect data on the number of residents that are Black or Latine, as well as the county's total population. I use this information to calculate the percentage of residents that were Black or Latine in the years 2011-2019.

[3] My original research design included a sub-analysis of providers that participate in the American Water Works Association (AWWA) survey, as it includes provider-level financial data not contained within the EFC files, such as providers' system development charges and annual capital needs. However, when my study became North Carolina-specific, the sample size of North Carolina providers that participate in the AWWA biennial survey was no longer large enough to conduct this sub-analysis. I am grateful to the Alexandre Honors Carolina Expendable Fund administered by Honors Carolina for awarding the funds to purchase this proprietary data at the time that my research design required it. I hope to expand my research design to conduct a multi-state comparative study in the future, and will utilize this data in this later analysis.

Economic Research Service (ERS)

The ERS is a division of the U.S. Department of Agriculture. It conducts research that aims to inform public and private decision makers about issues related to food, agriculture, and the environment (ERS, 2019). Their Rural-Urban Continuum Codes were developed in 1974 to classify counties across the nation as metropolitan or non-metropolitan for this research (ERS, 2020). These codes classify metropolitan counties by the size of the county's metropolitan area, and non-metropolitan counties by the county's degree of urbanization and adjacency to a metropolitan area. These metro/non-metro categories are then further divided into three "metro" and six "non-metro" categories (ERS, 2020). "Metro" counties in categories 1-3 are those in metro areas with a population of less than 250,000 people to 1 million or more. Non-metropolitan counties include those that are adjacent and non-adjacent to metro areas, and have urban population of 2,500 to 20,000 or more, or are completely rural with an urban population of less than 2,500. I utilized the ERS's 2013 data, the most recent dataset available.

PolicyMap

PolicyMap is a publically-available web-based geographic data tool that holds U.S. data from multiple sources, including the Census and ACS (PolicyMap, 2021). I used median income data from PolicyMap to examine North Carolina MHI at the county level by year.

Methodology

Because counties may be, and often are, serviced by more than one water provider, I manually matched each North Carolina water provider with the county they service in order to match EFC provider-level data to ACS, ERS, and PolicyMap, county-level demographic, urbanicity, and income data. Then, I separated the EFC files by year and data label, and appended these files with a loop code in STATA. Because the water and wastewater files contained similar information and often identical variable labels, their respective variables were given unique variable labels to allow for both the correct appending of the data, and two unique analyses of water and wastewater rates alone. Next, I matched this EFC data to the county-level ACS, ERS, and Policy Map data. I appended the ACS data, calculating the percentage of each county that was Black or Latine in the years 2011-2019. I matched each county with its respective FIPS code, a numerical identifier used by the federal government to uniquely designate counties in federal reporting. After the demographic variables had been created and the counties and their FIPS codes were properly matched, this ACS population and demographic data was matched to the EFC provider data (NITAAC, 2021).

Then, I merged the PolicyMap data into this dataset, using county names and FIPS code. PolicyMap data were time-sensitive, containing information on the overall MHI and MHI by racial or ethnic group for the years 2010-2014, and 2015-2019. To make sure these values matched with the correct year, I created a single variable for overall, Black, and Latine population, matched on the correct year value, and merged with the master dataset. Next, I merged the ERS data containing the urban indicator variable with this master data set on county name. Finally, I ran regressions in STATA, utilizing average water price and wastewater prices as outcome variables.

Missing Data

There is variation in the number of providers in the EFC data year to year, most of which is due to providers' inaction to complete the EFC's survey. Many local governments and providers know of the EFC and UNC School of Government, and providing the EFC the desired information creates a partnership that is mutually beneficial to the providers' decision-making (S. Eskaf., personal communication, March 24, 2021). However, some years, the providers do not respond to the EFC's multiple attempts to contact them for this data, leading to an unbalanced panel data set that does not contain the same number of providers year to year, with the number of participating utilities ranging from 408 to 557 in the years 2011-2019. Some of the variation is also due to provider consolidation and/or mergers, change in utility name, or changes to their rate structures year to year. This creates variation not only within and across years due to the participation of different utilities, but also on the provider level due to changes in name and/or rate structure. In addition to variation in the number of providers listed year to year, even when listed, some providers' rates were missing from the EFC data across all consumption tiers, leading to these providers' rates being uncaptured by my models.

Dependent Variables

My dependent variables are the cost of the average residential N.C. water or wastewater bills, measured as the cost of 5,000 gallons of residential water or 3,000 gallons of wastewater. The average family consumes 9,000 gallons of water per month, 25% of which is wastewater (EPA, 2018). The water consumption tiers provided by the EFC data closest to these figures is 5,000 gallons of water, and 3,000 gallons of wastewater, so I utilized these variables as a rough estimation of average water bill. Rather than use the overall average price of a combined water and wastewater bill, I examined these constructs separately to determine if North Carolina racial and ethnic minority individuals' water and wastewater prices are differentially affected. Additionally, conducting regressions using combined average water and wastewater bills omits approximately one thousand observations, as it excludes utility providers that only provider either water or wastewater services, rather than both. As well as the advantages of examining heterogeneous effects of water and wastewater bills, water and wastewater bill costs were evaluated alone to improve the internal validity of my results.

I am not utilizing the EPA water affordability standard because it does not fully capture affordability challenges for low-income consumers due to its reliance on MHI, a shortcoming documented by extant water affordability literature (Cardoso and Wichman, 2020; Mack and Wrase, 2017; Jones and Moulton, 2016). The EPA water affordability standard uses a census tract's median household income to determine if water bills are below 4.5% of the census tract's income. However, this measure does not consider the ability of low-income households or otherwise disadvantaged populations to meet this standard. Additionally, utilizing a binary measure of water affordability that defines "affordability" by its given threshold would limit my ability to document incremental changes in water bill price. By examining the prices of average residential water and wastewater bills, and the density of a county's minority population, defined by percentage of the county population that is Black or Latine, I hope to more fully capture the relationship between these variables than would be possible if my model utilized binary measures of minority presence and/or water affordability.

Independent Variables

The model contains two independent variables, "Percent Black" and "Percent Latine," which are the percentages of a North Carolina county's residents that were Black or Latine in a given year between 2011-2019.

Control Variables

Median Household Income (MHI)

I control for MHI on the county level, weighted by the number of water providers, for the associated years of water rates data, 2011-2019, measured in U.S. dollars. Although this measure does not, of course, demonstrate the water affordability challenges faced by lower-income households, it is incorporated in the model to protect against endogeneity. Higher county MHIs may be associated with increased water use and consequent increases to household water and wastewater bills. Higher county MHIs may also be correlated with higher-quality infrastructure that is in less need of repair than a lower-income county, lowering the average residential water and/or wastewater bill.

Urban Indicator

My models also contain an urban indicator variable for North Carolina counties. This variable was coded as equal to one if the county was considered “metropolitan” per the ERS’s Rural-Urban Continuum Codes, and was equal to zero if not. Constructing this variable, I first utilized the ERS’s distinction between “metropolitan” and “nonmetropolitan” counties to classify N.C. counties as urban/non-urban. Counties that fell in to categories 1-3, the “metro” categories, were coded as “urban,” which was roughly half (52%) of North Carolina counties. Although there are various state and federal definitions of what classifies a county as “urban,” a relatively agreed-upon figure is that 80 of North Carolina’s 100 counties are “rural,” defined as having equal to, or less than, 250 people per square mile (North Carolina Rural Center, 2021; Knopf, 2018). Therefore, the federal ERS definition appeared to overestimate the urbanicity of the state.

Thus, I recoded the urban indicator variable to classify N.C. counties as “urban” if they fell into categories 1 or 2 of the ERS’s Rural-Urban Continuum Codes. Counties in category three, which had previously been considered “urban,” were those which had a metropolitan population of less than 250,000, causing suburban areas to be considered “urban.” When these counties were excluded from the “urban” category, 42% of N.C. counties were considered “urban,” rather than 52%. Although this is still an overestimate of the state’s urbanicity, this variable construction is more accurate than that set forth by the ERS. It is important to control for this urban indicator, as urban counties in North Carolina are more likely than rural areas to have large populations, which could influence the dependent variables, as larger populations provide a larger costumer base for providers to disperse their operating and system repair costs between (Mack and Wrase, 2017).[4]

<u>Year</u>

Finally, my models control for year fixed-effects. Although the coefficient for each of the nine years are not listed in **Model 6** of **Table 5.1 and 5.1**, they can be viewed in **Appendices G and H.** Because the data span a nine-year period, it is possible that some of the variation in water and wastewater rates is due to changes over time, rather than a relationship between minority populations and bill costs. To rule out this possibility, I control for year fixed-effects.

