# WHY WASTE? LOCAL FACTORS AND RECYCLING OUTCOMES: A CASE STUDY OF NORTH CAROLINA COUNTIES

by

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ABSTRACT

TITIKSHA FERNANDES. Why Waste? Local Factors and Recycling Outcomes. A case study of North Carolina Counties (Under the direction of DR. SUZANNE M. LELAND)

The U.S. Environmental Protection Agency (EPA) reported that in 2015 only 67.8 million tons or about 26% of the total waste generated was recycled, while the waste generated continued to rise. It is clear from the numbers above that the success of current recycling programs is limited. Increasing populations will continue to put pressure on our existing resources, compelling governments at all levels to take additional action to increase recycling efforts to transition from a linear model of make, use, and dispose to a closed-loop circular economy system, emphasizing reduce, reuse and recycle. Additional challenges arising from China's National Sword Policy have further exacerbated the recycling crisis.

Within this context, my research evaluates recycling programs at the county level in the state of North Carolina. The first part explores county level factors that affect recycling rates. Factors span across the economic, demographic, social, geographic, technical, and programmatic aspects of recycling programs. The second part of my study focusses on exploring the economic and environmental merits of recycling. Specifically, this section explores the GHG emissions and wage creation from recycling certain materials as compared to landfilling them, and the causal mechanism between recycling, and GHG emissions and employment generation. Qualitative interviews with stakeholders in the recycling community inform the findings of my quantitative analysis.

I found that recycling is moving away from being a behavior based on individual taste and preferences to a mainstream behavior—part of everyday life. We must view recycling not only as an individual altruistic action but also as a means to decrease the cost of goods, lower landfill costs, combat climate change, and reduce resource and energy use while engaging the community. Most important is the need for standardized measures for recycling, new ways to measure recycling performance, and greater consistency in solid waste management policies so that scholars and program analysts can conduct more comparative studies.

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## DEDICATION

To my grandmother Swaraj Sarin and my mother Poonam Fernandes, for showing me what true courage and perseverance looks like.

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| | |
|---|---|
| EC | European Commission |
| EPA | Environmental Protection Agency |
| FLIGHT | Facility Level Information on GHGs Tools |
| GHG | greenhouse gas |
| MRF | material recovery facility |
| MSW | municipal solid waste |
| MTCO2e | metric tons of carbon dioxide equivalent |
| NCDEQ | North Carolina Department of Environmental Quality |
| RCRA | Resource Conservation and Recovery Act |
| WARM | waste reduction model |

# CHAPTER 1: INTRODUCTION

The National Recycling Goal set forth by the United States Environmental Protection Agency (EPA) State aims to increase the national recycling rate to 50 percent by 2030 (epa.gov). While state and local governments continue to spend millions of dollars on recycling efforts, challenges arising from China's recycling import ban[1] and the limited growth of the U.S. recycling market highlight the need to evaluate current recycling practices. Understanding whether these efforts are achieving their environmental and economic goals and whether they align with the goals set forth by the EPA, can help policy makers and leaders identify the state of recycling and areas of improvement.

This dissertation focusses on recycling policy at the local level across North Carolina, to evaluate current recycling practices. My research builds on the existing literature by introducing new key variables of interest. To that end, this interdisciplinary mixed methods study addressed the following broad questions to evaluate recycling programs for the state of North Carolina and make policy recommendations based on the findings:

1. How do county level economic, political, social, structural, and geographical factors influence the recycling rates in North Carolina counties?
2. Does recycling lead to positive environmental and economic outcomes in North Carolina counties?
3. What county-level indicators help measure recycling-program performance? Does the quantity of items collected at the county level differ from what is recycled at the

[1] China's "National Sword" policy of 2018 banned the import of most plastics, resulting in a 99% decrease in plastic imports. This was done to keep contaminated materials, which were starting to create major problems for the country's natural environment, out of China (Katz, 2019)

Material Recovery Facilities (MRF)[2]? If yes, what might account for those differences? What are the motivations for recycling at the county level and at the MRFs?

**Relevance**

Population growth, followed by rapid urbanization and an increase in disposable incomes, has led to a rise in demand for both natural and human-made resources, thereby increasing pressure on existing resources (United Nations Environmental Programme, 2012). Resource demand is projected to grow over the coming decades, making way for a resource-constrained world in the 21st century (Bardi, 2014). Although efforts are underway to identify new reserves to combat the predicted depletion of resources, the significant trade-offs involved in the process are often not fully realized. This process does not preclude devastating price spikes, supply disruptions, monopolistic and strategic behavior, and geopolitical conflicts, all of which can have devastating impacts on economies and societies.

Equally, if not more important, are the worsening environmental (and, consequently, often social) impacts as better quality, more easily accessible resources deplete, and new extraction moves to lower quality resources in often remote, inaccessible, and ecologically vulnerable places. Environmental and social impacts include local environmental degradation, increased potential for catastrophic accidents, and growing energy use and its consequent greenhouse gas emissions.

As resource and environmental constraints become more prominent, strategies aimed at using these resources in a closed loop are gaining traction (Tisserant et al., 2017). The Ellen MacArthur Foundation (2014) termed this closed-loop system the "circular economy." A circular economy is an "economic system aimed at minimizing waste and making the most of resources."

[2] MRFs are solid waste management plants that process and prepare recyclable materials for manufacturers to be able to use as raw materials in their production (Hosanky, n.d.).

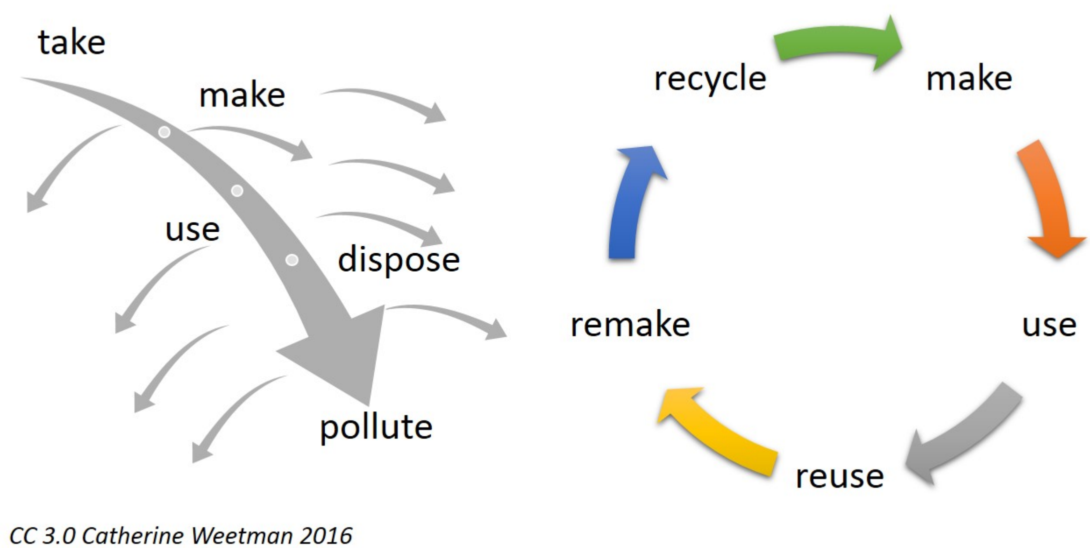
This regenerative approach contrasts with that of the traditional linear economy, which has a "'take, make, dispose' model of production" (Ellen MacArthur Foundation, 2014). Effective recycling practices bolster the closed-loop system by ensuring that waste is diverted from the landfill and back into the resource loop such that it could potentially replace primary materials and consequently the resource-extraction process (Maio & Rem, 2015).

Focusing on efficient utilization and recycling/reuse of resources creates multiple socioeconomic and environmental benefits. Acknowledging these benefits, countries are formulating integrated, comprehensive, national-level strategies to promote resource security and sustainability. The most notable among these national plans is the European Commission's (2015) Circular Economy Strategy, which aims to close the loop between resource supply and demand through recycling and reuse efforts, thereby directly addressing the 3 Rs of reduce, reuse, and recycle and moving away from a linear approach to products (Fig 1.1). Moreover, as of 2016, almost all countries had committed to achieving climate targets, which could motivate them to distance themselves from past practices dominated by energy-intensive extraction and overseas shipping of resources from far away. In addition to the environmental benefits, another beneficial characteristic of a circular economy–based strategy is its job creating potential that researchers have estimated to be significantly higher than the conventional "linear" economic model (McKinsey & Company, 2015). Thus, the circular economy has high economic and environmental potential, making it an effective strategy option for elected policy makers. With many areas in the developed world rapidly losing jobs due to deindustrialization and suburbanization (Heider & Siedentop, 2020), and cities in the developing world under pressure to provide jobs to their rapidly growing populations, the circular economy might offer a viable alternative to achieving these demands.

The adoption of the circular economy principles by the EU and countries such as Japan and China have proven successful in approaching sustainability goals, encouraging others to follow suit. Although the underlying concepts of the circular economy are not foreign, some cities in the United States have formally recognized the prospects of the strategy and applied it to their existing processes. Charlotte, North Carolina, is an example of a city that has adopted the circular economy to encourage zero-waste and boost economic development (City of Charlotte, n.d.). While other cities around the U.S. have taken up this initiative, the U.S. federal government has not yet developed or adopted a circular economy policy comparable to that of the EU. Further, the United States has no federal mandate on recycling, leaving states the option to voluntarily conduct recycling operations.

**Figure 1.1**

*From Linear to Circular*




*Note*. Retrieved from Wikimedia Commons

The end-of-life stage of a resource is one of the most crucial stages, given the policy framework within which the circular economy operates. Growing consumption implies increased disposal of products resulting in mass generation of waste, thereby increasing the importance of recycling in keeping these wastes out of landfills. Although other aspects of the circular economy (i.e., design, sourcing, manufacturing, distribution, and use) are equally important, they take much longer to evolve and require larger investments and mobilization of stakeholder groups than does recycling. For this reason, this study focused on solid waste management and recycling activities (or waste diversion[3] via recycling). The state of North Carolina was selected for this study due to its heterogenous political, economic, and social characteristics, which make the study of policy, especially one as complex as environmental policy, especially interesting.

## Recycling in the United States

At 5%, solid waste management's contribution to global greenhouse gas (GHG) emissions is small (Bogner et al., 2007). However, with rising concerns associated with climate change, countries across the world are becoming proactive at combatting greenhouse gas emissions (GHG), including actions to appropriately manage solid waste (Turner & Kemp, 2015). With the United States committing to a GHG emissions reduction of 26-28% below 2005 levels by 2025 (White House, 2014), reducing GHG emissions across all sectors would be a good strategy to achieve this target.

Recycling has been touted as one approach to reduce GHG emissions. Even in the absence of federal mandates to recycle, states and their local governments have been designing and implementing recycling programs. Objectives of recycling transitioned toward environmental merits, when landfills started to fill up quickly and environmental issues, such as acid rain, took prominence (Louis, 2004). Over time, justification for recycling has evolved to include arguments of improved environmental quality, job creation, cost savings, tax revenue,

[3] "Waste diversion" refers to minimizing solid waste generation through source reduction, recycling, reuse, or composting. Waste diversion also reduces disposal costs and burden on landfills (U.S. EPA).

and increased economic development opportunities. However, empirical evidence of these environmental and economic benefits has been limited (Makridis & Dawson, 2018). A report by Tellus (2011) indicated that, for every thousand tons of recycled material, 5.7 new jobs are created. In 2016–2017, North Carolina recovered a total of 1,700,609 tons of recyclables, which, if using Tellus's (2011) estimates, would have been expected to create 9,693 new jobs. However, a North Carolina Department of Environmental Quality (NCDEQ) report on state employment from recycling shows that, in 2015, recycling-related employment had decreased since 2013, by 4.3% (NCDEQ, 2015, p. 5). According to NCDEQ, this decrease was partly attributed to statistical adjustments and low-value markets for commodities. Because this is only a partial explanation for the decrease, further investigation is required to understand the reasons for the state's decline in recycling-related employment.

State and local governments spend millions of dollars on recycling efforts, including efforts to educate citizens about recycling, transportation costs and storage costs. It is important to consider these efforts in light of evaluating them for their intended outcomes. Additionally, given the current challenges arising from China's recycling import ban and the limited growth of the U.S. recycling market, it is important to evaluate the worthiness of recycling programs from a cost–benefit perspective. Finally, understanding whether these efforts are achieving their environmental and economic goals can help policy makers and leaders identify the state of recycling at the local level in North Carolina and areas of improvement (if any) within the contextual challenges.

In the United States, under Subtitle D of the Resource Conservation and Recovery Act of 1976, the burden to regulate nonhazardous waste and implement waste management programs lies within the jurisdiction of state governments. At the state level, the North Carolina Solid

Waste Management Act of 1989 gives the responsibility of planning and implementing waste management programs to the counties and municipalities. The first plan was adopted in 1991 and provided guidance on solid waste issues to the General Assembly and state and local administrators. The plan has since been revised every 10 years to incorporate new waste-reduction goals. While recycling remains mandated by state law, counties hosting waste management facilities are required to operate a recycling program. Funding for these programs comes from revenue collected from landfills, either in the form of taxes or tipping fees. Additionally, the NCDEQ provides a Solid Waste Management Trust Fund, to which local governments can apply to receive grants to fund their programs.

Because the major burden of designing and implementing waste management programs lies with the state and local governments, this study employs a formative evaluation[4] to explore county-level factors that lead to higher conversions of recycling rates[5] and whether those higher recycling rates result in positive environmental and economic outcomes. The following section provides insight into waste and recycling programs within the United States.

## Waste in the United States

Municipal solid waste (MSW) in the United States is defined as the total solid waste discarded by households, businesses, and retailers, typically categorized by either material or product type (see Figure 1.2 for more detail). Materials that do not make it to recycling plants or other forms of waste processing are discarded or diverted to a landfill. To use these landfills,

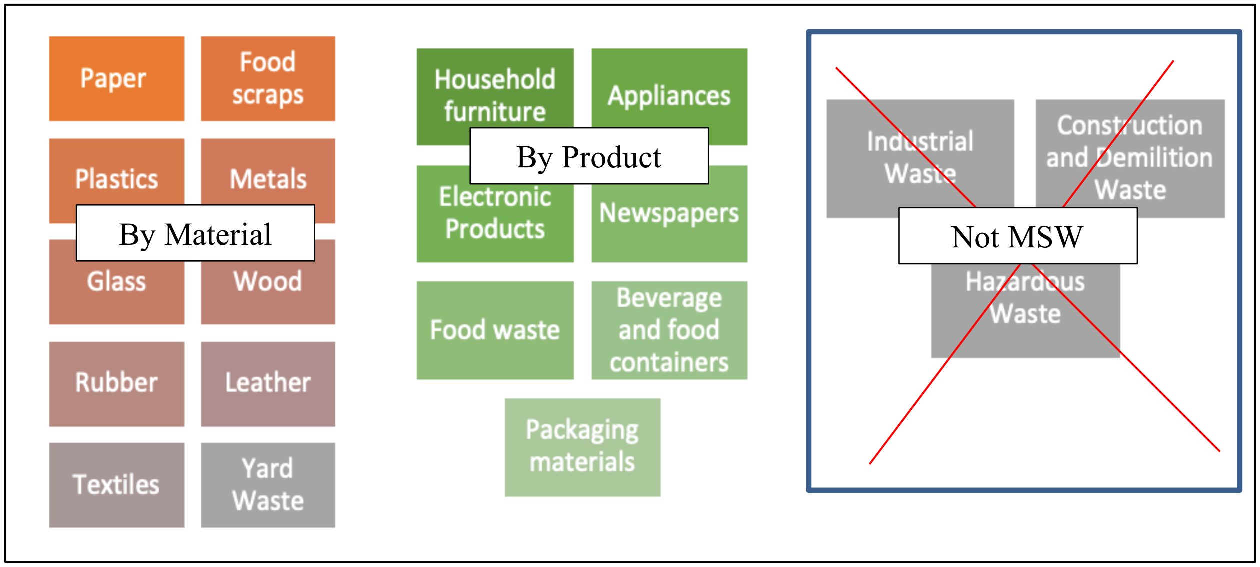
[4] A "formative evaluation" is a rigorous assessment process designed to identify potential and actual influences on the progress and effectiveness of implementation efforts (Stetler et al., 2006).

[5] The recycling rate for North Carolina is calculated as the total Municipal Solid Waste (MSW) collected (in lbs.) for recycling divided by the total MSW collected (in lbs.). This recycling rate is then divided by the population to calculate the recycling rate per capita.

counties and municipalities pay a tipping fee, which is the cost associated with disposing a single ton of MSW into a landfill (Repa, 2005).