Models

$$PriceWaterBill_{pt} = \beta_0 + \beta_1 PercentBlack_{ct} + \beta_2 PercentLatine_{ct} + \beta_2 Urban_c + \beta_3 MedianIncome_{ct} + \beta_4 Year_t + \varepsilon_{cpt} \quad \text{(Equation 1)}$$

$$PriceWastewaterBill_{pt} = \beta_0 + \beta_1 PercentBlack_{ct} + \beta_2 PercentLatine_{ct} + \beta_2 Urban_c + \beta_3 MedianIncome_{ct} + \beta_4 Year_t + \varepsilon_{cpt} \quad \text{(Equation 2)}$$

Limitations of Data and Methods

There are shortcomings to the EFC data. First, the data is an unbalanced panel, as the number of providers in the EFC 2011-2019 data vary from 408 to 557 between these nine years. If the water providers who abstained from participating in the EFC survey did so due to limited administrative staff support and/or lack of knowledge about the EFC and the benefits of partnering with the organization, this may bias my findings. If these factors led to non-

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[4] See **Appendices A and B** for two-sample t-tests of the relationships between "Percent Black" and "percent Latine" with the urban indicator variable. T-tests indicate if the means of two groups differ. For the t-test between "Percent Black," and "Urban," I reject the null hypothesis that the difference in the mean values of "Percent Black" and "Urban" are 0, and fail to reject the alternative hypotheses that the difference in these means is greater than zero. For the t-test between "percent Latine" and "Urban," I reject the null hypothesis that the difference between these two means is zero, and fail to reject the alternative hypothesis that the difference in these means is less than zero.

participation, these providers may vary systematically from other providers in the sample in size, age, or other relevant features that affect the provider's ability to deliver affordable water services to their consumers.

Second, many providers in my sample serviced more than one N.C. county. In these cases, I researched what county the provider primarily serviced and matched it with its "majority county." Although I was able to match nearly all of the providers in this manner, some of these providers serviced two counties equally, or their "majority county" information was not available online. From my sample of over 500 North Carolina utilities, seven of the providers were unable to be matched for this reason. Although this is a small proportion of my sample, if these counties are spilt because they service small populations, this may bias my results, as these providers' fixed costs would be divided amongst smaller service populations, increasing consumers' absolute water bills **(Table 1.1)**.

Table 1.1: Unmatched N.C. Water Providers

Municipality/Provider	Counties
Beech Mountain	Avery and Watauga
Blowing Rock	Caldwell and Watauga
Elkin	Surry and Wilkes
Fork Township Sanitary District	Wayne and Johnston
Kannapolis	Cabarrus and Rowan
Orange-Alamance Water System	Orange and Alamance
Whitakers	Edgecombe and Nash

Data Source: EFC (2011-2019)

Lastly, a shortcoming of the ACS demographic data is that it does not account for individuals who are both Black and Latine, listing these categories as mutually exclusive, and only recording the number of individuals in a county who identify with one of these groups. This rigid data collection method therefore may not reflect water affordability challenges for North Carolina individuals who are both Black and Latine.

Chapter 4: Results

Table 2.1: Descriptive Statistics of Independent Variables

	(1)	(2)	(3)	(4)	(5)
VARIABLES	N	mean	sd	min	max
Percent Black	4,264	0.23	0.155	0.00152	0.633
Percent Latine	4,264	0.074	0.0419	0.000953	0.222
Median Income	4,264	45,947	9,878	29,388	80,591
Urban	4,264	0.41	0.491	0	1

Data Sources: ACS (2010-2020), PolicyMap (2010-2020), US Department of Agriculture (2013)

Mean Values of Independent Variables

The mean value for "Percent Black" is 0.23, indicating that the population of an average water provider service area in North Carolina was 23% Black in the years 2011-2019. The mean value for "Percent Latine" is 0.07, indicating that the population of an average service area in North Carolina was 7% Latine in the years 2011-2019. The mean value for the median income variable is 46,045. This value indicates that the average of each service area's associated county-level MHI measures was $46.045 in the years 2011-2019. However, the median income for Black and Latine residents is lower than this overall MHI measure, while the MHI for white North Carolinians was higher **(Table 3.1).** The mean value for the urban indicator variable is 0.42, indicating that 42% of North Carolina counties were classified as "urban."

Table 3.1: Median N.C. Household Income by Racial or Ethnic Group, 2011-2019

	Median Income	Difference from Median Overall Income
Overall	$46,044.72	0
Black	$32,592.14	- $13,452.58
Latine	$36,486.14	- $9,558.58
White	$51,564.67	+ $5,519.95

Data Source: PolicyMap (2010-2020)

Table 4.1: Descriptive Statistics of Dependent Variables

	(1)	(2)	(3)	(4)	(5)
VARIABLES	N	mean	sd	min	max
Residential Water Price	4,264	32.34	11.46	6.55	107.7
Residential Wastewater Price	4,264	23.55	9.06	4.55	101.6

Data Source: EFC (2011-2019)

Mean Values of Dependent Variables

The average price of a residential water bill between 2011-2019 in North Carolina was $32.34, while the average price was $23.55 for wastewater bills.

Primary Variable Relationships

Overall, the proportion of Black residents has positive relationship with average water and wastewater bill prices, meaning that for service providers who service areas with higher proportions of Black residents, bills are more expensive. Conversely, the proportion of Latine residents had a negative relationship with both average residential water and wastewater bill prices, meaning that for service providers who service areas with higher proportions of Latine residents, water bills are more affordable. The urban indicator variable had a negative relationship with both water and wastewater bills, indicating that residents in urban N.C. counties have lower average residential water and wastewater bills than N.C. residents who live in non-urban areas. The MHI variable had a negligible positive effect on both residential water and wastewater bills.

Regression Results

While increases in a N.C. county's Black population is associated with increases to average residential water and wastewater bills, increases in a N.C. county's Latine population is associated with decreases to average residential water and wastewater bill prices **(Tables 5.1 and 5.2)**. The variable "Percent Black" had a positive effect on both water and wastewater bills, with the effect being greater on wastewater bills than water bills.[5] Further, when utilizing wastewater bill cost as the outcome variable, the results were statistically significant across all models. In contrast, only the results of Model 5 were significant at $p<0.1$ when utilizing water bill costs as the outcome variable. Thus, more of the disparity in affordability is due to the positive relationship between a service area's percentage of Black residents and wastewater bills than water bills.

[5] Tables 5.1 and 5.2 display robust regression results. See **Appendices I and J** for regression results clustered by FIPS code, and **Appendices K and L** for regression results clustered by utility provider. With the exception of the "Percent Black" regressor in Table 5.1, all robust regression results are statistically significant at $p<0.01$. However, when clustering by FIPS code or utility, not all results are statistically significant across both models.

Table 5.1: Average Residential Water Bill Price in NC, 2011-2019

VARIABLES	(1) Model 1	(2) Model 2	(3) Model 3	(4) Model 4	(5) Model 5	(6) Model 6
Percent_Black	0.28		0.097	-0.58	2.27*	1.05
	(1.140)		(1.142)	(1.226)	(1.253)	(1.227)
Percent_Latine		-12.86***	-12.84***	-12.57***	-18.72***	-20.36***
		(3.415)	(3.400)	(3.381)	(3.359)	(3.252)
Urban				-0.56	-2.33***	-1.46***
				(0.382)	(0.409)	(0.414)
Median Household Income					0.00022***	0.00011***
					(2.02e-05)	(2.25e-05)
Constant	32.27***	33.29***	33.27***	33.63***	24.20***	25.31***
	(0.296)	(0.318)	(0.389)	(0.471)	(1.014)	(1.089)
Observations	4,264	4,264	4,264	4,264	4,264	4,264
R-squared	0.000	0.002	0.002	0.003	0.027	0.073

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Data Sources: EFC (2011-2019), ACS (2010-2020), PolicyMap (2010-2020), US Department of Agriculture (2013)
Note: Column 6 includes year fixed-effects, which have been omitted from the table for improved readability

Utilizing water bills alone as the outcome variable, the variable "Percent Latine" is statistically significant across all models, providing strong evidence that as a service area's Latine population increases by one percentage point, the cost of water bills falls. In contrast, there is little evidence of a relationship between a service area's Black population and water bill cost, as these coefficients are not statistically significant. A one percentage point increase to a service area's Latine population is associated with a $0.13 decrease in average residential water bills, an effect that holds when controlling for the "Percent Black" regressor" **(Table 5.1, Models 2 and 3**). Controlling for the urban indicator variable **(Table 5.1, Model 4)**, I observe that a percentage point increase to a service area's Latine population is associated with a $0.12 decrease in average residential water bills. Next, controlling for median income **(Table 5.1, Model 5)**, the effect of the "Percent Black" regressor is statistically significant for the first and only time when utilizing average residential bills alone as the outcome variable. A one percentage point increase to a service area's Black population is associated with a $0.02 increase in average water bills, while the effect of one percentage point increase in the Latine population is a $0.18 decrease to average water bills. Finally, incorporating the year fixed-effects into the water bill model, **(Table 5.1, Model 6)** the effect of a one percentage point increase in the Latine population is a $0.21 decrease to average residential water bills.