**Figure 1.2**

*Municipal Solid Waste Classification Categories*




*Note. Created by author using data from EPA and NCDEQ websites.*

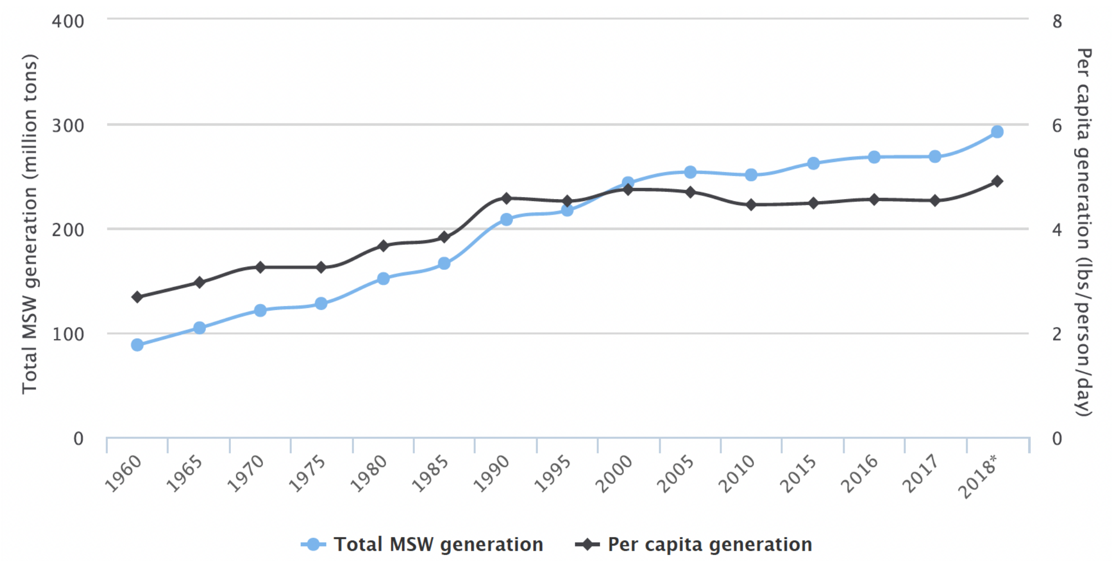
The U.S. Environmental Protection Agency (EPA) report on MSW shows that the amount of MSW generated in the United States increased from 88.1 million tons in 1960 to 262.4 million tons in 2015 (EPA, 2018). Of the 262.4 million tons, an estimated 137.7 million were disposed into landfills, and 67.8 million, or about 26% of the total waste generated was recycled (excluding composting; EPA, 2018). To understand these numbers within the context of a growing population, in 2018, while MSW rates were on the rise, the US recycling rate was 32.1%, down from 34.7% in 2015 (WPA.gov; also see Figures 1.3 and 1.4). These numbers suggest limited success of U.S. recycling programs, particularly when the rates are juxtaposed with some European nations, such as Germany, Belgium, and Sweden, where recycling rates exceed 50% (Organisation for Economic Co-operation and Development, 2018).

Another study claimed that a 1% increase in national U.S. per capita income is associated with a 0.69% per capita increase in MSW (Johnstone & Labonne, 2004). This increase is worth considering as the US continues to put pressure on existing resources due to its increasing population and economic growth rates. Therefore, a policy goal could be to enhance waste management efforts in pursuit of transitioning from a linear model of make, use, and dispose to a closed-loop, circular-economy system emphasizing reduce, reuse, and recycle. Additional challenges arise as developing economies, such as China and India, implement a ban on their waste imports from developed countries, including the United States. These bans could have strong effects on the domestic market for recycling, exacerbating existing recycling challenges in the country (Brooks et al., 2018).

In an era of increasing consumption and consequent increases in waste, new approaches to manage solid waste have surfaced (Acuff & Kaffine, 2013). Recycling is just one of the methods for waste disposal. Other methods include landfill disposal, incineration, and composting. However, under the right conditions, recycling is one of the most efficient means to tackle the growing waste problem (Merrild et al., 2012). As mentioned earlier, recycling not only is associated with the creation of new products from waste materials but also spurs economic development by creating jobs and wealth in the new “waste economy.” Although recycling takes place locally, an investigation of the relationships between higher-level and local governments provides a valuable piece of the bigger picture.

**Figure 1.3**

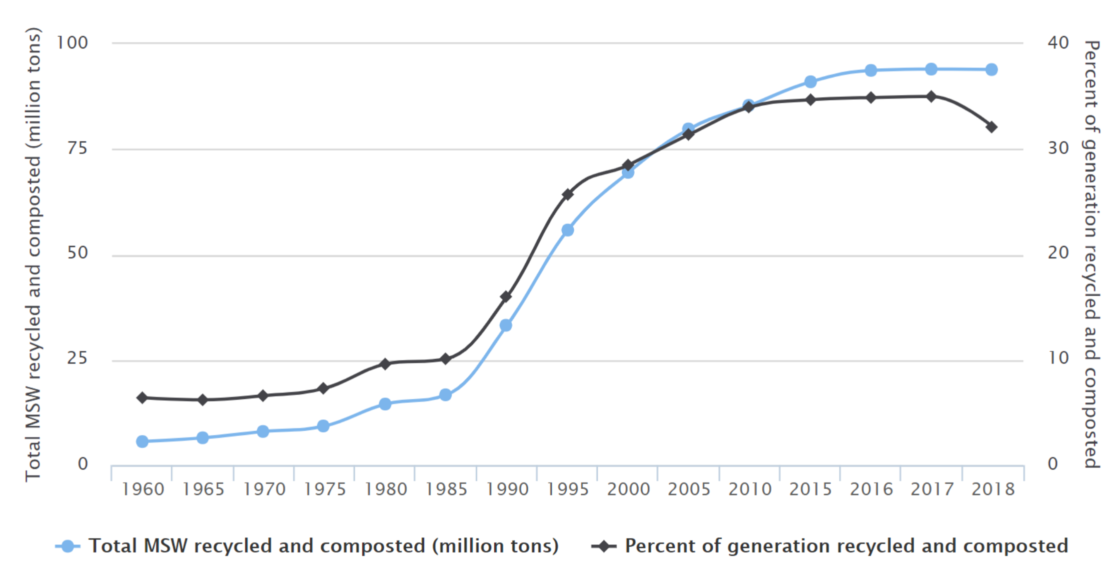
*U.S. MSW Generation and Recycling Rates, 1960–2018*




*Note*. From *National Overview: Facts and Figures on Materials, Wastes and Recycling*, by Environmental Protection Agency, n.d. (https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/national-overview-facts-and-figures-materials#recycling). In the public domain.

**Figure 1.4**

*MSW Recycling and Composting Rates, 1960–2018*




*Note*. From *National Overview: Facts and Figures on Materials, Wastes and Recycling*, by Environmental Protection Agency, n.d. (https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/national-overview-facts-and-figures-materials#recycling). In the public domain.

## The Federal–State Relationship

In the United States, state governments have long been considered "laboratories of democracy" for experimenting with socioeconomic policies that benefit the citizens of the region without affecting the rest of the country. Growing federalism and devolution of powers from the federal to the state governments has enabled states to adopt and implement their own policies (Blomquist, 1991; Crotty, 1987). As described by Honadle (2001), "The 'Devolution Revolution' of the 104th Congress was the most recent scene in the ongoing drama called 'the new federalism'" (p. 78). With the federal government burdened by the operations of multiple programs, the approach moved toward one of delegating responsibility to local governments, giving rise to federalism. This has led to researchers scrutinizing the capacity of local governments to manage these new responsibilities (Honadle, 2001).

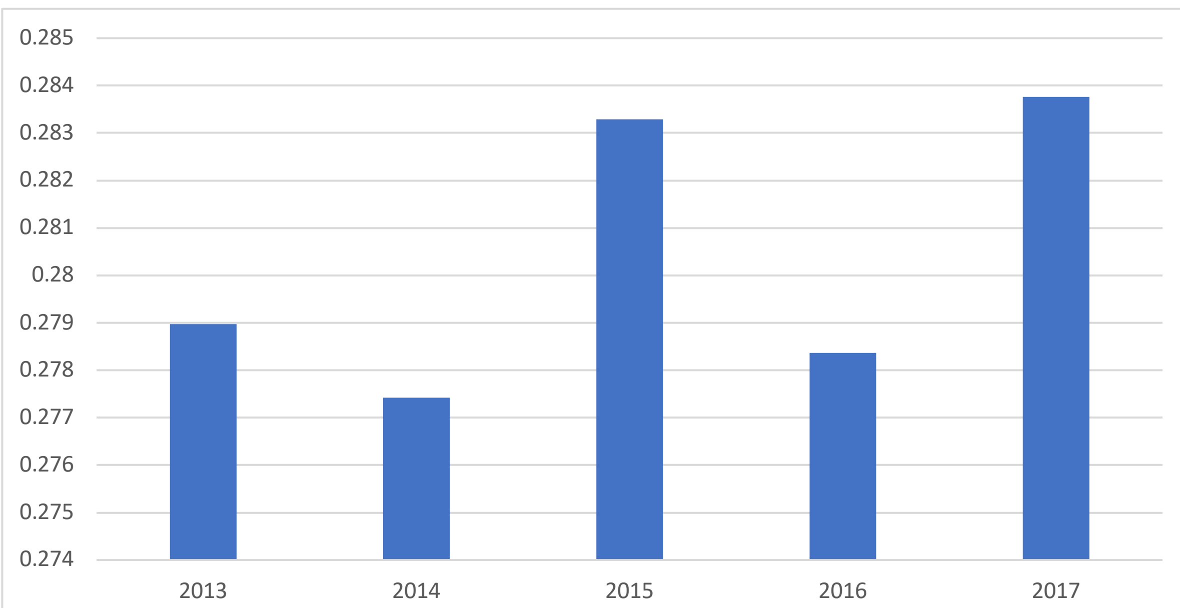
In the case of waste disposal and recycling, where the practices and industries creating the waste vary significantly across states, the EPA adopted the Resource Conservation and Recovery Act (RCRA) of 1976, giving states the responsibility of planning and implementing waste management programs. This meant that states now had the autonomy to design, plan, and implement their own waste efforts. Under subtitle D of this Act, the RCRA also assigned the states with the task of internalizing the social costs of waste disposal (Callan & Thomas, 1997). Since the adoption of RCRA, state governments have designed several mechanisms to reduce the external costs of waste disposal, including motivating local governments to recycle.
The following section details the laws and policies that guide waste management in the state of North Carolina.

## Waste in North Carolina

The recycling rate in North Carolina from 2013 to 2018 remained steady, at about 0.2 pounds per capita per day (Figure 1.5). Compared to the national average of 1.16 pounds per person per day, North Carolina ranks far behind. Although 0.2 pounds per capita per day is the overall average recycling rate for the state, recycling rates vary substantially across the counties. For example, for 2017, Halifax County ranked at the bottom of the county recycling performance list, with about 0.014 pounds of recycling per capita per day (5.3 lbs. per capita per year). In contrast, Catawba County ranked highest, with a daily per capita recycling rate of about 0.73 pounds (269 lbs. per capita per year). These wide gaps in recycling rates highlight underlying differences in recycling programs across the state, which could be programmatic (operations and resources) or contextual (demographics, geographical).

**Figure 1.5**

*North Carolina Recycling Rate (Pounds per Capita per Day) From 2013 to 2017*




*Note*. Created by author using NCDEQ website.

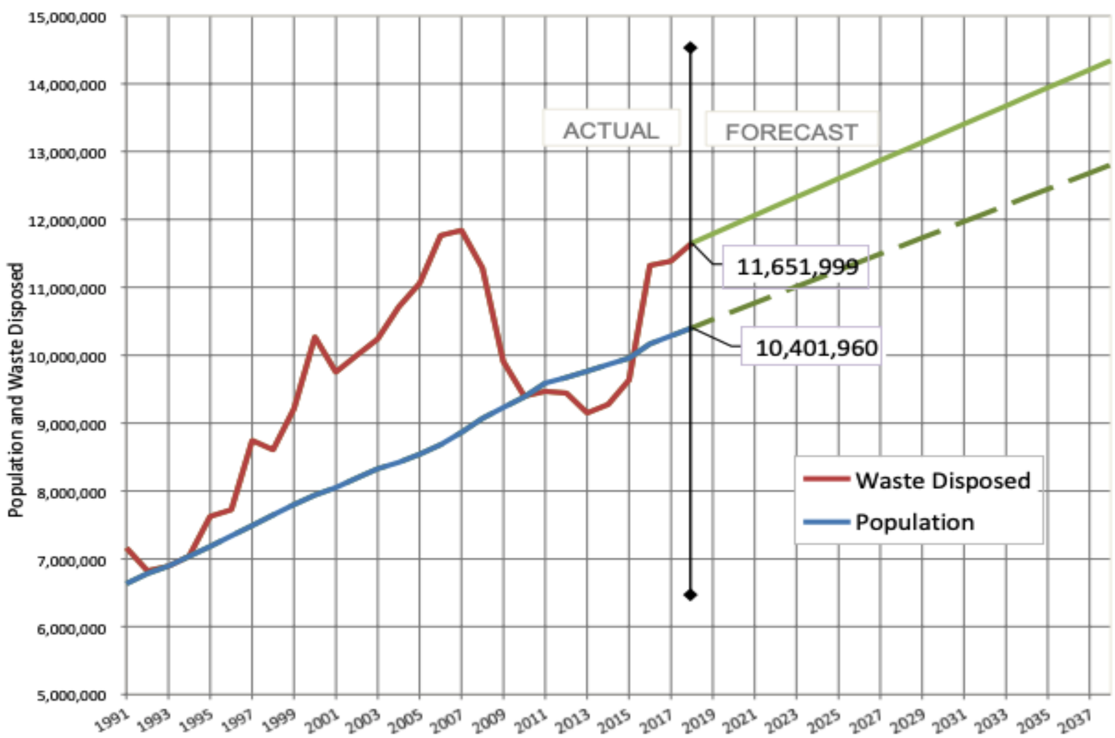
## North Carolina Law

Following the adoption of RCRA, North Carolina passed the North Carolina Solid Waste Management Act of 1989, which led to 10-year waste management plans. The latest approved plan, which covered 2003 to 2013 is still being implemented, whereas the 2014–2024 state plan remains under consideration. The reasons for the delay in approving the plan are unknown.

How the delay currently affects recycling outcomes is unknown. While North Carolina does not mandate recycling by law, state and local governments continue to operate their recycling activities (nerc.gov). Counties are left to create their own programs, but most counties are rural and, presumably, operate on small, perhaps strained budgets. Despite the efforts, the level at which existing recycling programs operate may not be enough. A North Carolina state report indicated a steady rise in disposed waste relative to population growth, putting pressure on existing landfills in the years to come (Figure 1.6). Landfilling costs money (disposal costs), and in the instance where landfills are open dumping sites, they have added external costs, such as air, land, and water pollution. This highlights the need to further push for waste-diversion strategies, such as recycling. Recycling not only reduces pressure and costs associated with landfills but could possibly help reduce reliance on nonrenewable virgin materials (Kinnaman, 2014). The next section elaborates on North Carolina's county recycling programs.

**Figure 1.6**

*Per Capita Disposal Trends and Forecast for North Carolina*



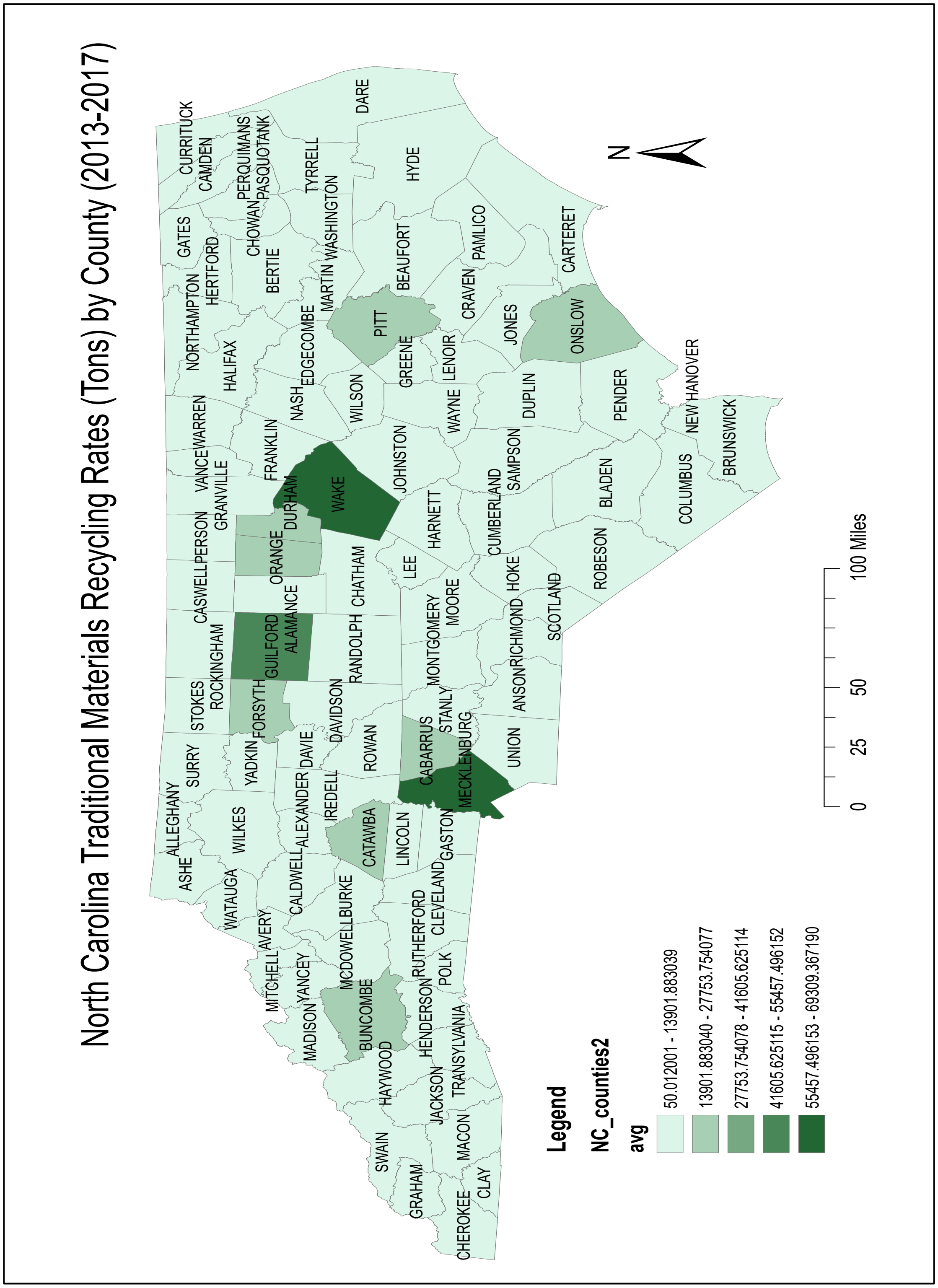

*Note*. From *Annual Report to the North Carolina General Assembly*, Division of Waste Management, North Carolina Department of Environmental Quality, January 2020 (https://files.nc.gov/ncdeq/Waste%20Management/DWM/DEQ-Consolidated-Waste-Report-2020-01-15.pdf). In the public domain. Original figure note read: "Population data source: https://www.osbm.nc.gov/demog/county-projections_revision_date_12/03/2018. Methodology: Population for FY2017-18 uses the July 2018 population projection by the NC Office of State Budget and Management [OSBM]. The [a]ctual historical population data is graphed using the most recent data provided in the 12/03/2018 data set."