Table 5.2: Average NC Residential Wastewater Bill Price, 2011-2019

VARIABLES	(1) Model 1	(2) Model 2	(3) Model 3	(4) Model 4	(5) Model 5	(6) Model 6
Percent_Black	2.45***		2.23**	1.29	3.10***	2.15**
	(0.876)		(0.879)	(0.931)	(0.958)	(0.940)
Percent_Latine		-15.82***	-15.38***	-15.01***	-18.91***	-20.13***
		(2.618)	(2.616)	(2.601)	(2.616)	(2.534)
Urban				-0.77***	-1.90***	-1.22***
				(0.294)	(0.312)	(0.317)
Median_Income					0.00014***	5.58e-05***
					(1.50e-05)	(1.70e-05)
Constant	22.99***	24.72***	24.18***	24.68***	18.69***	19.61***
	(0.222)	(0.249)	(0.298)	(0.357)	(0.762)	(0.825)
Observations	4,264	4,264	4,264	4,264	4,264	4,264
R-squared	0.002	0.005	0.007	0.008	0.024	0.067

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Data Sources: EFC (2011-2019), ACS (2010-2020), PolicyMap (2010-2020), US Department of Agriculture (2013)
Note: Column 6 includes year fixed-effects, which have been omitted from the table for improved readability

Examining wastewater bill costs as the outcome variable, the effect of a one percentage point increase to a county's Black population is an increase in $0.02 cents in the average wastewater bill, and a decrease of $0.16 to the average wastewater bill for every one percentage point increase to the Latine population **(Table 5.2, Models 1 and 2)**. Controlling for the "Percent Black" regressor, the effect of on percentage point increases in the Latine population decreases slightly to $0.15 decreases in wastewater bills, while the effect of one percentage point increases to the Black population remains the same when controlling for the "Percent Latine" regressor **(Table 5.2. Model 3)**. One percentage point increases to the Latine population is associated with $0.15 decreases to average wastewater bills when controlling for the urban indicator variable, while the effect of the "Percent Black" regressor is not statistically significant **(Table 5.2, Model 4)**. Next, controlling for MHI at the county level, weighted by the number of service providers **(Table 5.2, Model 5)**, average residential wastewater bills increase by $0.03 for every one percentage point increases to the Black population, and fall $0.19 for every one percentage point increase in the Latine population. Finally, incorporating the year fixed-effects into the model, **(Table 5.2, Model 6**) average residential wastewater bills increase by $0.02 for every one percentage point increases to the Black population, and decrease $0.20 for every one percentage point increase in the Latine population.

Differential Effects of Minority Presence on Water and Wastewater Bills

While the effect of the "Percent Black" variable remained positive and the "Percent Latine" variable remained negative across models, the discrepancy in affordability between these groups is larger for wastewater bills than water bills. In fact, the effect of "Percent Black" is null on water bill costs for nearly all models, while it is statistically significant at $p<0.01$ for wastewater bills **(Tables 5.1, 5.2, and 6.1)**. There are a few reasons for this discrepancy in the effects of changes to the Percent Black or Percent Latine population on water and wastewater bill costs.

Table 6.1: Effect of Black and Latine Population on Residential Water and Wastewater Bill Costs

	Water Bills	Wastewater Bills
VARIABLES	Model 6	Model 6
Percent Black	1.05	2.15**
Percent Latine	-20.36***	-20.13***
Observations	4,264	4,264

*** p<0.01, ** p<0.05, * p<0.1
Data Sources: EFC (2011-2019), ACS (2010-2020), PolicyMap (2010-2020), US Department of Agriculture (2013)
Note: Results of Model 6 control for the Urban indicator variable, MHI, and year fixed effects

Treatment Costs

Before being released, wastewater goes through a process of solid waste removal and disinfectant that is not necessary for non-wastewater. As a result, water providers' wastewater treatment costs are greater than that of drinking water, increasing the costs they pass off to their consumers, relative to water bills alone

Climate Change

Wastewater systems handle storm water, and are therefore under more stress due to climate change than drinking water systems. Because climate change causes increased frequency and intensity of weather events, these systems require more repairs than drinking water systems (Mack and Wrase, 2017). Consequentially, these repair costs are absorbed by increases to consumers' wastewater bills, but not their water bills.

Infrastructure Quality

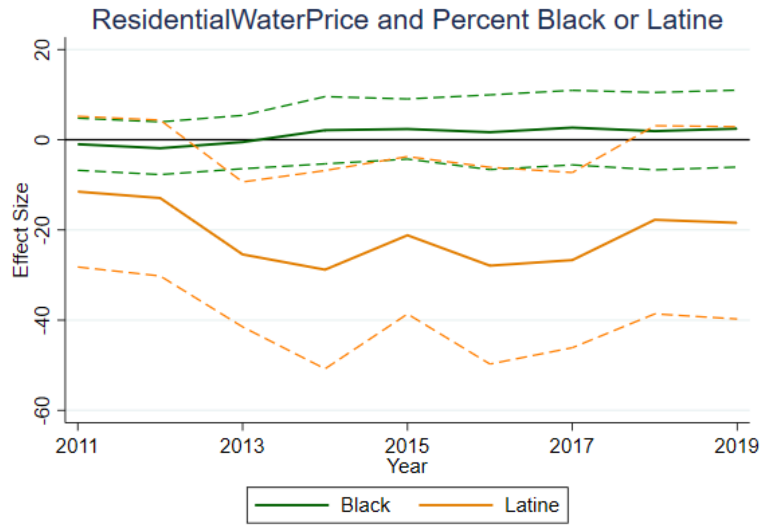
Finally, these differential impacts of Black and Latine presence on water bill affordability may be due to these individuals living in regions with different infrastructure quality. The variables "Percent Black" and "Percent Latine" had nearly no correlation **(Table 7.1)**, indicating that high proportions of Black and Latine individuals do not reside in the same counties across North Carolina. That is, if Latine North Carolinians live in "whiter" areas, they have increased access, relative to Black North Carolinas, to higher-quality infrastructure. This higher-quality infrastructure results in wastewater systems that are in need of less need repair than lower-quality infrastructure. As a result, water providers in these areas will not have a need to increase their consumers' bills to absorb repair costs. These results mirror Cardoso and Wichman's (2020) findings, as their nation-wide survey demonstrated a positive relationship between affordability concerns and proportion of Black residents, and no relationship between affordability concerns and the proportion of Hispanic residents.

Table 7.1: Correlation Matrix

	Percent Black	Percent Latine	Median Income
Percent Black	1.00	-0.0536	-0.3687
Percent Latine	-0.0536	1.00	0.1562
Median Income	-0.3687	0.1562	1.00

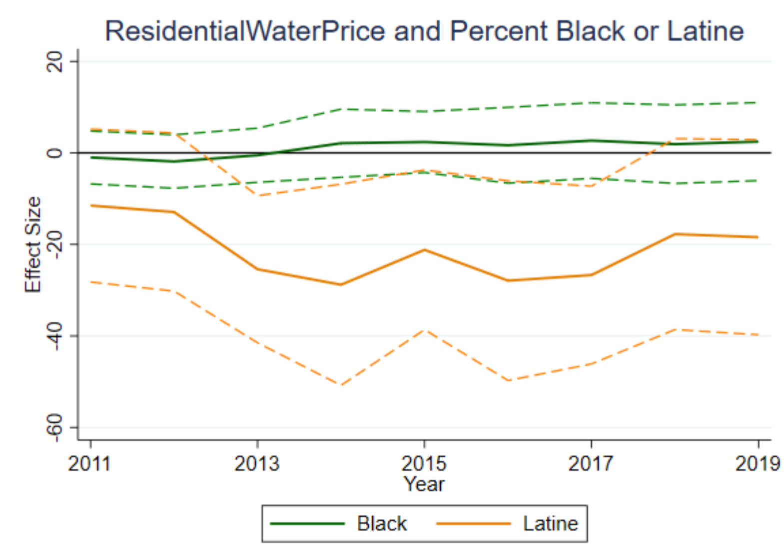
Data Sources: EFC (2011-2019), ACS (2010-2020), PolicyMap (2010-2020)

Figure 1.1: Effect Size of Black and Latine Population on Average N.C. Residential Water Bills



Data Sources: EFC (2011-2019), ACS (2010-2020)

Figure 1.2: Effect Size of Black and Latine Population on Average NC Residential Wastewater Bills



Data Sources: EFC (2011-2019), ACS (2010-2020)

Figures 1.1 and 1.2 plot the effect of increases to a county's Black or Latine population, using the results from **Model 6** of **Tables 5.1 and 5.2** by year. The solid lines indicate the effect of a one percentage point increases to the Black or Latine population in a given year, and the dashed lines of the same color represent the confidence interval for the associated observations. For both outcomes, the effect of "Percent Latine" on both water and wastewater bill costs was negative and statistically significant across all years. In contrast, the effect of "Percent Black" on water and wastewater bill costs was a smaller, positive effect that has increased over the last decade. For average residential water bills **(Figure 1.1)**, the disparity between the effect size of "Percent Latine" and "Percent Black" has slightly widened over the last decade. The positive effect of "Percent Black" has increased after becoming positive in 2013, and the negative effect of "Percent Latine" has increased in absolute value. The disparity between the effect size of "Percent Latine" and "Percent Black" on average residential wastewater bill costs has also slightly widened over the last decade **(Figure 1.2)**. The positive effect of "Percent Black" has increased after slightly crossing the zero value and becoming negative in 2012, while the negative effect of "Percent Latine" has increased in absolute value.