## County Performance

North Carolina's 100 counties together experienced an increase in recycling collections by 5.3% in FY 2016–2017 (NCDEQ, 2017). This is, however, an aggregated number for the entire state—the disaggregated numbers vary by county (Figure 1.7). These differences arise from a disparity in the recycling structure, operation, and performance of county recycling programs. More details about recycling programs, their structures, and operations are described in the next section.

**Figure 1.7**

*North Carolina Traditional Materials Recycling Rates (Tons) by County (2013–2017)*




*Note.* *Cartography by Author*

The use of a variety of materials in the manufacturing process results in a heterogenous material mix at the end of life of the product. Simultaneously, diverse consumer preferences lead to a variety of products in recycling bins. Governments, therefore, must design appropriate recycling systems to best collect, sort, and process these heterogenous materials. For example, local governments could choose to implement drop-off or curbside recycling programs (CRPs) depending on the community they are serving. Although drop-off involves placing recycling bins on public or private lots to facilitate voluntary recycling by residents, curbside recycling provides private bins and trash pickup services to residents. From a supply-side perspective, drop-off services cost less and may be more convenient to administer. However, this type of program is least convenient from a demand-side perspective because households not only need to dedicate space to storing recyclables but also must transport the recyclables to the drop-off site. Participation rates for such systems are generally low compared to CRPs, unless consumers are offered a financial incentive, such as buyback centers (Folz, 1991). In contrast, curbside recycling programs provide curbside trash collection services to residents so that residents do not have to leave the convenience of their home to deposit their recyclables. Additionally, curbside recycling programs also provide their customers with bins for private storage of recyclable materials. Moreover, curbside recycling programs invest in education and communication outreach activities, such as meeting with local interest groups and developing informational flyers (Folz & Hazlett, 1991). Therefore, one could decipher that, compared to drop-off programs, CRPs are less convenient and more cost intensive on the supply side but more convenient and less cost intensive on the demand side.

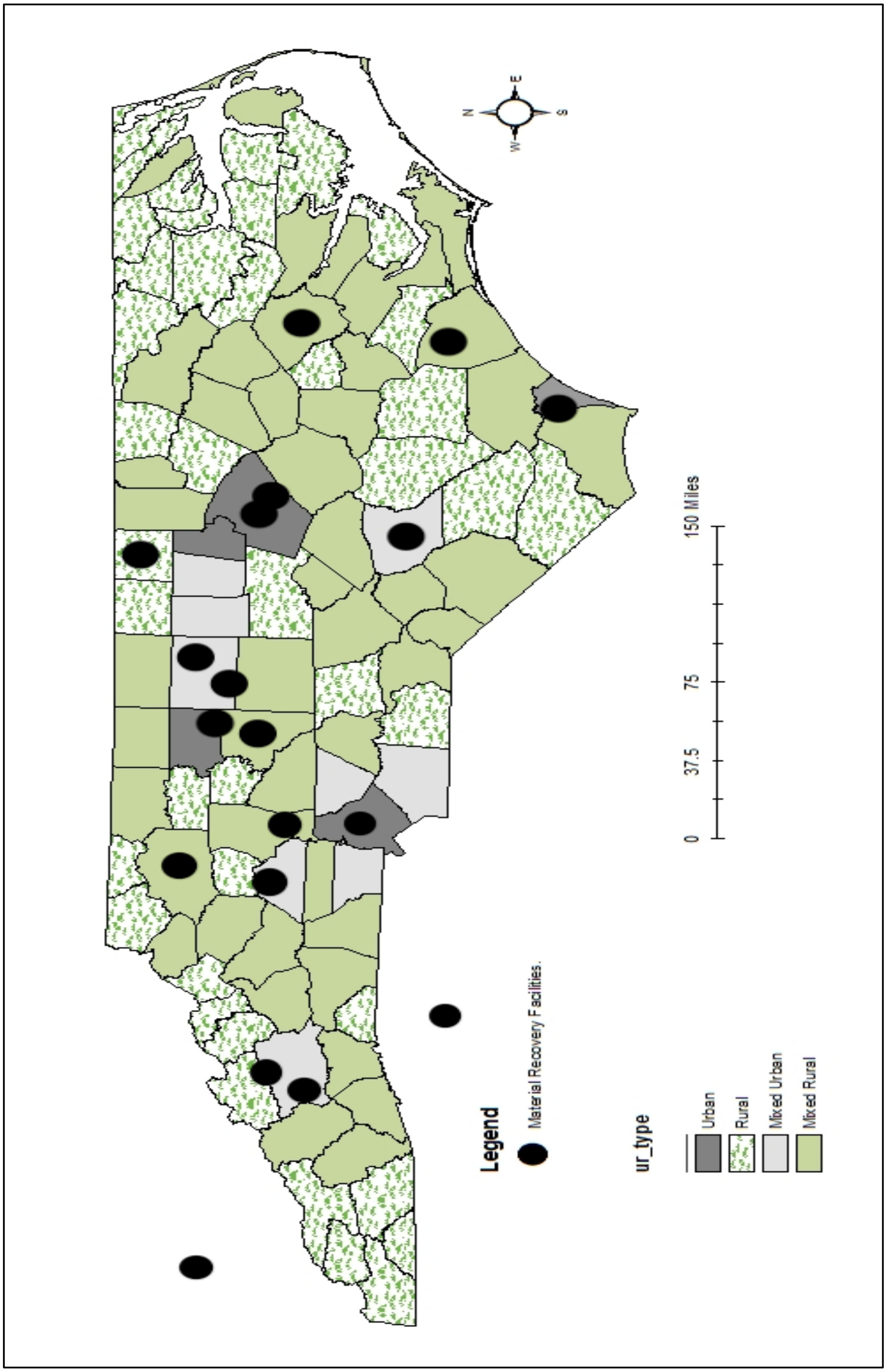
Over time, most local communities in the United States have moved toward single-stream recycling; that is, before, households were segregating their recyclables into separate categories (wood, paper, plastic, metal), whereas now residents are able to put all of these items into a single bin, leaving the sorting to the waste management service agency. This approach has considerably increased the amount of items that end up in recycling bins. While single-stream recycling offers consumers the incentive to recycle more, it has increased the burden on agencies to manage recyclables in an efficient yet cost-effective manner.

Another component of recycling program structure is the access to material recovery facilities (MRFs), where counties drop off their recyclables for processing. North Carolina has 19 MRFs (Figure 1.8), each of which cater to multiple counties at a time. However, it is possible that some items deposited or collected for recycling are inadvertently diverted to the landfill. This happens because either the MRF does not possess the technology to process a specific material or the materials are too contaminated for processing. This highlights a challenge for recycling educators to inform residents about what can be recycled and the correct way to dispose recyclables.

The urban-rural characteristic of a county also determines its recycling capacity. Interestingly, most North Carolina counties exhibit more rural characteristics than urban. Figure 1.8 illustrates North Carolina's skewed urban-rural dynamic and the location of MRF's in relation to the counties. As can be seen, most of the MRF's are located closer to urban and urban-mixed counties, which possibly exacerbates the already limited capacity of rural areas to operate their recycling services in an efficient manner.

**Figure 1.8**

*North Carolina Counties Urban Rural typology and Material Recovery Facilities.*




*Note.* *Cartography by Author*

Success of recycling programs depends on the policies chosen, their selection process, and their implementation. Along with these programmatic indicators, contextual and spatial factors define recycling outcomes at the county level (Folz & Hazlett, 1991). Therefore, it is important to consider all of these factors when evaluating recycling programs. Knowledge of what works and why, is useful for informing future policy and assessing current indicators for measuring the effectiveness of recycling programs.

As local governments are assuming more responsibility for policy making, management, and implementation of important national goals, it is important to consider their capacity or ability to take on these added responsibilities (Honadle, 2001). Given what the field has established on waste generation and the challenges that come with it, this study aimed to evaluate recycling programs at the local level in North Carolina. Evaluation provided insight into what influences recycling rates and what environmental and economic outcomes recycling programs generate. From these findings, the study highlighted and identified existing efficiencies and future potential policy strategies for implementing recycling programs. The next chapter details the existing literature on recycling and its many components, which is helpful in informing the theory and research design for this study. Chapter three discusses the data selected and the justification for their selection, followed by the methodology selection for the study. Chapter four presents the results and discusses the findings based on the inferences drawn from the results. Finally, chapter five lists the study limitations and the theoretical and policy implications of the results.

# CHAPTER 2: LITERATURE REVIEW

The extant literature is useful for understanding the vast context within which recycling policymaking and implementation takes place. Exploring the literature also helps identify the factors that influence policy outcomes. I drew on scholarship from the fields of public policy, public administration, political science, economics, sociology, and geography to build a theoretical foundation to guide my research. Bringing together knowledge from various social-science fields helps highlight the value of interdisciplinary research in improving the field's understanding of how complex processes, such as policy making and outcomes, influence environmental policy in general and particularly, recycling policy.

Earlier evidence of research investigating the determinants of household recycling can be found as far back as the 1970s (McGuiness et al., 1977, Reid et al., 1976). Earlier scholars placed these key predictors into three main categories. First, external variables or contextual variables such as demographics and socioeconomic predictors. The second category includes internal variables such as attitudes, beliefs, and norms, which are seated in psychology, and third, programmatic predictors such as cost and convenience (Saphores & Nixon, 2014).

For this study, I explore literature directly covering the first and second categories, and indirectly associated with the third category. Although scholarship from public policy, public administration, and political science guided my selection of political variables, the field of economics helps illuminate economic factors vital to the recycling process. The field of sociology highlights the importance of contextual factors, such as demographics, which complement all other factors in the study of policy. Finally, the discipline of geography highlights the importance of location and distance, especially as they pertain to recycling policy. The urban–rural continuum is used to categorize counties as urban, rural, urban mixed, or rural mixed. These categories help understand county access to resources, and consequently, how they implement policies.

I argue that an evaluation of recycling programs is incomplete without an understanding of all the factors that help enhance or prohibit its success. Additionally, once this evaluation is complete, an understanding of how to measure success within this context is equally vital.

**Local Government Policy and Outcomes**

In addition to local-level factors and their influence on recycling rates, an analysis of the literature reveals underlying themes regarding local government decision-making and implementation of policies and programs. This understanding is essential to view the entire landscape of recycling policy, from adoption to implementation. The literature identifies several factors influencing local-government decision-making in the adoption of recycling programs.

Clingermayer and Feiock's (2014) work on intergovernmental theory and institutional structural theory provides insight into how external policies directly shape local action and the costs associated with it. Policy adoption by the state can result in local governments perceiving the issue as salient, motivating them to adopt and implement complementary policies. However, the outcomes of these policies are influenced by the structure of the government implementing the policy (Clingermayer & Feiock, 2014). Substantiating this relationship between government structure and outcomes, Bae and Feiock (2013) stated that the form of government is important and has a direct influence on a community's sustainability actions. They argued that mayor-council structures are more efficient at initiating government programs than community interventions. Governments with a separate sustainability office are more successful at implementing and promoting sustainability efforts within the community (Bae & Feiock, 2013).

Other theories of policy adoption stem from the need for governments to provide public-service bundles that attract new residents, encouraging competition among governments to provide the highest quality of services (Tiebout, 1956). Governments that can attract more residents gain the advantage of a larger tax base, which could help to bolster the local economy. Governments providing recycling services such as curbside pickup or recycling educational programs may be able to attract consumers of convenience when it comes to recycling. On the other hand, if a government provides only a drop-off service for recycling, individuals may not prefer this option.

Kinnaman's (2014) investigation "Why Municipalities Recycle" highlighted other factors about why governments adopt policies and continue to implement them. Among the influential factors is the economics of recycling programs. According to Kinnaman, only when the revenue collected from selling recycled materials exceeds the costs of collection will local governments possibly find it advantageous to implement recycling programs. A second factor identified by Kinnaman is recycling mandates by state legislatures. If the state mandates recycling or internalizes the social costs of waste disposal, then local governments might be incentivized to implement recycling programs. The third factor identified by Kinnaman is residents' willingness to recycle. Residents not in favor of waste generation are more likely to pay for recycling or request mandatory recycling services from their officials. These "environmentally conscious" residents then compel governments to take action to appease their community members. This mechanism has been endorsed by scholars in the field of public administration and political science as well. As far back as the '70s, Tremblay and Dunlap (1978) coined the term "differential exposure," arguing that people who live in cities place a higher value on environmental quality and, thus, support any efforts toward maintaining healthy environmental quality in the area. It is therefore possible that city political leaders are responding to their constituents by adopting innovative environmental policy strategies (Krause et al., 2019).

Additionally, Krause et al. (2019) emphasized the importance of "fiscal and human resource" capacities of local governments in the likelihood of cities proactively adopting environmental policies.

While these theories provide us with an understanding of why governments adopt recycling policies, they can also help in examining the rationale behind why governments continue to implement a policy post-adoption. The literature on local factors and recycling outcomes highlights a similar set of elements stemming from the fiscal and administrative capacity of local governments and resident demands. These are detailed below.

## Local Factors and Recycling Rates

Scholars from various disciplines, such as finance, economics, political science, sociology, psychology, geography, and public administration, have investigated factors that influence recycling outcomes. Several factors have been highlighted in the literature. While some scholars have analyzed recycling at the local and/or state levels, others have focused on household characteristics and recycling outcomes. The local level factors analyzed across the literature can be placed into three broad, but somewhat overlapping categories, where each category is couched in several underlying theories and themes that help understand the importance of these factors. The three categories along with the factors that stem from each are listed below.

### Programmatic Factors – Public Service Provision by Local Governments

In the context of recycling programs, the provision of programmatic factors by local governments is motivated by several factors, which are similar to the factors detailed in the prior section regarding local government policy adoption. First, local governments fiscal capacity i.e., the financial resources available determines how much or how many services to provide (Kinnman, 2014). The second motivation is the presence of a policy requirement to provide the service (Kinnaman, 2014). The third motivation stems from the theory of Tiebout Sorting (Tiebout, 1956); governments want to attract more residents and therefore provide certain services to compete with other localities. The fourth motivation is when the constituents demand a service, and the government provides it in order to keep the constituents happy. These four motivations help us understand the provision of programmatic factors in the recycling process. These include curbside recycling, recycling education programs, and appointed recycling managers to improve the recycling system.

From a programmatic perspective, the introduction of curbside recycling programs has been found to contribute significantly to increases in recycling rates. Curbside recycling programs provide residents with the convenience of having their recyclables collected from their curb, which encourages recycling and, thus, increases collection rates (Domina & Koch, 2002; Ewing, 2001; Folz, 1991; Kinnaman & Fullerton, 2000; Park & Berry, 2013). While these studies have been widely cited, the generalizability of their results are limited, either because they used a small number of observations (cross-sectional) or relied on survey responses from a small number of households. However, acknowledging the positive benefits of curbside programs, several counties throughout the United States have adopted this program to achieve their recycling commitments. Although curbside recycling programs increase convenience-based recycling, they also increase the costs of managing recyclables post collection. Increased costs are a result of the growing supply of single stream services at the curbside, which often incentivizes residents to contaminate[6] the recycling stream, in turn requiring additional labor to sort through the contamination. However, when curbside recycling operates efficiently, it could reduce the cost to dispose waste at a landfill and produce revenue from the sale of recyclables

[6] When a recyclable material is deemed unfit for recycling, either because it was placed in the wrong bin, or because it was not properly cleaned before placing in the recycling bin/cart

(Kinnaman & Fullerton, 2000). Similarly, Deyle & Schade (1991) argue that curbside recycling costs have been found to be efficient only when collection costs, recycling rates, and recovered material markets help facilitate it. While curbside recycling is a government provision, the magnitude of the effectiveness of these programs is also dependent on residents' willingness to utilize the service. For this reason, curbside recycling can also be viewed as an outcome of resident behaviors.

Higher landfill tipping fees are also associated with better recycling outcomes (Renkow & Rubin, 1998). Landfill tipping fees are the amount landfill owners collect for every ton of waste disposed of in their landfill, in other words, the cost to counties and municipalities for disposing waste in a landfill. Kinnaman and Fullerton (1997) found that the likelihood of implementing a recycling program (or higher recycling collection) increases with a $1 increase in landfill tipping fees. In fact, a study of waste generation in North Carolina found that a higher tipping fee for the state meant lower waste generation, thereby reducing the amount of waste disposed in landfills (Hockett et al., 1995). However, this study was conducted more than twenty years ago when recycling was still a new phenomenon. Today, a decline in waste at the landfill is related to an increase in recycling rates.

Education campaigns, including media campaigns and other community outreach activities, have shown to encourage recycling activities (Feiock & West, 1996; Folz & Hazlett, 1991; Martinez & Scicchitano, 1998; Nixon & Saphores, 2009; Timlett & Williams, 2009). How the information is dispersed, combined with its timing and accuracy, determines its effectiveness (Davies et al., 2005; Timlett & Williams, 2009, Tucker & Speirs, 2002). Some scholars have advocated for increased recycling as a result of information printed on the bins (Thomas, 2001). Some others have argued for face-to-face campaigns (Schultz et al., 1995; Read, 1999; Tucker &

Speirs, 2002), while other schools of thought support the use of a diverse pool of media with custom narratives (Timlett & Williams, 2009; Tucker & Speirs, 2002) to increase recycling collection. In this regard, “coproduction,” the practice of involving citizens in the creation and delivery of public policies and services, provides for a unique understanding of recycling outcomes. Proponents of coproduction argue that communities receiving recycling awareness and education programs are successful at informing residents about the benefits of recycling along with proper ways to recycle (Folz, 1991; Landi & Russo, 2019). Residents prioritizing cleaner environments not only consume the education received but also participate more in sorting household waste, carrying the waste to drop-off sites, and volunteering with community clean-up programs. This increase in active participation in all aspects of recycling improves the quality of the service itself, which, in turn, can help attract new residents. Education programs can appeal to citizen’s self-interests—environmental, communitarian, and economic (Feiock & West, 1996). However, other scholars from the ’80s and ’90s have argued that prompts and information on recycling have the weakest effects on recycling outcomes and do not spur long-term behavior changes (De Young, 1986; Hopper & Nielsen, 1991).

Although the literature does not speak directly to the influence of having a recycling coordinator and/or sustainability manager at the county level, hypotheses can be drawn from literature focusing on government structures and implementation. Bae and Feiock (2012) suggested that “Appointed managers in council-manager systems have been demonstrated to have a stronger interest in efficiency and innovation in government operations” (p. 780). However, they found that council-manager systems, when efficient, work in the best interest of the government and not necessarily the larger community. They perceived this finding to be important when considering sustainability policy implementation in communities. Similarly, Folz & Abdelrazek (2009) find that after controlling for socio-demographic differences, cities that have a professional city manager and an adaptive or administrative type of local government structure are somewhat more likely to provide qualitatively higher levels of municipal services. This finding suggest that professional managers play an important role in advancing public services. Carr (2015) refuted this idea in his examination of propositions assessing form of government and performance, arguing that there is no strong evidence for one form of government performing better than another. From these findings we can infer that the presence of a recycling manager or someone assigned the role of specifically overseeing recycling activities could increase recycling outcomes. Higher landfill tipping fees are also associated with better recycling outcomes (Renkow & Rubin, 1998). Landfill tipping fees are the amount landfill owners collect for every ton of waste disposed of in their landfill, in other words, the cost to counties and municipalities for disposing waste in a landfill. Kinnaman and Fullerton (1997) found that the likelihood of implementing a recycling program (or higher recycling collection) increases with a $1 increase in landfill tipping fees. In fact, a study of waste generation in North Carolina found that a higher tipping fee for the state meant lower waste generation, thereby reducing the amount of waste disposed in landfills (Hockett et al., 1995). However, this study was conducted more than twenty years ago when recycling was still a new phenomenon. Today, a decline in waste at the landfill is related to an increase in recycling rates.

**Residential behavior – Demographics and Political Preferences**

Resident recycling behavior can be best understood by the underlying factors that facilitate higher recycling outcomes. Altruism is one such self-interest behavior that guides residential action to recycle (Ewing, 2001; Kalinowski et al., 2006). Residents like to ‘feel good’ about their actions and recycling makes them feel like they’re part of the movement to preserve the planet and its resources. Another emerging trend in the literature and in practice is that younger generations are slowly moving away from anthropocentric views, encouraging them to take part in ecocentric activities such as recycling (Dunlap & Van Liere, 1978; Roberts et al., 2006). A parallel to views of ecocentrism or nature-centered behaviors can also be found in the literature scoping the behavior of individuals who subscribe to a liberal ideology. Liberals tend to be more pro-environmental and therefore are more likely to engage in recycling activities (Davis & Wurth, 2003; Dunlap et al., 2001; Feinburg & Willer, 2013). Another theme that emerges from the literature is the presence of an economic incentive as a motivator for pro-recycling behaviors. This understanding extends to convenience in recycling. The right economic incentive will determine if residents choose to recycle or not. The next section provides a review of the literature examining demographic and political factors in the context of recycling.

Studies have indicated that presidential voting results are a good indicator of a community's environmental attitudes (Krause et al., 2019; Neumayer, 2004). Democratic votes reflect a more liberal citizenry that is willing to spend more on the environment, whereas Republican votes reflect more conservative points of view on environmental issues (Davis & Wurth, 2003). These outcomes are based in the ideological beliefs of the two parties. In their examination of Americans' attitudes toward the environment, Feinberg and Willer (2013) demonstrated that liberals take a moral approach to environmental issues, whereas conservatives do not. Similarly, Dunlap et al. (2001), in their investigation of partisan and ideological differences in public support for the environment, stated that Republicans tend to support business and advocate for limited government intervention, which contradicts the regulatory measures brought about by implementing environmental policy. Dunlap et al. (2001) argued that, unlike in the 1970s, it is acceptable now that the environment is no longer a "motherhood" issue, and partisan differences moderate people's perception of it.

Education, sex, and age have been widely studied in relation to recycling outcomes. The literature shows that female, younger, and/or more educated individuals are more likely to engage in recycling activities (Barr et al., 2003; Feiock & West, 1996; Schultz et al., 1995; Ungar, 1994). Researchers have argued that educated citizens are more likely to recycle because of their preference for cleaner environments (Feiock & Kalan, 2001; Kinnaman & Fullerton, 1997). However, others, such as Tilikidou and Delistavrou (2001) and Mitchell (1989), have suggested that demographic factors are not significant in explaining recycling behaviors. Findings for education levels have varied, with some studies reporting a positive correlation (e.g., Barr et al., 2005) and others concluding that it does not matter statistically for recycling (Mitchell, 1989; Tilikidou & Delistavrou, 2001; Van Liere & Dunlap, 1980). Population density, a factor mostly examined outside the United States, has been shown to have an effect on recycling outcomes (Karousakis, 2009; Matsunaga & Themilis, 2002). The studies conducted within the United States have used regression analysis to determine the likelihood of recycling with an increase in population density, finding that the likelihood of recycling increases by 0.39% with every hundred-person increase per square mile (Kinnman & Fullerton, 1997). This increase in recycling is associated with economies of scale: Average collection costs decrease by $1.62 as population density increase by 100 persons per square mile (Bohm et al., 1999; Dubin & Navarro, 1988).

Income is an economic attribute associated with environmentally responsible behavior. Communities with higher incomes are more environmentally responsible, resulting in increased engagements in recycling activities (Irwan et al. 2013; Matsunaga & Themilis, 2002; Schultz et al., 1995). Policies designed to help improve and preserve the environment often require time and monetary investment from individuals. Only those who can afford it are incentivized to divert their resources to environmental causes. The ones left behind are usually minority populations, those who cannot afford to spend time on or pay for (but might be concerned about) better environmental conditions (Bullard et al., 2007; Kaswan, 2011). Due to the nuances involved with people's willingness and affordability to participate, as well as differences in distribution of municipal resources, Valenzuela-Lev (2009) argued against using income as an economic factor in predicting recycling outcomes; instead they encourage the use of infrastructural provisions, such as convenience and incentives to predict recycling outcomes. Various studies have found that user fees (incentives) and curbside recycling programs (convenience) influence the amount of trash disposed and recycling collected (Feiock & West, 1996; Jenkins et al., 2003; Judge & Becker, 1993; Kinnaman & Fullerton, 2000). Kinnaman and Fullerton (2000) provided evidence for a decrease in trash by 412 pounds and an increase in recycling by 30 pounds per person per year, associated with a $1 fee per bag. Jenkins et al. (2003) found an association between higher recycling rates and the introduction of curbside recycling programs.

**Spatial Context**

The third broad category within which the local factors can be placed is the spatial context. This includes urban-rural typology, distance from and location of MRFs, and population density. Theories of differential exposure or environmental deprivation theory which posits that one's exposure to good or bad environmental conditions determines their engagement with environmental behaviors (Whitaker et al., 2005). From this one can argue that those living in very dense urban areas are more exposed to deteriorating environments brought about my industrialization and therefore care more for cleaner environments. On the other hand, one can argue that because those living in rural areas are more exposed to natural amenities, their affinity for cleaner environments is stronger (Freudenburg, 1991). However, this argument assumes the presence of access to recycling services in rural areas. Another underlying theme with regards to urban and rural areas is economies of density that argues that more dense areas are able to execute recycling programs in a more efficient and economical manner owing to the close proximity of all consumers of public services. The specific spatial variables found in the literature are explored below.

Within the spatial categories, studies exploring broader topics such as the urban-rural dynamics of environmental policies more generally posit that urban residents are more likely than their rural counterparts to engage in pro-environmental activities (Williams Jr. & Moore, 1991). Other scholars have shown that household waste recycling performances can significantly vary between communities, spatially within communities, and with time (Tucker, 1998). In support of this, Freudenburg (1991) suggests that while earlier studies have shown that urban areas tend to perform better on environmental activities than rural areas, the performance of rural areas should be determined by if the rural area is actively involved in agricultural or extraction industries. Freudenburg (1991) found that agricultural rural areas tend to be more environmentally active than extractive rural communities. Contrary to these findings, Jones et al. (2009), in their more recent study of rural and urban environmentalism found no significant differences between rural urban areas when questioning their pro-environmentalism. They attribute this to residents' exposure to national parks and other natural amenities. These studies indicate that a county's rural–urban identification should be important in the consideration of its recycling outcomes.

To my knowledge, literature exploring the influence of material recovery facilities (MRFs) on recycling rates has been limited. This might be because the introduction of MRFs is more recent, drawing more attention to their technical efficiency in the recycling process, rather than their siting. MRFs help reduce the waste stream by diverting waste from landfills and reducing the demand for raw materials by providing secondary materials in the manufacturing process. Furthermore, they reduce the amount of pollution emitted during the manufacturing of new products. Therefore, MRFs play a vital role in the recycling process and help manage resources effectively. The 2016 State of Curbside Recycling Report highlights the role of MRF facilities in accelerating recycling collection (Bandhaeur et al., 2016). More MRFs mean more recyclables can be managed. The distance these facilities are from the collection point will determine the ease with which a county can operate its recycling program. Sultan and Mativenga (2019) argue that finding the optimal location of recycling processing plants is vital to increasing recycling outcome. In areas that do not have proximate access to MRFs, hub-and-spoke models have been introduced to manage recyclables. These hub and spokes allow for multiple counties to stock their recyclable materials in one central place. Materials are then collected for transporting to an MRF (Bandhaeur et al., 2016).

**Recycling Rates and Recycling Outcomes**

According to Krause (2011), any GHG-reducing policy undertaken by a local government has three dimensions—an emissions sector, a target population, and a policy instrument. Since the 1970s, recycling has received increased attention for its potential to produce positive environmental (GHG reduction) and economic benefits (job creation). Proponents of Green Economic Development have argued that environmental protection and economic development go hand in hand. They further argue that there is no trade-off between the two, and in fact green industries could be more labor-intensive, thereby offsetting job losses from traditional sectors to achieve net employment gain (Fankhauser et al., 2008; Feiock and Coutts, 2013; Fitzgerald, 2010; Portney, 2009).

A series of domestic and international studies have examined potential environmental savings from reduced GHGs and material use. Due to methodological differences, however, different interpretations can be drawn from this line of literature (Franchetti & Kilaru, 2012; Maio & Rem, 2015; Tisserant et al., 2017; Weitz et al., 2002). To examine the GHG savings potential, life-cycle assessments for specific products in the recycling loop have been conducted. Most have found that recycling reduces GHG emissions and that this decrease is attributable to the lessened need to produce new materials (Acuff & Kaffine, 2013). However, some scholars have argued that current recycling programs utilize significant energy to process recyclables into materials, thereby making it a costlier process than the production of new products from virgin materials (Makridis & Dawson, 2018; Makridis, 2020).

To be able to test the relationship between recycling and GHG, an exploration of other variables that could possibly explain the variation in GHG emissions are considered. Landfills which are one of the methods used for managing solid waste, emit carbon dioxide, methane and other pollutants into the air. This is a result of anaerobic decomposition of organic waste found at landfills (Lou & Nair, 2009). Therefore, there is reason to believe that waste that is not recycled, but instead landfilled, may be contributing to GHG emissions.

Some scholars have talked about increased resource consumption as a rebound effect of recycling (Caitlin & Wang, 2013; Ma et al., 2019; Marco & Vivanco, 2018). This means that as people recycle more, they feel better about their actions, and as a result, consumer more goods. This is counterproductive and could result in more waste generation and therefore higher GHG emissions.

Other local factors such as age, population density, income, etc., have been shown to influence GHG emissions (Liddle, 2014; O'Neill et al., 2012). Young adults (20-34) have a statistically positive relationship with GHG emissions, while older adults (34-60) have a statistically negative relationship (Liddle, 2014; Liddle & Lung, 2010). Additionally, more urban areas have a statistically negative influence on GHG emissions (Liddle, 2014).

Studies from the 1990s show that environmental regulation and protection result in job creation. (Ackerman, 1997; Bezdek, 1995; Goodstein, 1999; Hall, 1994; Morgenstern et al., 2000; Renner, 1991; Templet, 1996). Therefore, recycling, which is an environmental protection and conservation effort, has job-creating and revenue potential. The establishment of more facilities for recycling creates employment opportunities, and increases tax collection (Makridis & Dawson, 2018). Park et al. (2015), in their study of solid waste management and recycling jobs in Florida, found that private sector jobs in the solid waste management jobs had increased between 1989 and 2011, while public sector jobs had fluctuated in the same years. Thus, a relationship between recycling and positive environmental and economic outcomes is germane to an efficient waste management program.

## Theoretical Framework

The study employed multiple frameworks to understand local-level factors that influence recycling outcomes and the environmental and economic benefits (if any) from those outcomes. I adopted theories from previous literature regarding factors that influence recycling—administrative and fiscal capacity of local governments, resident composition, spatial location, and technical capacity to manage recycling. My approach for this study was to amalgamate all of those factors to provide a comprehensive understanding of recycling systems. To these theories of demographics, structural provisions, and voting preferences, I added spatial components of urban–rural classification and distance from MRFs. In the study of local governments' recycling practices, how the existence of technical structures such as MRFs assisted or hindered the efficiency of implementation provided an important dimension to understanding local-level recycling outcomes.

The second part of this study examined recycling and environmental and economic outcomes. This part was anchored in theories of environmental protection and conservation, which advocate for recycling to reduce environmental impact (Ackerman 1997; Bezdek 1995; Goodstein 1999; Hall 1994; Morgenstern et al. 2000; Renner 1991; Templet 1996). The circular economy as a theoretical framework predicts large environmental and economic benefits from conservation strategies. Although the circular economy framework provides for a holistic foundation for the effectiveness of recycling programs and their environmental and economic benefits, government waste management and recycling policy also helps inform existing theory of the benefits associated with recycling programs. The contents of rules, policy, and law deepen scholars' and policy makers' understanding of the expected outcomes of an activity. Per the 2003–2013 North Carolina Waste Management Plan, "When recycled materials are used in industrial production, energy and other resource demands decrease" (p. 44). Therefore, one would expect decreased energy consumption and thereby decreased GHG emissions. Furthermore, recycling is touted to increase employment in the recycling industry. According to the same document, "North Carolina's economy has boomed since the last ten-year state plan was released" (p. 32). Therefore, one would expect an increase in recycling-related employment due to a spur in recycling activities. However, is it recycling that influences these outcomes? Or do other local factors explain these variations?

To my knowledge, an empirical study assessing both the factors that influence recycling and the benefits of recycling has not been conducted for the counties of North Carolina. Additionally, previous literature is generally outdated and stems from single disciplines, neglecting the interdisciplinary aspects of recycling programs. Furthermore, although previous studies have focused on cross-sectional variations or contingent valuation reports of recycling programs, this study used observational data from multiple sources to better understand the nuances of recycling and the results to date. This place-based study was innovative in that it looked at recycling outcomes using panel data across several parameters at the local level. A closer look at local-level recycling mechanisms in North Carolina helped to uncover what recycling could look like for these areas in the future. Using smaller geographic units, such as counties, as the unit of analysis provided variation in both the dependent and independent factors needed to parse out individual effects. Additionally, the use of county-level data was appropriate given that each county implements its own recycling program with supervision and guidance from the state. Currently, North Carolina is facing major challenges regarding its local recycling economy in the face of China's import ban, compelling some counties to charge higher landfill tipping fees or entirely withdraw from curbside recycling (Rosengren et al., 2019). An investigation into these changes and what they mean for the future of recycling within the counties was needed. Finally, the study evaluated alternatives to better recycling outcomes, which could help inform local- and state-level policy making. The findings from this study could be extended and applied to states that are facing similar challenges as North Carolina.

My research fits well among these studies, focusing on what local factors affect recycling outcomes and the broad environmental and economic impacts of recycling. Conducting a state level analysis contributes to the research highlighted above, as well as other state level analyses that examine recycling in a local context. In addition to the variables that exist in the literature, I include MRF distance, recycling coordinator, and urban-rural typology, to account for other factors in the recycling process. I also use proxy measures for GHG emissions and employment to incorporate any impacts from recycling. Finally, I conduct a qualitative analysis to help understand the findings from the quantitative analysis. Earlier research is used to guide the selection of variables and methodologies, which are described in chapter three.