Impact of Effect Size Disparities on Bill Costs

The interpretation of the regression results show that for each one percentage point increase in Black populations, wastewater bills alone increase by a few cents, while the cost of both water and wastewater bills decreases by approximately twenty cents for each one percent increase in a county's Latine population. Although this effect is small, its consistency across years and models indicates systematic differences in water affordability by race and ethnicity in the state.

Concentration of Black population across North Carolina

The relatively small effects on water or wastewater bills demonstrate the outcome of a one percentage point increase in the Black or Latine population. However, such small increases in the percentage of Black North Carolinians between counties is not typical, as there are multiple majority-Black counties in the state whose residents would experience even greater increases to their water and wastewater bills. While the only a small percentage of the state's Western counties' populations are Black (approximately 0.58%-6.93%) **(Figure 2.1)**, populations of counties in the Northeastern part of the state have larger Black populations (approximately 33.08% - 62.68%). Therefore, even cents to the percentage point effects would increase the water bills of residents in these counties. While the wastewater bills of Black North Carolinians in Western counties would be $0.01 to $0.15 higher than average, the wastewater bills of Black North Carolinians in Eastern counties would increase $0.71 to $1.35 higher than average.[6] For example, the population of Haywood county, in the Western region of the state, was approximately 1.4% Black in the years 2011-2019. As a result, the wastewater bills of Haywood residents was $0.03 higher than average.[7] However, the population of Bertie county, in the Northeast region of the state, was approximately 62.6% Black in the years 2011-2019. Therefore, the wastewater bills of Bertie residents would be $1.35 higher than average. [8][9]

Additionally, predominantly-Black North Carolina counties are not located in urban centers in the state, and therefore lack the larger populations and/or higher-quality infrastructure that could improve water bill affordability. In contrast, nearly all counties with higher proportions of Latine residents are urban counties **(Figure 4.1)**. **Appendices C-F** show the

[6] 0.58 × 0.0215 = 0.01; 6.93 × 0.0215 = 0.015; 33.08 × 0.0215 = 0.71; 62.68 × 0.0215 = 1.35
[7] 1.4 × 0.0215 = 0.03
[8] 62.6 × 0.0215 = 1.35
[9] See **Appendix N** for a county map of North Carolina

differential effects of the “Percent Black” and “Percent Latine” variables by service population size. These tables model the different effects of one percentage point increases to these populations above and below a 25,427 service population, the mean service population value for the providers in my sample. **Table 8.1** shows the results of **Models 5 and 6** from **Tables 5.1 and 5.2** by service population. The results of regressions that examined the relationship between Black and Latine presence and both water and wastewater bills for small providers (service population <25,427) was statistically significant at $p<0.05$ or $p<0.001$, for both the “Percent Black” and “Percent Latine” regressor. One percentage point increases to the Black population in small service areas was associated with increases to water and wastewater bills. However, examining the relationship between Black and Latine presence and both water and wastewater bills for providers with larger service populations (service population ≥ 25,427), one percentage point increases to the Black population are associated with decreases to average residential water and wastewater bills, but this negative relationship is not statistically significant.

These negative effects of the “Percent Black” regressor demonstrate the affordability of both water and wastewater bills in urban counties, relative to non-urban counties, in the state. Living in an urban county not only increases these individuals’ access to higher-quality infrastructure, but also provides a larger customer base for their providers to offset their compliance and maintenance costs, decreasing absolute increases to these households’ water and wastewater bills However, because predominantly-Black counties are largely not urban, Black residents do not reap the benefits of urban water and wastewater affordability modeled in **Table 8.1**.

Table 8.1: Effects of Black and Latine Population on Residential Water and Wastewater Bill Costs, by provider size

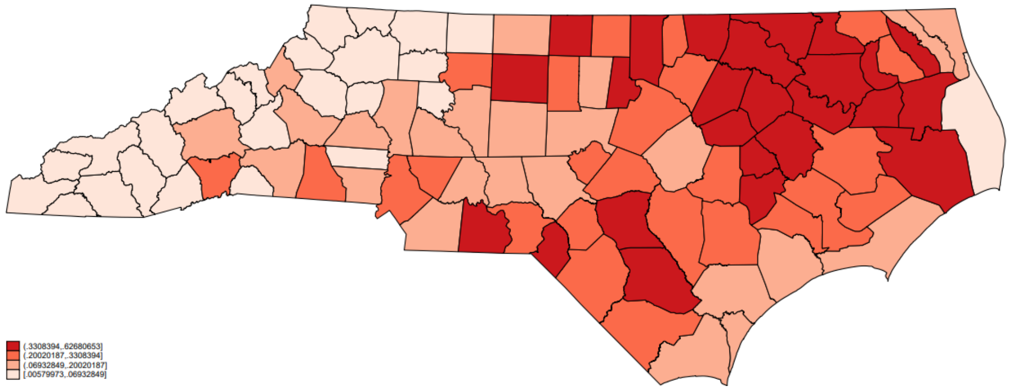
	Service Population < 25, 427		Service Population ≥ 25, 427	
VARIABLES	Water Bills	Wastewater Bills	Water Bills	Wastewater Bills
Percent Black	3.24**	4.00***	-1.39	-1.25
Percent Latine	-14.49***	-14.75***	-57.78***	-60.92***
Observations	3,617	3,617	647	647

*** p<0.01, ** p<0.05, * p<0.1
Data Sources: EFC (2011-2019), ACS (2010-2020), PolicyMap (2010-2020), US Department of Agriculture (2013)
Note: Results of Model 6 control for the Urban indicator variable, MHI, and year fixed effects

Concentration of Latine population across North Carolina

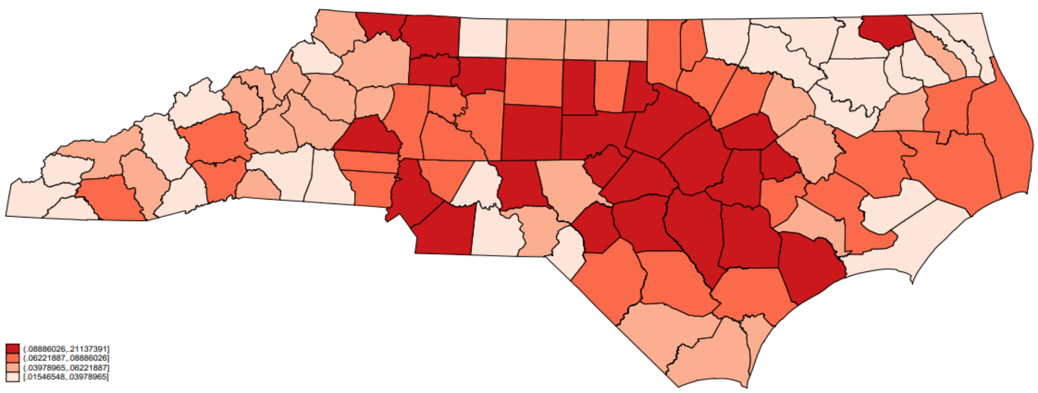
Although counties across the state have a smaller proportion of Latine residents than Black residents (maximum of a 21.13% Latine population compared to a 62.68% Black population), Latine residents similarly cluster in certain areas, increasing the total negative effect of the “Percent Latine” coefficient. Counties whose populations have higher proportions of Latine residents, relative to other parts of the state, however, are clustered in the central and Southern regions of the state **(Figure 3.1).** While some of these counties with higher proportions of Latine residents have the lowest MHI ($32, 208.62-$39,401.24), many are located in counties that are in the highest MHI group ($49,225-$73,856.55) **(Figures 3.1 and 5.1)**.

Figure 2.1: N.C. Percent Black population, 2011-2019



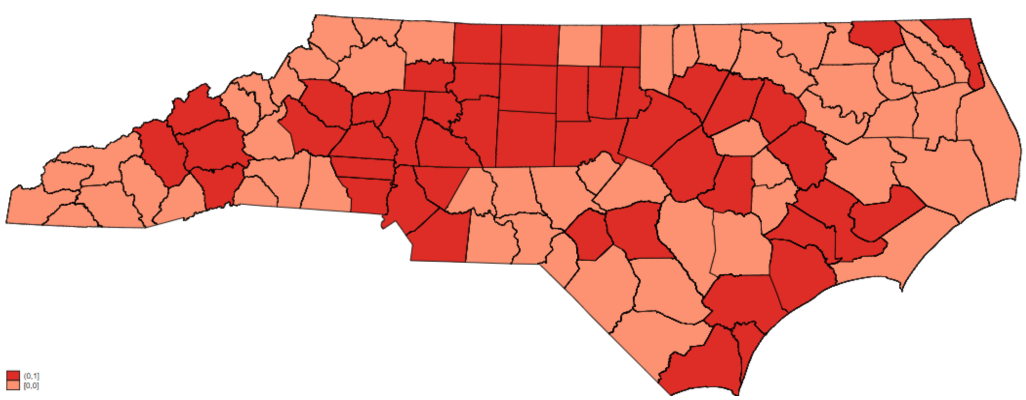
Data Sources: ACS (2010-2020), PolicyMap (2010-2020)

Figure 3.1: N.C. Percent Latine population, 2011-2019



Data Sources: ACS (2010-2020), PolicyMap (2010-2020)

Figure 4.1: Urban Counties in N.C.