# CHAPTER 3: DATA AND METHODS

The literature detailed in Chapter 2 provides a firm foundation for the analytical approach used in this study. I applied the knowledge and in-depth insight from previous studies to develop a research design to test the effects of my explanatory variables on my dependent variable. I systematically used quantitative and qualitative analyses to examine North Carolina counties to test the effects of various county-level factors on recycling efforts and to deepen understanding of aspects of recycling across the state. The results from this analysis add to and complement the scholarship on recycling systems.

To ensure meaningful results, I used a research design which incorporates variables that help achieve validity. Although some effects on recycling were unobserved or not included in this study, I conceptualized and operationalized my variables in a manner appropriate for producing reliable results. Moreover, the interdisciplinary characteristics of the topic and the study allowed for a comprehensive research design, adding to the validity and reliability of the results. This chapter details the study's research design, data, and methods.

This study evaluated county-level predictors of higher recycling rates. It further assessed the economic and environmental benefits of current county recycling efforts and covered missed effects via qualitative interviews with experts in the field. Previous efforts to conduct similar evaluations have resulted in a mixed understanding of these effects. This chapter details the data and methods employed for (a) testing the effects of different county-level indicators on recycling efforts, (b) investigating the economic and environmental benefits to recycling, and (c) uncovering existing challenges and missed opportunities in the recycling process.

## Research Questions

### County-Level Factors and Recycling Outcomes

For the first part of my research, I analyzed the local-level factors that that might facilitate or hinder recycling rates across the counties. Local-level factors included bureaucratic (type of personnel responsible for recycling program), political (prior election data), economic (expenditure on recycling, per capita income), structural (MRFs, type of recycling program), geographic (urban–rural classification, distance from material recovery facility), and social (recycling education program, demographics).

I used panel data over cross-sectional data to provide more "informative data, more variability, less collinearity among variables, more degrees of freedom and more efficiency" (Gujarati et al., 2012, p. 623). Panel data provide better detection and measurements of effects, which can be more challenging to observe in cross-sectional data (Gujarati et al., 2012).

The primary research question was:

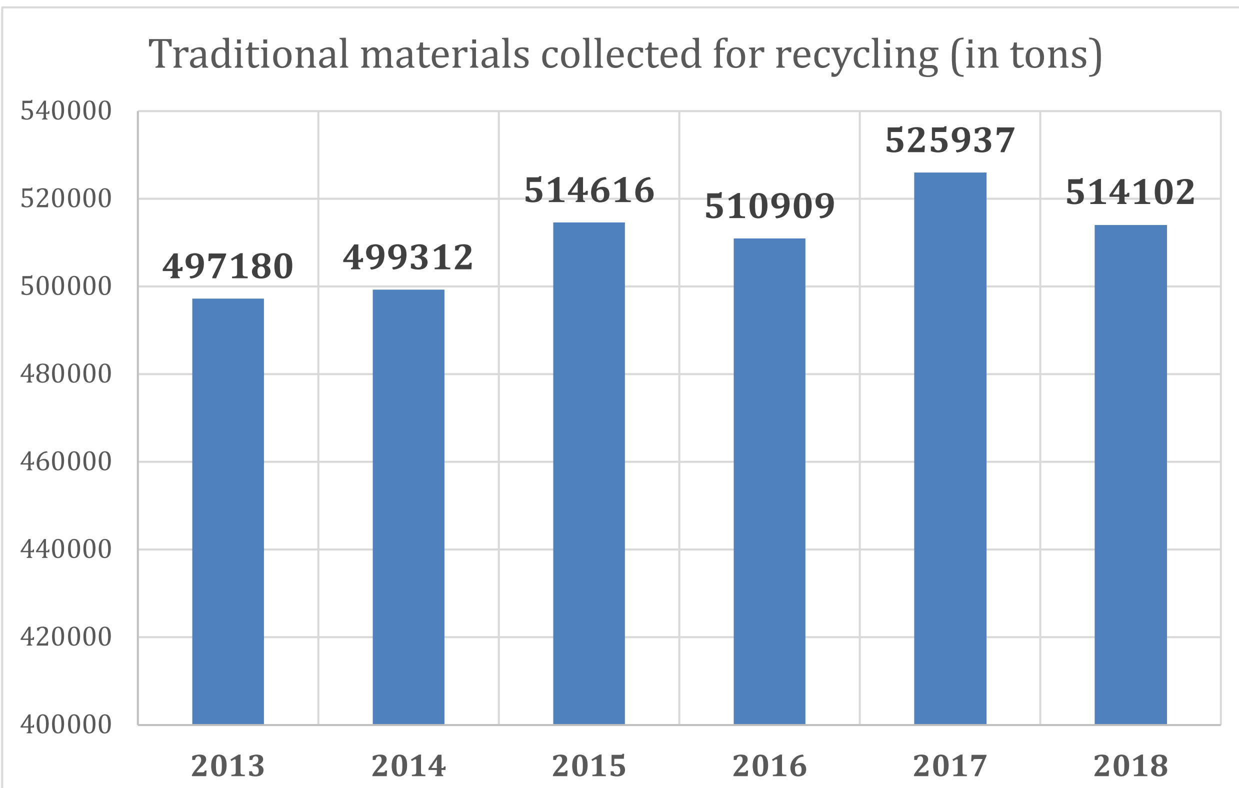
$RQ_1$ What local-level factors influence recycling rates across North Carolina counties?

The dependent variable is the recycling rate for each county, which is specifically the total traditional materials collected for recycling from each county in tons for the years 2013–2018. Data for this variable were obtained from the NCDEQ Solid Waste Management Annual Reports 2013–2018, which provided county recycling rates for each year and ranked counties by recycling rate. Although recycling rate has been used widely in the literature (Hotta, 2016), the measure's definition varies by state. For North Carolina, where the recycling rate is simply the recyclables collected, there are limitations to understanding source reduction efforts (Starr & Nicolson, 2015). Collection of recyclables only addresses the last "R" in the 3R framework of reduce, reuse, and recycle.

Figure 3.1 shows the recycling rate (i.e., tonnages of recyclables collected) at the state level which indicates a gradual increase in recycling from 2013 to 2015, and 2017 marks the peak of recycling for the years 2013–2018. After 2016, we see a gradual increase in recycling until 2018. In the section that follows, I discuss my explanatory variables; the reason for their selection, their data sources, and how I operationalized them in my study.

**Figure 3.1**

*Recycling Rate, by Year*




*Note*. Recyclables collected in tons.

**Explanatory Variables**

I list all the factors that were under consideration for this study in Table 3.1. The table includes data sources and how I operationalized each variable in the model. Below, I discuss the explanatory variables in more depth.

**Table 3.1**

*Study Variables—RQ1*

| Serial. No. | Variable | Definition/Measure | Coding/Format | Source |
|---|---|---|---|---|
| Dependent Variable | | | | |
| | recyc | Total Traditional recyclable materials collected through local government programs | Continuous variable | North Carolina Department of Environmental Quality |
| Independent Variable | | | | |
| 1 | coord | A designated recycling coordinator at the county | 1- If county has a recycling coordinator<br>0- If county doesn't have a recycling coordinator | North Carolina Department of Environmental Quality |
| 2 | rural_urban | County classifications into rural, urban, mixed rural, and mixed urban | 1- Urban county<br>2- Rural county<br>3- Mixed urban<br>4- Mixed rural | Andrew Isserman U-R codes (Full definitions in Appendix A) |
| 3 | pol | Voter registration statistics by county | Continuous variable–percentage of registered Democrats | North Carolina State Board of Elections 2013–2018 |
| 4 | recyc_ed | County recycling education and awareness programs | 1- If county has a recycling education program<br>0- If county does not have a recycling education program | North Carolina Department of Environmental Quality |
| 5 | hh_inc | Median household income by county | Continuous variable | Census Bureau |
| 6 | crb | County curbside recycling program | 1- If county provides curbside recycling services<br>0- If county has no curbside recycling services, only drop-off | North Carolina Department of Environmental Quality |
| 7 | educ | Percentage of residents with at least a four-year degree | Continuous variable | Census Bureau |
| 8 | dist | Distance between county center point and nearest MRF | Continuous variable | North Carolina Department of Environmental Quality |
| 9 | Age | Median age of county | Continuous Variable | Census Bureau |
| 10 | Pop_density | Population density of county | Continuous Variable | Census Bureau |

***Programmatic Factors***

Previous literature shows curbside recycling encourages recycling because of the convenience of not having to take recyclables to a drop off point (Domina & Koch, 1999, 2002; Ewing, 2001; Folz, 1991; Park & Berry, 2013). I hypothesize that the presence of curbside recycling services is likely to influence higher recycling rates compared to only drop-off services. I collect curbside recycling data from the NCDEQ Solid Waste and Materials Management Annual Reporting Forms filled out by local county governments. Data from 2013 to 2018 are available. The form requests county governments to report if they offer curbside recycling programs, drop-off recycling programs, or both. I operationalized this information as a categorical variable where counties offering curbside recycling services (and drop-off services) are coded as 1, and those offering drop-off only are coded 0. My first hypothesis then is:

> $H_1$ Counties with curbside recycling services are more likely to have higher recycling rates than counties with no curbside recycling services or only drop-off services.

Studies in Public Administration have shown that, at the local level, council-manager government systems are more efficient and innovative, especially when considering the implementation of sustainability policy in communities (Bae & Feiock, 2013; Krause et al., 2014). Professionalizing and institutionalizing the recycling process could improve the capacity to implement recycling programs, while signaling the local government's commitment to recycling. Therefore, I hypothesized that, if a county had a recycling coordinator, as appointed by the council-manager system, then recycling rates for that county would be higher than for counties with no recycling coordinator. I operationalized this variable using data from the NCDEQ Solid Waste and Materials Management Annual Reporting Forms completed by local county governments. The data from these forms were available from 2013 to 2018. The forms contain a section where county governments can report whether they have a recycling coordinator. I use this as my variable, converting it into a binary variable, where 1 was coded for counties with an appointed recycling coordinator and 0 was coded for counties with no recycling coordinator. My second hypothesis was thus as follows:

$H_2$ Counties with a recycling coordinator are more likely to have higher recycling rates than counties with no recycling coordinator.

My next variable of interest was recycling education. Education campaigns focusing on increasing resident recycling awareness and action have been shown to encourage recycling behavior (Folz & Hazlett, 1991; Martinez & Scichhhitano, 1998; Timlett & Williams, 2009). These studies indicated that involving citizens in the planning, design, and implementation of solid waste management activities results in an increase in efficiency and effectiveness of recycling programs. Therefore, I expected that communities that implement recycling awareness programs have higher recycling rates. I operationalized this variable using data from the 2013–2018 NCDEQ forms mentioned above. These forms also contain a section for county governments to report whether they have an educational program. I used this as my variable, converting it into a binary variable where 1 was coded for counties with a recycling program and 0 was coded for counties with no recycling program. My third hypothesis was as follows:

$H_3$ Counties with a recycling education program are more likely to have higher recycling rates than counties with no education program.

**Contextual Factors**

The next variable of interest was the voting preferences of county residents. From the literature, I expected that Democratic voters would exhibit more pro-environmental views and attitudes than would Republicans (Davis & Wurth, 2003). The North Carolina State Board of Elections maintains a voter database providing information on the number of registered voters by county across each of the U.S. political parties and other demographics. Registrants affiliate with five political parties: Democratic, Republican, Libertarian, Green, and Constitution. Following the methodologies from previous literature, I selected only Democratic and Republican voters. This variable was operationalized by converting the absolute number of Democratic and Republican voters into percentages. Specifically, the model included a variable for the percentage of Democratic voters in each county. Data were available for 2013–2018. 62 counties have a higher number of registered Democrats than Republicans, an almost even split. My third hypothesis then was as follows:

> $H_4$ Counties with a higher percentage of registered Democratic voters than registered Republican voters have higher recycling rates.

Although educational programs are important in converting higher recycling rates, the educational level of county residents is also an important factor in determining recycling rates. Educated citizens are more likely to engage in environmental activities because of their increased preference for cleaner environments (Kinnaman & Fullerton, 1997). I attained data for this variable from the U.S. Census Bureau's 2013–2017 American Community Survey 5-Year Estimates. I combined the categories from the survey's tables to create a variable that, for each county, showed the percentage of people with a bachelor's degree or higher and operationalized it as a continuous variable in my model. My fourth hypothesis then, was as follows:

> $H_5$ Counties with a higher number of residents with a bachelor's degree or higher have higher recycling rates

The income of county residents has been another widely explored indicator of recycling rates. Counties with higher income tend to have higher recycling rates (Irwan et al. 2013; Matsunaga & Themilis, 2002; Schultz et al., 1995). I retrieved data for this variable from the U.S. Census Bureau's 2013–2018 Five-Year American Community Survey and operationalized it in the model as a continuous variable. My next hypothesis was as follows:

> $H_6$ Counties with higher median household incomes are more likely to have higher recycling rates than counties with lower median household incomes.

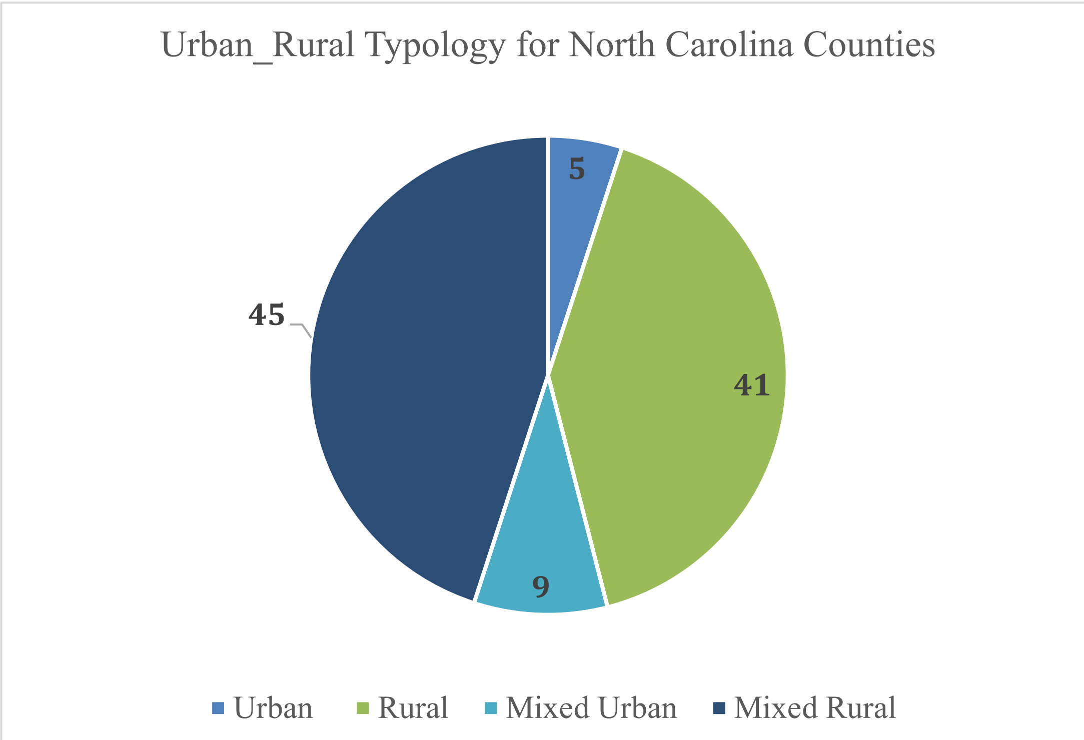
### *Spatial Factors*

Regarding the spatial dimension of recycling programs, I expected that urban communities, because of larger density, might have lower recycling operational costs and therefore higher recycling collection rates. Additionally, because urban communities tend to exhibit more Democratic voting tendencies and, by extension, more pro-environmental behaviors, I expected recycling rates in these areas remain high. Data for urban–rural characteristics of counties were drawn from the urban–rural Isserman code developed by Andrew Isserman (2005). This code deviates from the traditional method of categorizing counties as purely urban or rural, which does not accurately measure the diversity in population density that exists across counties. Instead, the Isserman code ranks counties on a continuum into four classes: urban, urban mixed, rural, and rural mixed. Studies have defined and categorized urban and rural in various ways. I used the Isserman classification because it allowed for inner and outer suburban counties or mixed-urban and mixed-rural areas to be evaluated along the rural–urban continuum. No one county is truly entirely urban or entirely rural, so the ability to categorize counties based on population density patterns across the county into four versus two categories is more reflective of U.S. demographic and land-use patterns (Isserman, 2005). The coding for each classification can be found in Table 3.2 and the frequency chart is in Fig 3.1. As can be seen, North Carolina, while heterogenous in other attributes, skews heavily when it comes to its spatial dynamics. North Carolina has more rural and mixed rural counties, which causes bias in the results. For the analysis, I use ‘urban’ as my reference category. My sixth hypothesis was as follows:

> $H_6$ Counties classified as urban are more likely to have higher recycling rates than counties classified as urban mixed, rural, and rural mixed.

**Figure 3.2**

*Spatial Characteristics of NC Counties*




The last variable of interest in my model was distance from MRF. As mentioned in Chapter 2, this was a less explored variable in the scholarly literature. Some organizational reports, such as the *2016 State of Curbside Recycling Report*, have highlighted the importance of the distance from MRFs in determining recycling rates. An MRF located farther from a county might translate into higher operational costs, such as longer travel distance for trucks carrying recyclables, than an MRF located closer. Therefore, we expect that higher operational costs would contribute to reduced recycling rates. I operationalized these data by using the data on the location of the 22 MRFs that serve North Carolina, five of which are located outside the state. Data are available on the NCDEQ website. I used ArcGIS to geocode the location of these MRFs and superimposed this information on a shape file of North Carolina counties. I then used the "Generate Near Table (Analysis)" to calculate the distance between the county centroid and the nearest MRF. This produced a continuous distance variable, which I included in my final regression. My seventh hypothesis was as follows:

> $H_7$ Counties closer to MRFs are more likely to have higher recycling rates than counties farther from MRFs.

Descriptive statistics are an important first insight into the data and variable distributions. Table 3.2 provides the descriptive statistics for all variables under consideration. All descriptions are for the years 2013–2018. On average, all counties across North Carolina collected about 5103.428 tons of traditional materials. A little over 60% of the counties had an assigned recycling coordinator to overlook recycling operations for the county. Almost 74% of counties have some recycling educational and awareness program. Roughly 57% of the counties have a higher number of registered Democratic voters compared to registered Republican voters. The average median household income for the state during 2013–2018 was approximately $43,147. For reference, the average national median household income for the United States for 2013–2018 was $55,614. On average, about 14% of the population across the counties has a bachelor's degree or higher. Last, on average, only about 21% of the counties have a curbside recycling program.

**Table 3.2**

*Descriptive Statistics*

| Variable | Obs | *M* | *SD* | Min | Max |
|---|---|---|---|---|---|
| Recycling rate | 600 | 5,103.43 | 10,607.16 | 21.25 | 78,745.83 |
| Recycling coordinator | 600 | 0.63 | 0.48 | 0 | 1 |
| Recycling education | 600 | 0.74 | 0.44 | 0 | 1 |
| Curbside recycling | 600 | 0.21 | 0.41 | 0 | 1 |
| Urban–Rural-Mixed | 600 | 2.94 | 1.03 | 1 | 4 |
| Density | 600 | 205.08 | 284.76 | 8.48 | 2,077.64 |
| Distance from MRF | 600 | 46,624.09 | 25,579.36 | 2945.28 | 134,028.69 |
| % Regd. Democrats | 600 | 56.93 | 17.12 | 14.35 | 89.61 |
| Household Income | 600 | 43,147.16 | 8,506.99 | 29,388.00 | 76,956.00 |
| % Bachelor's degree or higher | 600 | 14.65 | 6.39 | 4.56 | 38.63 |
| Median age | 600 | 41.73 | 4.83 | 25.80 | 52.80 |

The next step to gaining data insight is to conduct a correlation analysis. Table 3.3 shows the correlation between all variables. The coefficients from a correlation analysis depict the strength of the relationships between two variables. Larger coefficients indicate stronger relationships between two variables, whereas a negative or positive sign indicates the direction of the relationship (Gujarati et al., 2016).

The variable *recycling coordinator* showed a consistently low correlation with the other variables. However, it had a positive relationship with the *recycling rate.* Similarly, *recycling education* had a low correlation with all the variables but a positive relationship with *recycling rate.* The same relationships applied to *curbside recycling* and *urban–rural* type. *Density* and *recycling rate* correlated strongly with one another, a relationship consistent with findings from previous studies (Karousakis, 2009; Matsunaga & Themilis, 2002). Density also had a strong positive relationship with education, which is consistent with the understanding that education rates are higher in urban areas (high density). Distance from MRF showed a somewhat strong negative relationship with recycling rate, meaning that increased distance from an MRF facility was related to a decrease in the recycling rate. This relationship was an expected outcome of this

**Table 3.3**

*Matrix of Correlations*

| Variables | Recycling rate | Recycling coordinator | Recycling education | Curbside recycling | Urban–rural | Density | Distance from MRF | Voter registration | Income | Education | Age |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Recycling rate | — | | | | | | | | | | |
| Recycling coordinator | .208 | — | | | | | | | | | |
| Recycling education | .211 | .169 | — | | | | | | | | |
| Curbside recycling | .173 | -.054 | .169 | — | | | | | | | |
| Urban–rural | -.199 | -.017 | .076 | -.081 | — | | | | | | |
| Density | .891 | .219 | .223 | .149 | -.221 | — | | | | | |
| Distance from MRF | -.463 | -.074 | -.015 | -.040 | -.044 | -.494 | — | | | | |
| Voter registration | .006 | -.017 | .008 | .104 | -.175 | -.022 | .197 | — | | | |
| Income | .501 | .113 | .250 | .196 | -.028 | .492 | -.301 | -.308 | — | | |
| Education | .605 | .185 | .259 | .191 | -.097 | .601 | -.276 | -.191 | .694 | — | |
| Age | -.404 | -.193 | -.183 | -.025 | -.184 | -.184 | .409 | -.188 | -.217 | -.148 | — |

study. Surprisingly, voter registration patterns showed weak relationships across the set of variables. Not surprisingly, income had a strong positive relationship with recycling rate and education. Based on previous studies, I expected this relationship. Interestingly, age showed a negative, somewhat strong relationship with recycling rate, meaning that, as the age of residents increased, the recycling rate decreased. Because the correlations were not very high, I decided to keep all the variables in my model. Additionally, all my models had theoretical value and helped inform predictions about the outcome variables.

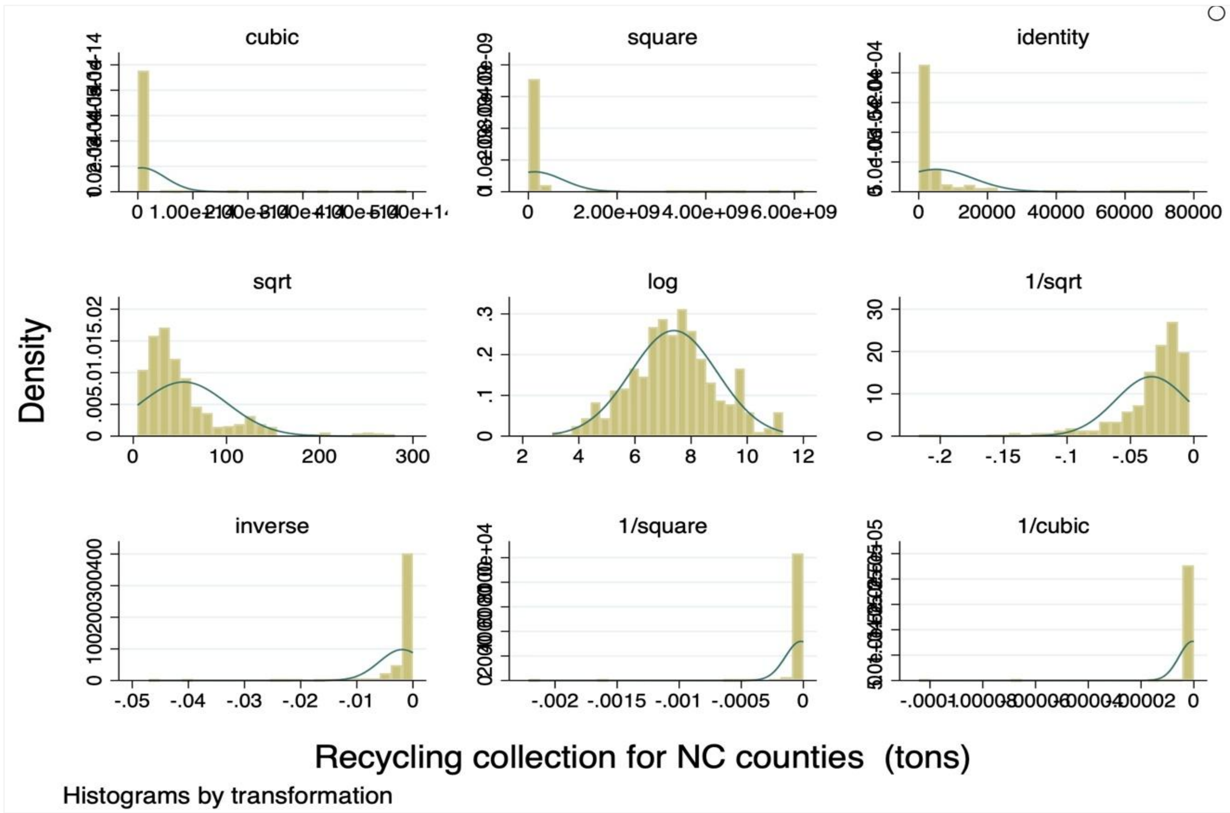
The next step before running my final model was to check the specifications of all my variables. I ran *gladder* in STATA for each of my variables, starting with recycling rate as my dependent variable. The different transformation options are shown in Figure 3.3. As can be seen in Figure 3.4, transforming the dependent variable *recyc* to a log was most suited for achieving normality.

I provided the gladder results for the independent variables in Appendix B. The original (identity) variable, and transformations (where needed) are also provided in Appendix C. I did not check for the distributions on my binary or categorical variables because I did not expect them to have normal distributions. After running diagnostics on all my explanatory variables, I transformed only education and density to their natural log form to meet the assumptions of normality.

The descriptive statistics and correlation matrix presented above provide context for the data. This baseline evaluation helped me understand the distribution, organization, and relationships among the study variables. Having this broad understanding helped me select my modeling strategy.

**Figure 3.3**

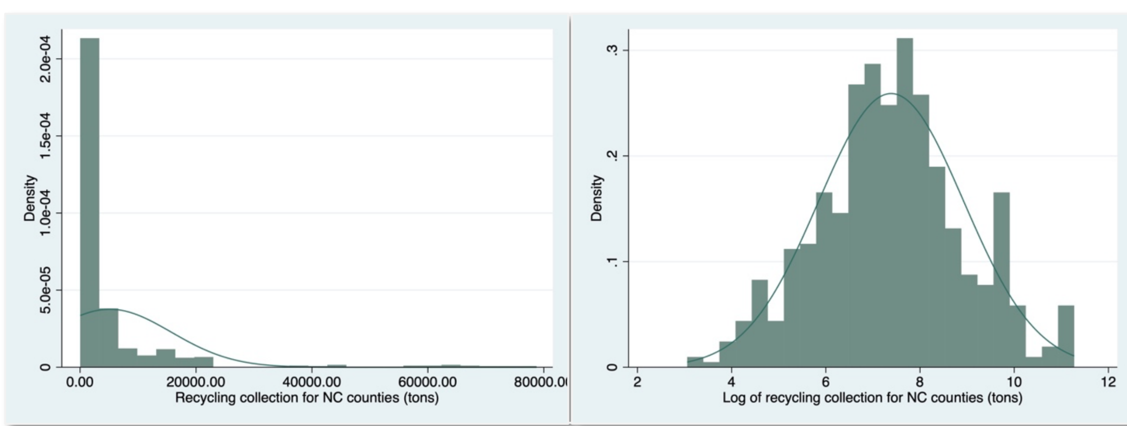
*Recycling Collection for NC Counties*




*Note*. Units in tons. Histograms by transformation.

**Figure 3.4**

*Transformation of the Dependent Variable Recyc to a Log*



In this study's conceptual framework, county-level recycling outcomes are influenced by an aggregated combination of county-level factors. The basic econometric model takes the following form:

$$Y_{it} = \alpha + \beta_1 coord_{it} + \beta_2 recyc\_ed_{it} + \beta_3 crb_{it} + \beta_4 ur\_type_i + \beta_5 dist_i + \beta_6 pol_{it} + \beta_7 log_e(educ_{it}) + \beta_8 age_{it} + \varepsilon_i, \quad (1)$$

Where $Y_i$ is the dependent variable, $\alpha$ is the intercept, the explanatory variable coefficients are $\beta_{1 \ldots 8}$, and $\varepsilon$ is the error term. To test for both time-variant and time-invariant effects in my model, both fixed and random effects were used. A fixed-effect model controlled for inherent differences between counties and analyzes changes within counties over time. In contrast, a random-effects model helped capture variable changes across time, within counties, and across counties. Additionally, random-effects models assume that the independent variables have no correlation with the error term (Starr & Nicolson, 2015). Although the variables I selected for this study fit the fixed-effects criteria, my observations were made within a randomly chosen period (i.e., 2013–2018). Natural disasters and changing economic conditions from year to year could have influenced recycling outcomes. Therefore, it is possible that the observation year had some random effect on the outcome or, in other words, brought about some systemic variation. Although I did not intend to test for the direct effects of time, it was important to account for its possible effect in the model.

Therefore, to capture both fixed and random effects of my variables, I chose a linear mixed model to obtain my results. Linear mixed models allow for flexibility in the analysis of panel data and combine the strengths of both random- and fixed-effects models (Schunck & Perales, 2017; Verbeke et al., 2018). There are three types of mixed models: standard linear, generalized linear, and nonlinear models (Verbeke et al., 2018). I used standard linear because of the continuous nature of my dependent variable, recycling rate. Mixed models relax the assumptions of general linear regression models regarding independency among variables (Schnuck, 2013; Schnuck & Perales, 2017; Seltman, 2012). Mixed models assume some dependence among variables, which was the case in my model. Verbeke et al. (2018) argued that in longitudinal studies where the subject is repeatedly measured over time, the statistical challenge is to account for the fact that the measurements within the clusters, in this case, cluster within each year, are not independent from each other, making mixed models far more applicable than standard linear regression models.

**Environmental and Economic Benefits of Recycling**

The second part of this study aimed to explore the environmental and economic benefits of recycling in North Carolina. To measure the environmental benefits of recycling, GHG savings incurred from recycling products and their reintroduction into the manufacturing process were calculated. Recycling of materials at the end of their life allowed for decreased reliance on virgin materials, reducing energy usage by eliminating the need for extraction, shipping, and processing of raw virgin materials. Recycling materials instead of landfilling results in decreased GHG emissions (Maio & Rem, 2015; Tisserant et al., 2017).

To evaluate the economic benefits of recycling, I calculate the wages generated from recycling of materials after they have been collected from households. These wages are then compared to the wages generated from landfilling the same materials as opposed to recycling them. Recycling materials instead of landfilling them results in employment creation (Ackerman, 1997; Bezdek, 1995; Goodstein, 1999; Hall, 1994; Morgenstern et al., 2000; Renner, 1991; Park et al., 2015; Templet, 1996).

RQ2: Do recycling rates influence economic and environmental outcomes in the counties of North Carolina?

For evaluators and decision-makers looking to make informed decisions regarding their local waste management activities and identify emission-reduction opportunities, there needs to be some way to quantify the GHG savings from material recycling. Although a plethora of scholarly articles rooted in the sciences and economics have evaluated the GHG and energy savings from recycled materials, there has been no region-specific or state-specific study relevant to North Carolina. In this section I derive partial life-cycle assessments for some recyclable materials collected locally. The goal for this part of the analysis was to quantify the GHG emissions from recycling of certain materials.

The EPA designed the waste reduction model (WARM) to assess the GHG emissions, energy usage, and economic impacts of a baseline and alternative waste management scenario. The agency provided these parameters across materials' source reduction, recycling combustion, composting, anaerobic digestion, and landfilling. An assessment of the environmental and economic impacts of recycling versus landfilling allows an understanding of where North Carolina counties are in terms of their recycling outcomes.

The NCDEQ local government annual forms supply limited data on the specific materials recycled. Over time, local governments in North Carolina have been reporting most of the collected recyclables under the "commingled" category. Local governments have increasingly been reporting commingled recyclables over the years, which is a mixture of all recyclables collected from households through the single-stream mechanism. However, recycling facilities volunteer to provide NCDEQ with rough estimates of what some commingled materials comprise. Recyclable materials as a whole—including glass, plastics, and metals—comprise just

15% of the total materials collected for recovery. This is a very small stream. Other recyclables, which were not part of this study, are yard waste, electronics, organics, tires, and construction and demolition materials. Organics make up 46.2% of the total.

I took advantage of the data regarding how much commingled recyclables are collected and coupled that with the approximations available regarding their composition. Those calculations allowed me to assess the GHG savings of these materials from recycling versus landfilling and using the virgin materials. The November 2020 WARM update includes an economic assessment of recycled materials, providing labor hours and wage generation from the process.

Because the data from NCDEQ was not useable in its original format, I prepared the data for my analysis. I began by combining the commingled rates for each municipality under each county to calculate total commingled rates for each of the hundred counties from 2014 to 2018. Commingled tons include curbside, drop off, and any other public run recycling programs. Given that I was focusing on traditional waste streams, this analysis did not include yard waste, tires, household hazardous waste, special wastes, used oil, or batteries. To these commingled tons, I applied the composition percentages provided by the NCDEQ on their website. After calculating each county's tonnage by category, I totaled the state's tonnage for each year. The recycling composition trend for 2014–2018 is provided in Figure 3.5.