Data Source: US Department of Agriculture (2013)

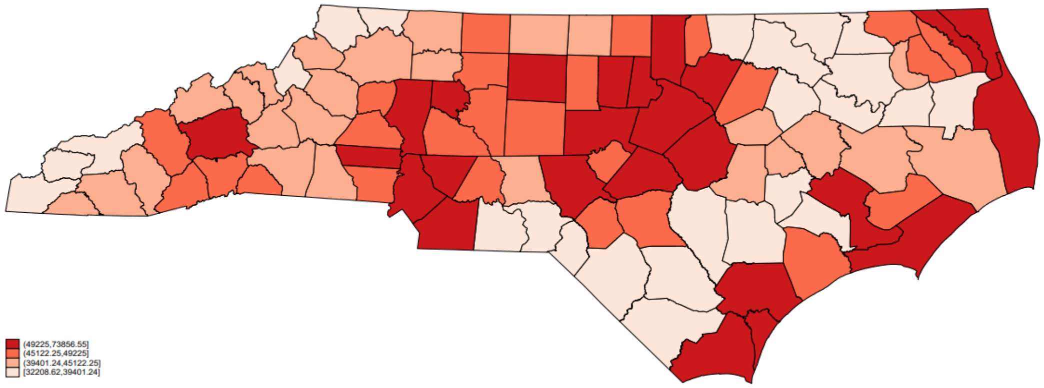
Median Income Differentials

Further, Black North Carolinians have the lowest median household income **(Table 3.1).** While the overall MHI is $46,044.72, it is only $32,592.14 for Black households, a difference of $13,452.58 less income annually. Comparatively, Latine households make $9,558.58 less than the overall MHI annually, while white households in North Carolina make $5,519.95 more than the overall MHI annually. **Figure 4.1** illustrates that North Carolina counties with higher proportions of Black residents have the lowest MHI. Because Black households have the lowest MHI, even small increases to their water bills would cause more economic distress than for their Latine and/or white counterparts, whose MHI is higher. The concentration of Black residents and lower MHI both compound Black North Carolinians' water affordability challenges modeled in **Tables 5.2 and 6.1**. Not only do they experience increases to their water bills as the population of their county increases, they also have the lowest MHI of other racial and ethnic groups, compounding the burden of water affordability.

Consistency of Findings

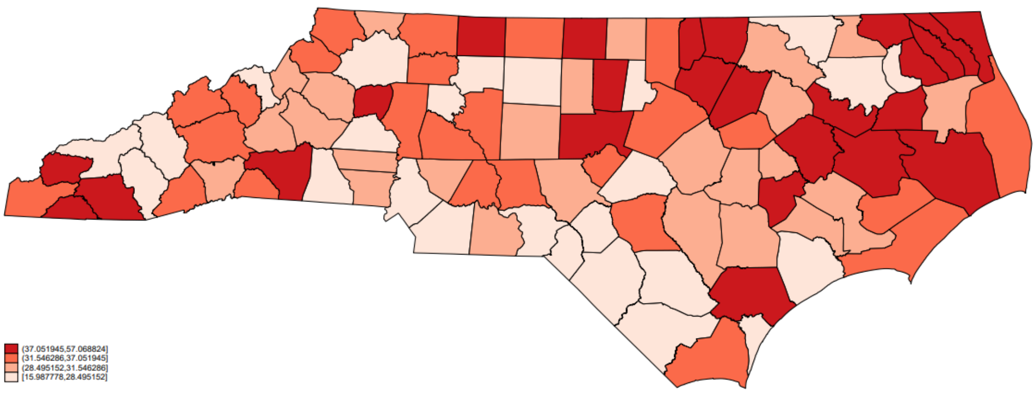
Examining the costs of water and wastewater bills, the highest bill values are consistently clustered in the Northeast region of the state, in counties that have the highest populations of Black residents, are less likely to be considered "urban" per the ERS variable construction, and have the lowest MHI **(Figures 2.1, 4.1, 5.1, 6.1, and 6.2)**.

Figure 5.1: Median NC Household Income in NC, 2011-2019



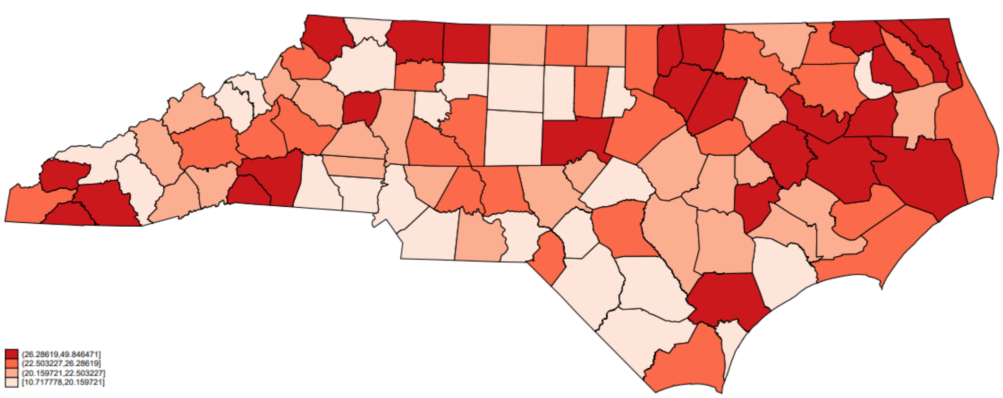
Data Sources: ACS (2010-2020), PolicyMap (2010-2020)

Figure 6.1: Average N.C. Residential Water Bill Price, 2011-2019



Data Sources: ACS (2010-2020), PolicyMap (2010-2020)

Figure 6.2: Average N.C. Residential Wastewater Bill Price, 2011-2019



Data Sources: ACS (2010-2020), PolicyMap (2010-2020)

Although a few counties in the Westernmost part of the state with low proportions of Black residents also have high water and wastewater bills **(Figures 2.1, 6.1, and 6.2)**. However, these counties also have the highest MHI, indicating that these higher bill costs may be due to increased use, rather than increased rates. These counties are also rural, meaning that their providers' fixed costs are spilt between fewer consumers, resulting in larger absolute increases to each household's bills. Finally, because these counties are on the border with Tennessee, and are part of the Blue Ridge mountain range, these may be region-specific affordability affects.

Chapter 5: Recommendations and Conclusions

Hypothesis

My research question was answered and my hypothesis was confirmed, in part. My findings were cohesive with my hypothesis that minority presence would increase water bill costs due to infrastructure quality differentials. However, my findings diverge from my hypothesis in two key ways. First, increases in the Black and Latine population had differential effects. While residential water and wastewater bills increase as a N.C. county's Black population increases, they decrease as the Latine population increases. Second, there are differential effects to water and wastewater prices. The positive effect of the "Percent Black" regressor is greater for wastewater bills than water bills, and the negative effect of the "Percent Latine" regressor is smaller for wastewater than water bills. Utilizing water bill costs as the outcome variable, the regression results for "Percent Black" were not robust, while the results for both "Percent Latine" and "Percent Black" were robust across all models when utilizing wastewater costs as the outcome variable. Both of these findings of my heterogeneous analysis demonstrate the importance of infrastructure quality on water affordability.

Limitations

Due to time limitations and the significant data cleaning I had to undertake with the EFC data, I did not incorporate climate zone data in my models. However, climate zone likely influences household water use, such as lawn watering. My analysis is also limited by the information collected by the EFC. Because this data did not contain information such as providers' costs incurred from system maintenance and repair, I cannot unequivocally claim that discrepancies between water and wastewater bills are due to wastewater infrastructure repairs and maintenance.

Generalizability

Because I only examined North Carolina, the generalizability of my findings may be limited to states that have similar water infrastructure quality, population demographics, and climates as North Carolina. However, water and wastewater billing structures are fairly consistent across many states, as demonstrated by the EFC collecting similar data for twenty states across the Northeastern, Southern, Midwestern, and Western regions of the nation. This continuity in rate structure increases the generalizability of my results.

Potential Bias/Errors

Dropped Providers

Some N.C. water providers service consumers in more than one county. In many cases, I researched their consumer base, and coded the county match for the provider with their “majority county.” From my sample of over 500 North Carolina water providers, there were seven that I was not able to match to a “majority county” because the provider equally serviced more than one county, or information about the address of the provider, or other publically-available information did not allow me to make a well-informed decision about how to code the provider’s “majority county” **(Table 1.1)**. Therefore, these seven providers and their associated data are not included in the regressions. Although it is unlikely that such a small proportion of my sample would change the outcome of the data, if these providers disproportionately served low-income and/or minority communities, then my findings may have been biased downwards, as the relationship between water bills prices and the percentage of Black or Latine individuals would not be fully captured.

Additionally, my outcome variables were constructed from water rates inside N.C. city limits, although the EFC data contained information for both inside and outside of city limits.

The sample of providers that serviced consumers both in and out of city limits was small, and no providers serviced only consumers outside of city limits across the nine years I examined. Some providers listed their "outside" rates as $0.00, even for highest consumption tier. This is likely due to these providers not servicing these areas, rather than actually providing water across the consumption tiers for free, but the EFC data does not make this distinction. For these reasons, water rates outside city limits were dropped from my observations.

However, for the providers that listed rates both for inside and outside of city limits, the "outside" rates ranged from a few dollars more than the "inside" rates, to more than twice as much. If these providers disproportionately serviced low-income consumers, then my examinations of water affordability may be underestimates. Further, because N.C. majority-Black counties are not located in "urban" counties **(Appendix M)**, excluding these observations may have biased my results downwards.

Missing Data

Some N.C. water providers did not regularly participate in the EFC survey, and/or did not provide their water nor wastewater rate information. There are 240 observations missing for both water and wastewater rates. For both water and waste water, twenty-eight providers are represented in some, but not all of the nine years of data collection, and sixteen providers are not represented at all. It is possible that these providers are sporadically represented, or absent completely, from the EFC's data due to limited administrative capabilities and/or lack of knowledge about the organization. If so, these providers may systematically vary from other N.C. utility providers, and their ability to provide affordable water services may be limited, relative to other utility providers. Therefore, their rate data being incomplete or missing from the

EFC dataset may lead to underestimates of water unaffordability, further biasing my findings downward.

Urbanicity Estimate

My urban indicator variable classified 42% of N.C.'s counties as "urban," an over-estimate of the 20% categorization set forth by the N.C. Department of Commerce (Knopf, 2018). Residents of urban counties may have lower water bills due to increased access to higher-quality infrastructure and/or their providers' fixed costs being distributed amongst a larger customer base (Mack and Wrase, 2017). Incorporating the urban indicator into the model decreased the coefficient of the "Percent Black" variable for both water and wastewater bills **(Table 5.1, Model 4; Table 5.2, Model 4).** Because this indicator variable overestimated the urbanicity of the state, however, my findings may underestimate water affordability challenges in the state.

Strength of Findings

There are multiple sources of error that would bias my findings. However, each possible error would lead to underestimations of water unaffordability due to the under-represented providers being outside of city limits and charging higher rates, lacking institutional capacity, and/or being located in a non-urban are with less consumers to offset federal regulation compliance and infrastructure repair costs. Therefore, my findings of a small, consistent positive effect on wastewater bill costs as a county's Black population increased by a percentage point may understate the scope of water unaffordability that these individuals and communities experience in North Carolina. Consequently, examining these possible sources of error strengths my finding that Black North Carolinians disproportionately face water affordability challenges, relative to other N.C. residents.

Alternative Hypotheses

Differential Access to Infrastructure Repair/Maintenance

Although the data show that Black and Latine individuals do not live in many of the same counties the state **(Table 7.1 and Figures 2.1 and 3.1)**, and are therefore not serviced by many of the same providers, this does not definitively indicate that Latine individuals have access to higher-quality infrastructure than Black individuals do. It is possible that rather than differential access the higher-quality water infrastructure, Latine N.C. residents live in areas with the same quality infrastructure as Black North Carolinians, and their water and wastewater bills are kept relatively lower by a lack of system repair and maintenance, rather than access to higher-quality infrastructure. That is, rather than their water systems being in less need of repair than those that service Black N.C. residents, they are simply not being serviced equally, and consequentially their service providers do not have to increase their bills to absorb system maintenance and repair costs. To my knowledge, data that would allow for infrastructure quality comparisons is not currently available, as both the EFC and AWWA data did not contain data on infrastructure age, annual repair costs, or other measures of infrastructure quality.

Inflated Wastewater Rates due to Sanitation Costs

The EFC data notes that some providers may have “inflated rates in order to preserve public health.” That is, some increases to water and/or wastewater bills may be necessary in order to adequately treat and clean water and/or wastewater, and maintain federally-complaint water and wastewater delivery systems. As a result, water rates will increase. Therefore, sanitation measures, rather than infrastructure quality differences, may lead to disparities in water affordability.

Policy Implications

Previous examinations of water affordability recommended implementing federal protections from water shutoffs (Jones and Moulton, 2016; Mack and Wrase, 2017). In addition to recent potential federal water infrastructure investment, the federal government should amend the CWA and SWDA so that they are no longer unfunded mandates, and instead provide state governments funding to be distributed to localities and/or utility providers. This funding would prevent states and/or utility providers from passing along these compliance costs to consumers, as they disproportionately burden low-income households**.**

On the state level, policymakers should implement equity-focused affordability programs and water-shutoff protections. My findings indicate Black North Carolinians have both the lowest median household income and face greater water unaffordability challenges, revealing that the current water affordability context leaves Black North Carolinians at the highest risk of water shut-offs.

Federal Models for Targeted Water Affordability Policy

Throughout the COVID-19 pandemic, the federal government has implemented multiple COVID-19 relief bills, some of which assist directly or indirectly with residential water affordability (EFC, 2021a). The Community Development Block Grant Cares Act (CDBG-CV), administered by the U.S. Department of Housing and Urban Development, may provide households directly affected by COVID-19 up to six months of emergency payment assistance if the grantee, which may be the state, metropolitan cities or urban counties, verify that these households are eligible after they apply (EFC, 2021a). The Emergency Rental Assistance (ERA) Program allocates $25 billion to assist renters who have been financially impacted by COVID-

19, face housing instability, and have an income that is at least 80% below the area median with up to twelve months of assistance paying their utility bills (EFC, 2021a).

In addition to these assistance programs targeted towards low-income households affected by COVID-19, the federal government has also passed legislation intended to alleviate water affordability challenges for all low-income households. The Low-Income Household Drinking Water and Wastewater Emergency Assistance Program, part of the Consolidated Appropriations Act, was signed in 2020 (EFC, 2021a). This is the first federal program to provide financial assistance for water and wastewater bills to low-income households. The department of Health and Human Services will distribute the $638 million to states based on the percentage of households that meet or exceed 150% of the federal poverty line in the state, and the percent of households that spend more than 30% of their monthly income on housing. Further eligibility requirements are unclear, and it is also unknown if HHS or states themselves will determine eligibility (EFC, 2021a).

N.C. COVID-19 Water Bill Relief

In March 2020, N.C. governor Roy Cooper prohibited shut-offs of water, wastewater, and other utilities for sixty days, with consumers being given a six-month window to repay their bills (NCDHHS, 2020). In July, the North Carolina Utilities Commission extended this disconnection ban until September 1, and extended consumers' six-months repayment period to twelve months (Henderson, 2020). Starting September 1, 2020, water, wastewater, and other utility providers were allowed to proceed with collecting past due charges and service disconnection, and no further legislation has been enacted at the state level (NARUC, 2021).

Recommendations for Future Water Affordability Policy in N.C.

Given the current inequities in affordability and lack of federal protections, the state government should extend water shut-off protections beyond the conclusion of the pandemic, and provide financial assistance to low-income households. The requirements for eligibility in the Low-Income Household Drinking Water and Wastewater Emergency Assistance Program could be re-utilized, or slightly amended to determine eligibility in the state program, as the rollout of this federal program could provide a model for implementation best-practices, as well as a pre-existing database of participants that could be readily-utilized. Automatic re-enrollment of previous participants would remove the requirement of program application, which could function as barrier to receiving aid for North Carolinians who do not speak English and/or lack intuitional access, time, or other resources that may leave them under-served. Additionally, by providing assistance to all low-income North Carolina residents, the racial equity of water affordability in the state would be addressed, at least in part, as Black and Latine North Carolinians have lower MHIs than the state's overall MHI.

To prevent consumers from bearing the burden of infrastructure updates, state policymakers should invest in water system infrastructure. Allocations for these updates should be delivered to areas with the lowest-quality infrastructure. For example, my research suggested that Northeastern and coastal areas of N.C. may be in the greatest need. Finally, the state should work with existing water research organizations, such as the EFC, to regularly examine the equity of N.C. water affordability. Given the significantly greater research capacity of such organizations compared to the present study, these surveys should include other racial and ethnic groups beyond Black and Latine populations alone. These reviews could match increases to low, median, and high-cost water and wastewater bills with county demographic, usage, income, climate, and other pertinent characteristics. These regular examinations could monitor changes in affordability to ensure water equity throughout the state, and serve as an indicator of which areas of the are in need of infrastructure investment to prevent its residents from being disproportionately burdened by affordability challenges.