**Figure 3.5**

*Composition of Commingled Recyclables for North Carolina in Tons, 2014–2018*

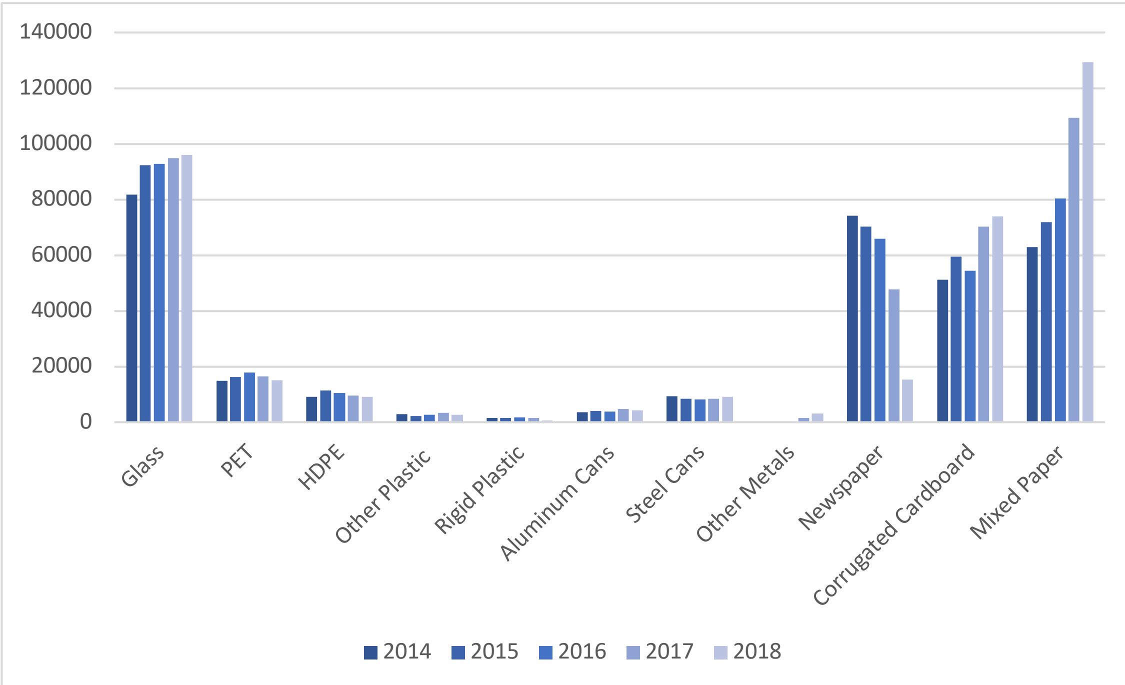



Figure 3.5 shows that glass, newspaper, corrugated cardboard, and mixed paper comprise the largest composition of commingled recyclables, while plastics and metals make up the smallest composition. It is interesting to note the significant drop in newspaper collection from 2016 to 2018. Discussion of why this is the case is included in the findings.

The WARM model can generate results specifically for North Carolina, which considers state context, where possible, such as the production processes used, fuel mixes, and other contextual factors involved in the waste management process. I selected the default "distance," which assumes an average of 20 miles each to a recycling center and a landfill station. The per-ton estimates of GHG emissions for baseline and alternative management scenarios and the wages made for processing each type of material are provided in Appendix D. Finally, I summed the totals by year for each material in the Analysis Input sheet of the WARM model. Results are provided in Chapter 4.

Inputting material collections in the WARM model provides the direct GHG and economic effects from recycling versus landfilling. However, I am also interested in estimating the causal effects of recycling on a broad set of environmental and economic outcomes to test theories of environmental protection and conservation, which advocate for recycling as a means to reduce environmental impact (Ackerman, 1997; Bezdek, 1995; Goodstein, 1999; Hall, 1994; Morgenstern et al., 2000; Renner, 1991; Templet, 1996) and increase economic productivity by introducing new jobs (Brookings Institution, 2011; epa.gov; Liu et al., 2011; Tellus, 2011).

To conduct this analysis, I gathered data on GHG emissions from all point sources and employment in all sectors for North Carolina counties. The U.S. EPA launched the Facility Level Information on GHGs Tools (FLIGHT) as part of its Greenhouse Gas Reporting Program (GHGRP), which provides information about GHG emissions from facilities with 25,000 or larger MTCO2e/year[7] in the nation. Using the FLIGHT tool, I collected and totaled GHG emissions from all point sources for each of the 100 North Carolina counties from 2014 to 2018. Point sources included filter manufacturing; glass production; municipal waste landfills; wastewater treatment; solid waste combustion; production of aluminum, ferroalloy, iron and steel, lead, magnesium, zinc, and other metals; and pulp and paper manufacturers, which comprise a little more than half of the total facilities that reported their GHG over the four study years. Although I could use only these facilities for my analysis, doing so could potentially overlook facilities that could benefit from the recycling process (Christensen & Austin, 2009).

Additionally, an assessment such as the present one has not been undertaken in the social sciences. This would be a first step in understanding any broad impacts recycling has on GHG

[7] "Metric tons of carbon dioxide equivalent or MTCO2e is the unit of measurement in this tool. The unit "CO2e" represents an amount of a GHG whose atmospheric impact has been standardized to that of one unit mass of carbon dioxide (CO2), based on the global warming potential (GWP) of the gas (EPA, 2014 p1)."

emissions. I graph the total North Carolina GHG emissions from all point sources in Figure 3.6. As can be seen, there has been a decline in GHG emissions from 2014-2017, after which GHG emissions increase. The variables and data sources are provided in Table 3.4.

To investigate causal mechanisms between recycling and employment, I collected data on paid "positions/employees" for each NC County from 2014 to 2018 from the County Business Patterns Dataset, which is hosted on the Census website. I used employment data from all sectors because recycling has the potential to create jobs throughout the supply chain (Liu et al., 2020; Makridis, 2020; Organisation for Economic Co-operation and Development, 2017; Park et al., 2015). Figure 3.7 shows the number of paid positions from 2014 to 2018. The descriptive statistics are provided in Table 3.4.

**Table 3.4**

*Study Variables GHG and Employment—RQ2*

| Serial. No. | Variable | Definition/Measure | Coding/Format | Source |
|---|---|---|---|---|
| Dependent Variable | | | | |
| 1 | ghg | Total greenhouse gas emissions from all point sources | Continuous variable | FLIGHT – EPA |
| 2 | emp | Total employment in all sectors | Continuous variable | County Business Patterns |
| Independent Variable | | | | |
| 1 | recyc | Total Traditional recyclable materials collected through local government programs | Continuous variable | North Carolina Department of Environmental Quality |
| 2 | disposal | Total waste sent to landfills from all point sources | Continuous variable | North Carolina Department of Environmental Quality |
| 3 | rural_urban | County classifications into rural, urban, mixed rural, and mixed urban | 1 Urban county<br>2 Rural county<br>3 Mixed urban<br>4 Mixed rural | Andrew Isserman U-R codes (Full definitions in Appendix A) |
| 4 | pol | Voter registration statistics by county | Continuous variable–percentage of registered Democrats | North Carolina State Board of Elections 2013–2018 |
| 5 | hh_inc | Median household income by county | Continuous variable | Census Bureau |
| 6 | educ | Percentage of residents with at least a four-year degree | Continuous variable | Census Bureau |
| 7 | age | Median age of county | Continuous Variable | Census Bureau |
| 8 | pop | Population by county | Continuous Variable | Census Bureau |

**Figure 3.6**

*Greenhouse Gas Emissions from All Sources, North Carolina, 2014–2018*

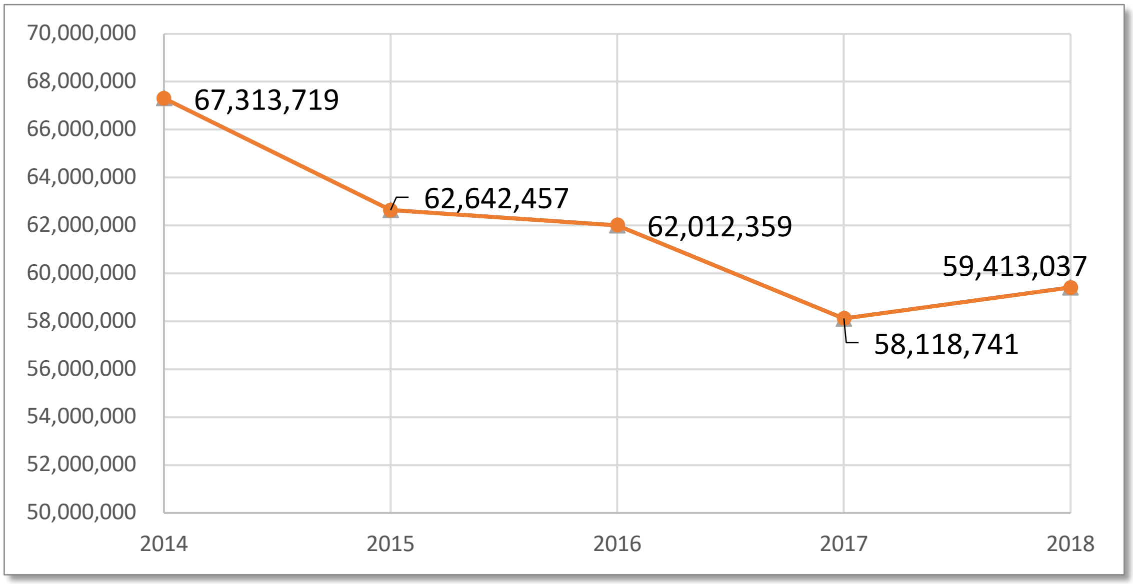
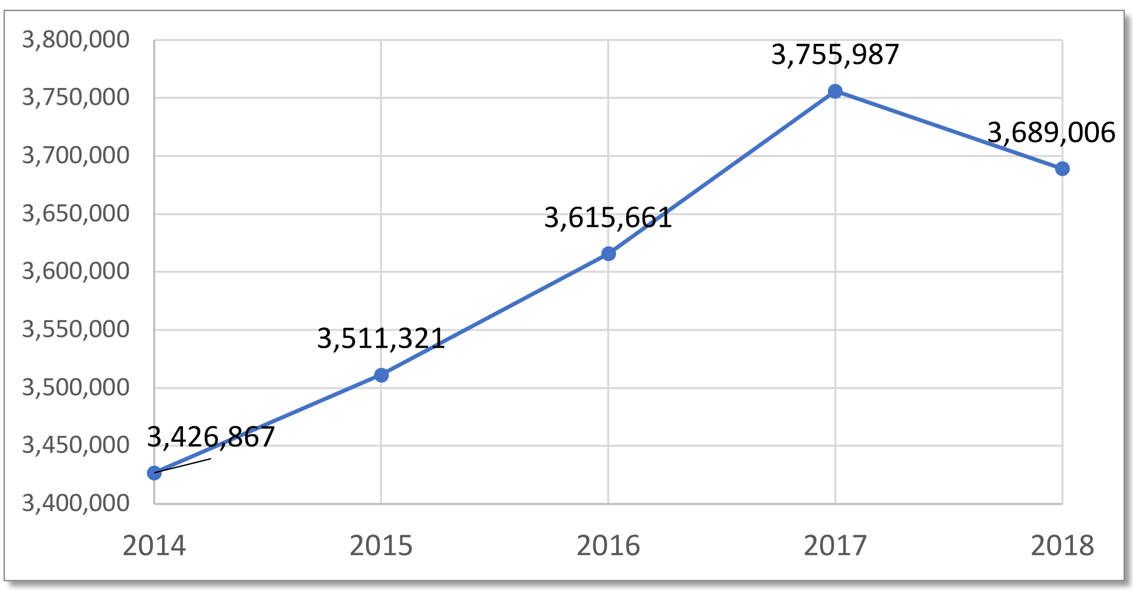



**Figure 3.7**

*Number of Paid Employees, North Carolina, 2014–2018*




To conduct an econometric analysis and isolate the effects of recycling on GHG, I needed to control for other county-level variables that might affect GHG emissions. One factor that was important in this regard was consumption. As counties grow, consumption increases. More consumption means more resources, which in turn require processing, thereby producing GHGs. Incorporating consumption into my model accounted for any “rebound effects”[8] associated with recycling (Catlin & Wang, 2013; Makov & Vivanko, 2018). Because it is difficult to capture overall consumption, I used waste disposal as a proxy for consumptions across counties. Waste impacts GHG and provides for a more holistic picture of the recycling process (Christensen & Austin, 2009; Lou & Nair, 2009). I used the Local Government Annual Reporting Forms from 2014 to 2018 to gather data on waste disposal, that is, waste sent to the landfill. It is important to note that waste disposal is the municipal solid waste collected by municipalities, including construction and demolition waste, a stream I have not incorporated so far. Unfortunately, there was no way to distinguish traditional waste from construction and demolition waste in this mixed waste stream. I present waste disposal in Figure 3.8 and display the difference in tons between the waste disposed and traditional recyclables collected in Figure 3.9. I controlled for other local demographic and spatial variables that could have influenced GHG outcomes (Liddle, 2014; O’Neill et al., 2012). The descriptive statistics and correlation matrix are provided in table 3.5 and 3.6, respectively. I selected the linear mixed-model approach for its ability to accommodate both fixed and random estimates in the data. The basic econometric model for this analysis was as follows:

$$GHG_{it} = \alpha + \beta_1 recyc_{it} + \beta_2 disposal_{ti} + \beta_3 age_{it} + \beta_4 education_{it} + \beta_5 income_{it} + \beta_6 urban\_rural_i + \beta_7 political_{it} + \varepsilon_i \quad (2)$$

[8] The term ‘Rebound Effect’ emerges from the economics literature, which proposes that, for example, in the case of recycling, increased recycling efforts on the part of consumers, may result in increased consumption of goods on their part, thereby mitigating any benefits of recycling in the first place (Catlin & Wang, 2013; Ma et al., 2019)

Similarly, to analyze the causal mechanism between recycling and employment, I used recycling as my key explanatory variable, followed by other demographic variables that influence employment at the local level (Levesque & Minniti, 2011). The descriptive statistics and correlation matrix are provided in Tables 3.7 and 3.8, respectively.

$$Jobs_{it} = \alpha + \beta_1 recyc_{it} + \beta_3 age_{it} + \beta_4 education_{it} + \beta_5 income_{it} + \beta_6 urban\_rural_{it} + \beta_7 political_{it} + \varepsilon_i \quad (3)$$

**Figure 3.8**

*Waste Disposal (in Tons), North Carolina, 2014–2018*

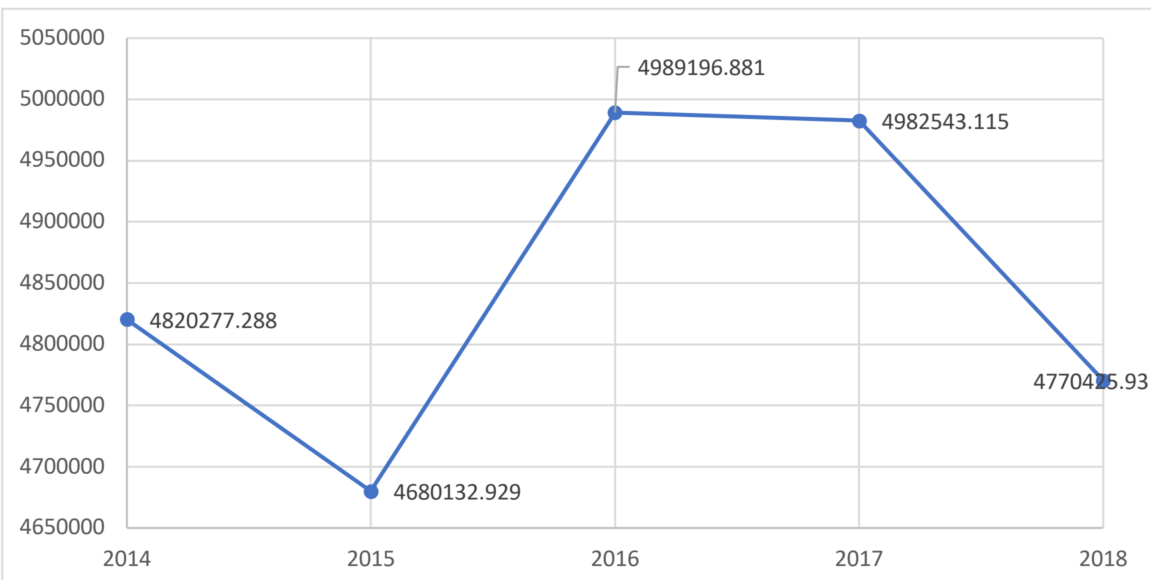


**Figure 3.9**

*Waste Disposal Versus Traditional Materials Recycling (in Tons), North Carolina 2014–2018*

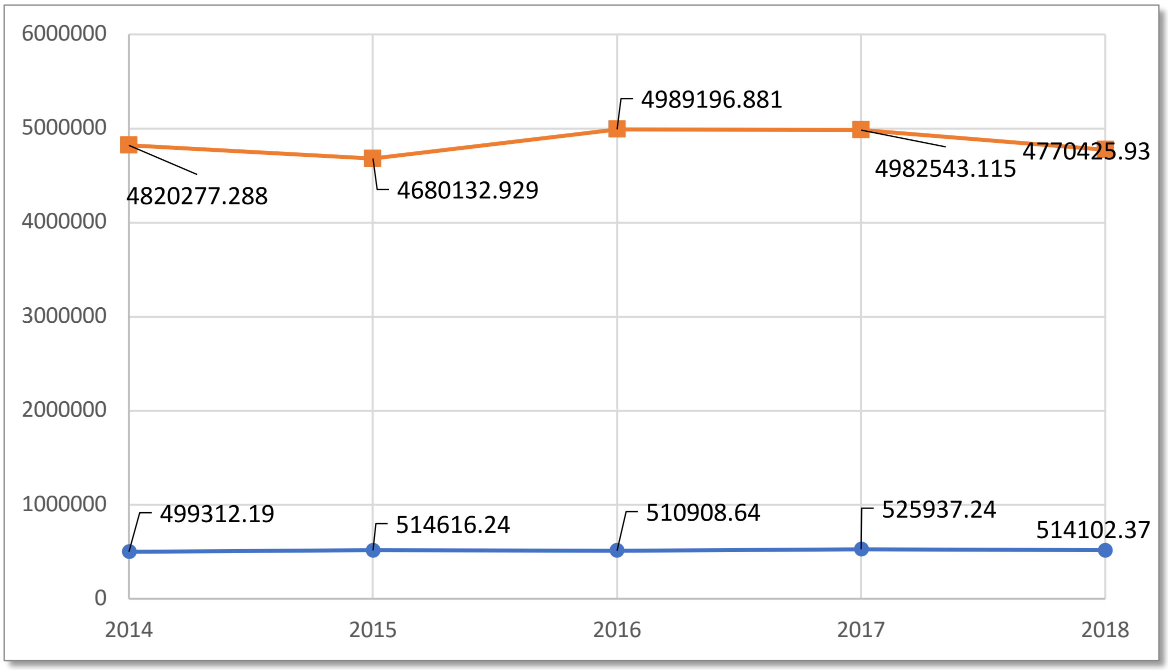



**Table 3.5**

*Descriptive Statistics GHGs and Recycling—RQ2*

| Variable | Obs | *M* | *SD* | Min | Max |
|---|---|---|---|---|---|
| GHG totals | 244 | 1,214,073.10 | 2,422,911.70 | 25,848.00 | 14,518,409.00 |
| Recycling rate | 500 | 5,129.75 | 10,710.16 | 21.25 | 78,745.83 |
| Disposal rate | 498 | 48,679.87 | 86,031.79 | 365.22 | 735,844.37 |
| Population Density | 500 | 100,367.78 | 156,252.49 | 4,119.00 | 1,054,314.00 |
| Age | 500 | 41.89 | 4.85 | 25.9 | 52.80 |
| Education | 500 | 14.81 | 6.43 | 4.94 | 38.63 |
| Income | 500 | 43,471.84 | 8,649.72 | 29,388.00 | 76,956.00 |
| Urban Rural type | 500 | 2.94 | 1.03 | 1.00 | 4.00 |
| % regd. democrats | 500 | 56.56 | 17.19 | 14.35 | 89.61 |