Recommendations for Future Research

The results of this study indicate the importance of access to urban wastewater infrastructure on wastewater affordability, and the differential impact of increases to both Black and Latine populations in urban and non-urban counties. My findings could be expanded, utilizing the EFC data for average water and wastewater bills outside of city limits. Because N.C. counties with the highest proportion of Black residents are in non-urban areas, such an analysis could further highlight disparities in N.C. wastewater affordability facing Black North Carolinians.

Future studies should expand to a multi-state analysis, incorporating more racial and ethnic groups, and controlling for source of between-state variation such as climate, infrastructure age and quality, and government involvement in utility service provision and/or subsidization. Measures of racial and ethnic segregation should also be integrated in multi-state analyses to strengthen causal inferences about the relationship between access to high-quality infrastructure and wastewater bill disparities. By comparing between-state variation in water affordability disparities, factors that minimize such disparities in certain states could be identified and, if able to be addressed via policy mechanisms, adopted in other states. Future studies of water affordability, whether single or multi-state, should incorporate demand elasticity metrics, accounting for changes in consumption based on previous bill costs, to more fully capture the relationship between water usage, demand, and affordability (Wichman, 2014).

Researchers should also examine how differences not only in water cost, but also water quality, vary in areas with higher concentrations of minority residents compared to areas with low proportions of non-white residents. This study highlights discrepancies in water affordability that leave low-income and/or minority communities vulnerable to shut-offs, and recommends shut-off protections, targeted affordability assistance, and infrastructure investment to alleviate consumers' financial burden. However, water quality is equally as important as guaranteed affordable access. Water pollution nor contamination levels are captured by the EFC data, limiting my analysis to water and wastewater cost. Equitable water access, affordability, and quality are all important to individual and community health and well-being, and should be the focus of further water affordability policy research and advocacy.

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APPENDICES

APPENDIX A: Percent Black and Urban Indicator t-test

Group	Mean	
Not Urban	0.28	
Urban	0.16	p-value
Difference	0.12	0.0000

Data Sources: ACS (2010-2020), US Department of Agriculture (2013)

APPENDIX B: Percent Latine and Urban Indicator t-test

Group	Mean	
Not Urban	0.072	
Urban	0.074	p-value
Difference	-0.0052	0.0000

Data Sources: ACS (2010-2020), US Department of Agriculture (2013)

APPENDIX C: Average N.C. Residential Water Bill price; service population <25,427

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Percent Black	0.19		0.058	0.95	5.04***	3.24**
	(1.185)		(1.186)	(1.293)	(1.331)	(1.313)
Percent Latine		-7.64**	-7.62**	-7.53**	-12.01***	-14.49***
		(3.555)	(3.539)	(3.544)	(3.493)	(3.374)
Urban				0.76*	-0.97**	-0.17
				(0.435)	(0.455)	(0.461)
Median Household Income					0.00028***	0.00015***
					(2.28e-05)	(2.61e-05)
Constant	32.54***	33.13***	33.12***	32.63***	20.18***	22.51***
	(0.313)	(0.327)	(0.406)	(0.501)	(1.138)	(1.239)
Observations	3,617	3,617	3,617	3,617	3,617	3,617
R-squared	0.000	0.001	0.001	0.002	0.034	0.078

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Data Sources: EFC (2011-2019), ACS (2010-2020), PolicyMap (2010-2020), US Department of Agriculture (2013)
Note: Column 6 includes year fixed-effects, which have been omitted from the table for improved readability

APPENDIX D: Average N.C. Residential Wastewater Bill price; service population <25,427

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Percent Black	2.49***		2.32**	2.68***	5.37***	4.00***
	(0.910)		(0.912)	(0.979)	(1.024)	(1.016)
Percent Latine		-10.55***	-9.996***	-9.959***	-12.91***	-14.75***
		(2.711)	(2.712)	(2.716)	(2.706)	(2.617)
Urban				0.303	-0.832**	-0.221
				(0.334)	(0.345)	(0.350)
Median Household Income					0.00018***	8.52e-05***
					(1.76e-05)	(2.09e-05)
Constant	23.21***	24.54***	23.96***	23.76***	15.57***	17.41***
	(0.236)	(0.255)	(0.311)	(0.377)	(0.887)	(0.984)
Observations	3,617	3,617	3,617	3,617	3,617	3,617
R-squared	0.002	0.003	0.004	0.004	0.027	0.066

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Data Sources: EFC (2011-2019), ACS (2010-2020), PolicyMap (2010-2020), US Department of Agriculture (2013)
Note: Column 6 includes year fixed-effects, which have been omitted from the table for improved readability

APPENDIX E: Average N.C. Residential Water Bill price; service population ≥25,427

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Percent_Black	0.17		2.48	-6.95*	-1.55	-1.39
	(3.895)		(4.278)	(4.102)	(4.175)	(4.204)
Percent_Latine		-59.32***	-60.58***	-36.48**	-57.13***	-57.78***
		(15.14)	(15.84)	(14.60)	(15.02)	(15.16)
Urban				-5.71***	-8.66***	-8.17***
				(0.922)	(0.916)	(0.922)
Median_Income					0.00026***	0.00022***
					(4.15e-05)	(4.36e-05)
Constant	30.93***	36.24***	35.81***	39.38***	27.83***	26.67***
	(0.904)	(1.464)	(1.499)	(1.507)	(2.415)	(2.614)
Observations	647	647	647	647	647	647
R-squared	0.000	0.022	0.022	0.076	0.138	0.163

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Data Sources: EFC (2011-2019), ACS (2010-2020), PolicyMap (2010-2020), US Department of Agriculture (2013)
Note: Column 6 includes year fixed-effects, which have been omitted from the table for improved readability

APPENDIX F: Average N.C. Residential Wastewater Bill price; service population ≥25,427

VARIABLES	(1) Model 1	(2) Model 2	(3) Model 3	(4) Model 4	(5) Model 5	(6) Model 6
Percent Black	0.33		2.86	-5.03	-1.35	-1.25
	(2.928)		(3.340)	(3.217)	(3.291)	(3.300)
Percent Latine		-65.18***	-66.64***	-46.48***	-60.52***	-60.92***
		(11.21)	(11.92)	(11.00)	(11.21)	(11.26)
Urban				-4.78***	-6.78***	-6.33***
				(0.726)	(0.732)	(0.733)
Median Household Income					0.00018***	0.00014***
					(2.95e-05)	(3.10e-05)
Constant	22.16***	28.02***	27.53***	30.51***	22.66***	21.74***
	(0.654)	(1.122)	(1.105)	(1.192)	(1.786)	(1.942)
Observations	647	647	647	647	647	647
R-squared	0.000	0.043	0.044	0.105	0.152	0.184

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Data Sources: EFC (2011-2019), ACS (2010-2020), PolicyMap (2010-2020), US Department of Agriculture (2013)
Note: Column 6 includes year fixed-effects, which have been omitted from the table for improved readability

APPENDIX G: Average N.C. Residential Water Bill Price in NC, showing year Fixed Effects

VARIABLES	(1) Model 1	(2) Model 2	(3) Model 3	(4) Model 4	(5) Model 5	(6) Model 6
Percent Black	0.283		0.0971	-0.581	2.266*	1.045
	(1.140)		(1.142)	(1.226)	(1.253)	(1.227)
Percent Latine		-12.86***	-12.84***	-12.57***	-18.72***	-20.36***
		(3.415)	(3.400)	(3.381)	(3.359)	(3.252)
Urban				-0.56	-2.33***	-1.46***
				(0.382)	(0.409)	(0.414)
Median Household Income					0.00022***	0.00011***
					(2.02e-05)	(2.25e-05)
2012.year						0.10
						(0.608)
2013.year						1.72***
						(0.606)
2014.year						2.85***
						(0.672)
2015.year						3.54***
						(0.669)
2016.year						4.32***
						(0.717)
2017.year						5.68***
						(0.727)
2018.year						7.11***
						(0.735)
2019.year						7.85***
						(0.740)
Constant	32.27***	33.29***	33.27***	33.63***	24.20***	25.31***
	(0.296)	(0.318)	(0.389)	(0.471)	(1.014)	(1.089)
Observations	4,264	4,264	4,264	4,264	4,264	4,264
R-squared	0.000	0.002	0.002	0.003	0.027	0.073

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Data Sources: EFC (2011-2019), ACS (2010-2020), PolicyMap (2010-2020), US Department of Agriculture (2013)

APPENDIX H: Average N.C. Residential Wastewater Bill Price in N.C., showing year Fixed Effects

VARIABLES	(1) Model 1	(2) Model 2	(3) Model 3	(4) Model 4	(5) Model 5	(6) Model 6
Percent Black	2.45***		2.23**	1.29	3.10***	2.15**
	(0.876)		(0.879)	(0.931)	(0.958)	(0.940)
Percent Latine		-15.82***	-15.38***	-15.01***	-18.91***	-20.13***
		(2.618)	(2.616)	(2.601)	(2.616)	(2.534)
Urban				-0.77***	-1.90***	-1.22***
				(0.294)	(0.312)	(0.317)
Median Household Income					0.000137***	5.58e-05***
					(1.50e-05)	(1.70e-05)
2012.year						0.72
						(0.481)
2013.year						1.26***
						(0.484)
2014.year						2.08***
						(0.547)
2015.year						2.74***
						(0.528)
2016.year						3.38***
						(0.580)
2017.year						4.35***
						(0.584)
2018.year						5.44***
						(0.580)
2019.year						5.92***
						(0.579)
Constant	22.99***	24.72***	24.18***	24.68***	18.69***	19.61***
	(0.222)	(0.249)	(0.298)	(0.357)	(0.762)	(0.825)
Observations	4,264	4,264	4,264	4,264	4,264	4,264
R-squared	0.002	0.005	0.007	0.008	0.024	0.067

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Data Sources: EFC (2011-2019), ACS (2010-2020), PolicyMap (2010-2020), US Department of Agriculture (2013)

APPENDIX I: Average N.C. Residential Water Bill Price in NC, clustering on FIPS code

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Percent Black	0.28		0.097	-0.58	2.266	1.045
	(3.461)		(3.498)	(3.585)	(3.565)	(3.577)
Percent Latine		-12.86	-12.84	-12.57	-18.72**	-20.36**
		(8.597)	(8.495)	(8.428)	(7.948)	(7.880)
Urban				-0.56	-2.33*	-1.46
				(1.277)	(1.291)	(1.282)
Median Household Income					0.000217***	0.000111*
					(5.35e-05)	(5.79e-05)
Constant	32.27***	33.29***	33.27***	33.63***	24.20***	25.31***
	(0.876)	(0.969)	(1.073)	(1.432)	(2.822)	(2.790)
Observations	4,264	4,264	4,264	4,264	4,264	4,264
R-squared	0.000	0.002	0.002	0.003	0.027	0.073

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Data Sources: EFC (2011-2019), ACS (2010-2020), PolicyMap (2010-2020), US Department of Agriculture (2013)
Note: Column 6 includes year fixed-effects, which have been omitted from the table for improved readability

APPENDIX J: Average N.C. Residential Wastewater Bill Price in NC, clustering on FIPS code

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Percent Black	2.45		2.23	1.29	3.10	2.15
	(2.609)		(2.640)	(2.691)	(2.726)	(2.731)
Percent Latine		-15.82**	-15.38**	-15.01**	-18.91***	-20.13***
		(6.649)	(6.673)	(6.443)	(7.090)	(7.071)
Urban				-0.78	-1.90*	-1.22
				(1.036)	(1.043)	(1.040)
Median Household Income					0.000137***	5.58e-05
					(3.84e-05)	(4.07e-05)
Constant	22.99***	24.72***	24.18***	24.68***	18.69***	19.61***
	(0.670)	(0.771)	(0.855)	(1.117)	(2.095)	(2.041)
Observations	4,264	4,264	4,264	4,264	4,264	4,264
R-squared	0.002	0.005	0.007	0.008	0.024	0.067

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Data Sources: EFC (2011-2019), ACS (2010-2020), PolicyMap (2010-2020), US Department of Agriculture (2013)
Note: Column 6 includes year fixed-effects, which have been omitted from the table for improved readability

APPENDIX K: Average N.C. Residential Water Bill Price, clustering on Utility

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Percent Black	0.28		0.097	-0.58	2.27	1.05
	(2.797)		(2.802)	(3.034)	(3.089)	(3.107)
Percent Latine		-12.86	-12.84	-12.57	-18.72**	-20.36**
		(8.032)	(8.007)	(7.948)	(7.920)	(7.945)
Urban				-0.561	-2.33**	-1.46
				(0.969)	(1.038)	(1.067)
Median Household Income					0.00022***	0.00011**
					(4.65e-05)	(5.49e-05)
Constant	32.27***	33.29***	33.27***	33.63***	24.20***	25.31***
	(0.731)	(0.786)	(0.967)	(1.203)	(2.378)	(2.530)
Observations	4,264	4,264	4,264	4,264	4,264	4,264
R-squared	0.000	0.002	0.002	0.003	0.027	0.073

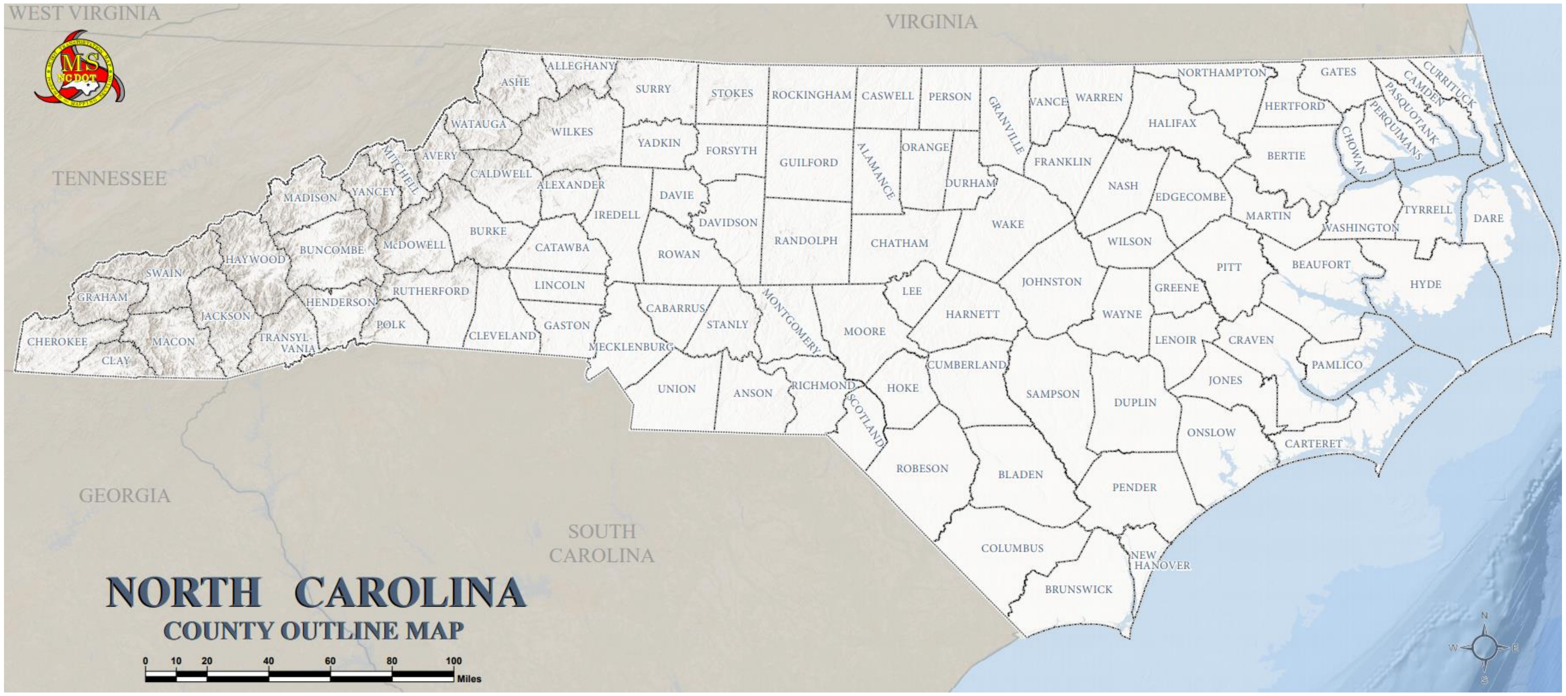
Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Data Sources: EFC (2011-2019), ACS (2010-2020), PolicyMap (2010-2020), US Department of Agriculture (2013)
Note: Column 6 includes year fixed-effects, which have been omitted from the table for improved readability

APPENDIX L: Average N.C. Residential Wastewater Bill Price, clustering on Utility

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Percent Black	2.45		2.23	1.29	3.10	2.15
	(2.609)		(2.640)	(2.691)	(2.726)	(2.731)
Percent Latine		-15.82**	-15.38**	-15.01**	-18.91***	-20.13***
		(6.649)	(6.673)	(6.443)	(7.090)	(7.071)
Urban				-0.78	-1.90*	-1.22
				(1.036)	(1.043)	(1.040)
Median Household Income					0.000137***	5.58e-05
					(3.84e-05)	(4.07e-05)
Constant	22.99***	24.72***	24.18***	24.68***	18.69***	19.61***
	(0.670)	(0.771)	(0.855)	(1.117)	(2.095)	(2.041)
Observations	4,264	4,264	4,264	4,264	4,264	4,264
R-squared	0.002	0.005	0.007	0.008	0.024	0.067

Robust standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$
Data Sources: EFC (2011-2019), ACS (2010-2020), PolicyMap (2010-2020), US Department of Agriculture (2013)
Note: Column 6 includes year fixed-effects, which have been omitted from the table for improved readability

APPENDIX M: Labeled N.C. County Map



Source: N.C. Department of Transportation (2021)