**Table 3.6**

*Matrix of Correlation, GHGs and Recycling—RQ2*

| Variable | GHG totals | Recycling rate | Disposal rate | Population density | Age | Education | Income | Urban Rural type | % regd. democra ts |
|---|---|---|---|---|---|---|---|---|---|
| GHG totals | — | | | | | | | | |
| Recycling rate | -0.076 | — | | | | | | | |
| Disposal rate | 0.001 | 0.801 | — | | | | | | |
| Population density | -0.127 | 0.964 | 0.796 | — | | | | | |
| Age | 0.181 | -0.445 | -0.320 | -0.444 | — | | | | |
| Education | -0.133 | 0.712 | 0.414 | 0.669 | -0.344 | — | | | |
| Income | -0.046 | 0.615 | 0.371 | 0.626 | -0.331 | 0.802 | — | | |
| Urban Rural type | 0.012 | -0.492 | -0.257 | -0.480 | 0.177 | -0.464 | -0.292 | — | |
| % regd. democrats | -0.150 | -0.018 | -0.058 | -0.056 | -0.108 | -0.026 | -0.375 | -0.334 | — |

**Table 3.7**

*Descriptive Statistics, Employment and Recycling—RQ2*

| Variable | Obs | *M* | *SD* | Min | Max |
|---|---|---|---|---|---|
| Employment | 500 | 721,214.19 | 3,257,696.40 | 414.00 | 40,233,729.00 |
| Recycling rate | 500 | 5,129.75 | 10,710.16 | 21.25 | 78,745.83 |
| Age | 500 | 41.89 | 4.85 | 25.90 | 52.80 |
| Education | 500 | 14.81 | 6.43 | 4.94 | 38.63 |
| Income | 500 | 43,471.84 | 8,649.72 | 29,388.00 | 76,956.00 |
| Urban rural type | 500 | 2.94 | 1.03 | 1.00 | 4.00 |
| Population density | 500 | 100,367.78 | 156,252.49 | 4,119.00 | 1,054,314.00 |

**Table 3.8**

*Matrix of Correlation, Employment and Recycling—RQ2*

| Variable | Employment | Recycling rate | Population density | Age | Education | Income | Urban Rural type | % regd. democrats |
|---|---|---|---|---|---|---|---|---|
| Employment | — | | | | | | | |
| Recycling rate | 0.612 | — | | | | | | |
| Population density | 0.608 | 0.960 | — | | | | | |
| Age | -0.192 | -0.401 | -0.444 | — | | | | |
| Education | 0.365 | 0.609 | 0.551 | -0.153 | — | | | |
| Income | 0.334 | 0.502 | 0.497 | -0.222 | 0.699 | — | | |
| Urban Rural type | -0.172 | -0.202 | -0.152 | -0.184 | -0.094 | -0.025 | — | |
| % regd. democrats | 0.034 | 0.001 | -0.007 | -0.190 | -0.186 | -0.309 | -0.176 | — |

## Uncovering Challenges and Missed Opportunities in the Recycling Process

This section of the study aims to uncover opportunities and challenges associated with recycling, by interviewing stakeholders involved in the process. Although the quantitative assessments in the previous sections provide a valuable overview of North Carolina's recycling mechanisms, a qualitative assessment is vital to understanding variables and concepts not captured by secondary data. The objective of the qualitative method is to provide insight into the factors (inform the independent variables and thereby the hypothesis) and to achieve triangulation or, as KKV put it, "methodological pluralism." This section explores the presence of other performance indicators at the county level.

In this part of the study, I employed a qualitative approach (semi-structured interviews; see Appendix E) to purposively sample counties based on their attributes for some key explanatory indicators (as listed in the first two sections of this chapter). Examples of such attributes include recycling rates (rankings listed on NDEQ website), education, and voter registration statistics. The purpose of the interviews was to draw descriptive inferences about performance indicators based on the chosen attributes and new explanations that might emerge from the interview responses. Variation on these explanatory variables permits the construction of comparative case studies, where each selected county is representative of a combination of each of the selected attributes. Simultaneously, MRFs catering to the purposively selected counties were interviewed to gain insight into what gets recycled and the role of market forces in the recycling system.

Qualitative data helps understand the performance of local governments and the efficiency of their recycling programs, while possibly highlighting the presence of unobserved variables, if any. This understanding and discussion of newly defined best practices, challenges, and future opportunities is relevant to policy makers and leaders in the field of solid waste management and recycling. The aim at the beginning of the study was to hold at least 10 interviews—five county officials and five corresponding MRF managers. The interviews were conducted during the COVID-19 pandemic, when most people were working at home, making it challenging to reach out to interviewees other than via email, which led to a low response rate. With the help of a state official, I was able to conduct five interviews, representing four jurisdictions, including a North Carolina state representative. The following were the questions I used to guide my interviews. The complete interview questions are available in Appendix F.

**County Questions**

- Could you give me a brief overview of the recycling program in your county?
- According to you, is your county's recycling program achieving its targets?
- Do you know how much of the recyclables you collect actually get recycled?
- What would you do to improve your recycling programs?
- Why does your county have a recycling program?

**Material Recovery Facility Questions**

- Could you give me a brief overview of your operations and the services you provide to counties?
- Are you achieving your recycling targets?
- What is your residual or contamination rate?
- What are some challenges you face?
- What do you think local governments or county/municipality residents can do to improve recycling performance?

The counties interviewed and their attributes as of 2018 are listed in Table 3.9. To protect the confidentiality of the interview participants, the names of the county and/or the officials are not used. As can be seen in the table, there was some diversity in characteristics of the interviewed counties. This diversity is helpful in making general inferences about recycling in North Carolina.

**Table 3.9**

*Counties Interviewed. Local Attributes as of 2018*

| County No. | Recycling rate (in tons) | Education rate (% with a bachelor's or higher) | Population | Voter characteristics |
|---|---|---|---|---|
| State average | 5,141 | 15.7 | 101,556 | Dem = 38%<br>Rep = 30%<br>Unaffiliated = 32% |
| 1 | 20,731 | 16 | 156,729 | Dem = 24%<br>Rep = 43%<br>Unaffiliated = 33.2% |
| 2 | 3,898 | 22 | 35,741 | Dem = 29%<br>Rep = 31%<br>Unaffiliated = 39.5% |
| 3 | 2,950 | 31 | 69,791 | Dem = 39%<br>Rep = 24.4%<br>Unaffiliated = 36.6% |

In this chapter, I have outlined my data and my methodological approach for systematically testing my hypotheses. In Chapter 4, I dive deeper into building my models and setting the random equations in my mixed-effects model. I also discuss the results from the WARM model and the model to test for a relationship between GHGs and recycling. Finally, I synthesize the results from the interviews.

# CHAPTER 4: RESULTS AND FINDINGS

In Chapter 3, I discussed my data and their sources, along with descriptive statistics for the variables in question. Preliminary diagnostics were valuable to understanding the distribution of the data and how to operationalize the variables in the models. I concluded with a discussion of my analytical approach and modeling strategy. The aim of this chapter is to describe the building of my data—what variables I kept and what I eliminated from the analysis. I include the method incorporated to improve the accuracy and reliability of my results. I conclude the chapter with a discussion of the relevant findings.

## Local Factors and Recycling Outcomes

To study the effects of local factors on recycling outcomes, I chose a mixed-effects model for my analyses, allowing for the interplay of two kinds of effects—fixed and random. As Hamilton (2013) described,

> Mixed-effects modeling is basically regression analysis allowing two kinds of effects: fixed effects, meaning intercepts and slopes meant to describe the population just as in ordinary regression, and also random effects, meaning intercepts and slopes that can vary across subgroups of the sample. (p. 387)

The aim of my first research question was to explore the county-level factors that affect recycling rates. Conducting an econometric analysis allowed for the systematic testing of my hypotheses and evaluate what factors at the county level are significant in influencing recycling rates. Understanding these relationships is useful for future research on county recycling and designing effective recycling policies.

I estimate baseline regression results to build my model systematically and conduct my analysis. I begin by estimating a simple regression model, which assumes the data to be cross-sectional. Performing this preliminary analysis provides the significance of each variable, helping to decipher which variables to keep in the final mixed-effects model. The results of the

OLS linear regression are in Table 4.1. The simple linear regression is not able to treat the dataset as a panel but still provides an estimate for the fixed effects present in the model; this is because I expected slow changes in the variable over the years. The intercepts and coefficients then describe the sample as a whole. Because adding *hh_inc* to the equation did not increase the value of $R^2$ and was not significant in the model, I dropped it from my study as a variable of interest.

Although I expected slow changes over time, the yearly pattern of recycling rates was not captured by only the fixed-effects part of the model. To capture the effects of each year, I included the year as the random intercept in my model. The original regression equation with only the fixed intercepts and coefficients was

$$Y_{it} = \beta_0 + \beta_1 coord_{it} + \beta_2 recyc\_ed_{it} + \beta_3 crb_{it} + \beta_4 ur\_type_i + \beta_5 dist_i + \beta_6 pol_{it} + \beta_7 log_e(educ_{it}) + \beta_8 age_{it} + \varepsilon_i. \tag{4}$$

The regression equation incorporating the random intercept then was

$$Y_{it} = \beta_0 + \beta_1 coord_{ij} + \beta_2 recyc\_ed_{ij} + \beta_3 crb_{ij} + \beta_4 ur\_type_{ij} + \beta_5 dist_{ij} + \beta_6 pol_{ij} + \beta_7 (educ_{ij}) + \beta_8 age_{ij} + \mu_{0j} + \varepsilon_{ij}. \tag{5}$$

The equation above depicts the value of *Y* for the *i*th county and *j*th year as a function of $x_{1,}\ x_{2,}\ \dots.\ x_8$ effects, which are the same for all years. The random intercept $\mu_{0j}$ allows for the possibility that the mean recycling rate for North Carolina is higher or lower among the counties for some years. I then ran the linear mixed-effects model in STATA. The results can be found in Tables 4.2 and 4.3.

**Table 4.1**

*Linear Regression Results*

| Log of recycling rate | Coef. | *SE* | *t* | *p* | 95% *CI* Lower | 95% *CI* Upper |
|---|---|---|---|---|---|---|
| Recycling coordinator | -.025 | .061 | -0.41 | .681 | -0.146 | 0.095 |
| Recycling education | .409 | .069 | 5.94 | .000*** | 0.273 | 0.544 |
| Rural | -2.006 | .188 | -10.67 | .000*** | -2.375 | -1.637 |
| Mixed urban | -.308 | .164 | -1.88 | .061* | -0.629 | 0.014 |
| Mixed rural | -1.037 | .170 | -6.11 | .000*** | -1.370 | -0.704 |
| MRF distance | -9.97E-06 | 0 | -7.35 | .000*** | 0.000 | 0.000 |
| Education | 1.172 | .103 | 11.35 | .000*** | 0.969 | 1.374 |
| Curbside recycling | .339 | .076 | 4.46 | .000*** | 0.189 | 0.488 |
| % registered Democrats | -.014 | .002 | -7.59 | .000*** | -0.018 | -0.011 |
| Age | -.160 | .069 | -2.31 | .021** | -0.296 | -0.024 |
| Age2 | .001 | .001 | 1.57 | .118 | 0.000 | 0.003 |
| Constant | 10.892 | 1.554 | 7.01 | .000*** | 7.84 | 13.944 |

*Note*. *M* of DV = 7.387; *SD* of DV = 1.540; number of observations = 600; $R^2$ = 0.808; *F* = 224.767; prob > *F* = .000; Akaike information criterion = 1,253.854; Bayesian information criterion = 1,306.618.

$^*p < .10$. $^{**}p < .05$. $^{***}p < .01$.

**Table 4.2**

*Mixed-Effects Regression with Year Intercept*

| Log of recycling rate | Coef. | *SE* | *t* | *p* | 95% *CI* Lower | 95% *CI* Upper |
|---|---|---|---|---|---|---|
| Recycling coordinator | -.025 | .061 | -0.42 | .678 | -0.144 | 0.094 |
| Recycling education | .409 | .068 | 6.00 | .000*** | 0.275 | 0.542 |
| Rural | -2.006 | .186 | -10.78 | .000*** | -2.370 | -1.641 |
| Mixed urban | -.308 | .162 | -1.90 | .057* | -0.625 | 0.010 |
| Mixed rural | -1.037 | .168 | -6.17 | .000*** | -1.366 | -0.708 |
| MRF distance | -9.97E-06 | .000 | -7.42 | .000*** | 0.000 | 0.000 |
| Education | 1.172 | .102 | 11.47 | .000*** | 0.971 | 1.372 |
| Curbside recycling | .339 | .075 | 4.50 | .000*** | 0.191 | 0.486 |
| % of registered Democrats | -.014 | .002 | -7.66 | .000*** | -0.018 | -0.011 |
| Age | -.160 | .069 | -2.33 | .020** | -0.295 | -0.026 |
| Age2 | .001 | .001 | 1.58 | .114 | 0.000 | 0.003 |
| Constant | 10.892 | 1.538 | 7.08 | .000*** | 7.877 | 13.908 |

*Note*. *M* of DV = 7.387; *SD* of DV = 1.540; number of observations = 600; $\chi^2$ = 2,522.895; prob > $\chi^2$ = .000; Akaike information criterion = 1,257.854.

$^*p < .10$. $^{**}p < .05$. $^{***}p < .01$.

**Table 4.3**

*Mixed-Effects Regression with County Intercept and Year Slope*

| Log of recycling rate | Coef. | *SE* | *t* | *p* | 95% *CI* Lower | 95% *CI* Upper |
|---|---|---|---|---|---|---|
| Recycling coordinator | -.011 | .045 | -0.24 | .807 | -.100 | .078 |
| Recycling education | .045 | .062 | 0.73 | .464 | -.076 | .167 |
| Rural | -3.346 | .410 | -8.16 | .000*** | -4.149 | -2.542 |
| Mixed urban | -.797 | .412 | -1.94 | .053* | -1.605 | .010 |
| Mixed rural | -2.061 | .383 | -5.38 | .000*** | -2.812 | -1.310 |
| MRF distance | -1.02E-05 | .000 | -2.97 | .003*** | 0.000 | 0.000 |
| Education | .105 | .126 | 0.83 | .404 | -.141 | .351 |
| Curbside recycling | .397 | .105 | 3.77 | .000*** | .190 | .603 |
| % of registered Democrats | -.016 | .004 | -3.75 | .000*** | -.025 | -.008 |
| Age | -.398 | .114 | -3.48 | .000*** | -.623 | -.174 |
| Age2 | .005 | .001 | 3.40 | .001*** | .002 | .007 |
| Constant | 19.237 | 2.482 | 7.75 | .000*** | 14.372 | 24.102 |

*Note*. *M* of DV = 7.387; *SD* of DV = 1.540; number of observations = 600; $\chi^2$ = 356.276; prob > $\chi^2$ = .000; Akaike information criterion = 569.455.

*$p < .10$. **$p < .05$. ***$p < .01$.

The mixed-effects model with year random intercepts returned a *p* value of 1.00 for its Likelihood Ratio (LR) test versus linear regression test. This indicates that the model is not a significant improvement from the linear regression model with fixed effects only. I ran another model with random county intercepts and year slope, which accounts for yearly effects at the county level. This allows for year random slopes at the county level. Table 4.3 presents the results for this model. The AIC (569.455) for this model specification is lower than the previous one (1,257.854), which indicates that this is a more appropriate specification. Therefore, I select this as my final model.

The final regression model had an *N* of 600, which was 100 counties over the course of six years. Having a designated recycling coordinator ($b$ = -.011, $p$ > .05), recycling education program ($b$ = .045, $p$ > .05), and residents' education ($b$ = .105, p > .05), showed no statistically significant relationship with the dependent variable (recycling rate). For the Andrew-Isserman urban–rural typology I found that compared to urban counties, rural counties ($b$ = -3.346, $p$ <

.01) have the largest difference in recycling rates, followed by mixed rural counties ($b = -2.061$, $p < .01$), and then mixed urban counties ($b = -.797$, $p < .1$). The spatial distance between MRF and the county centroid has a positive and significant relationship ($b = .0000102$, $p < .01$) although the coefficient is almost zero. As expected, curbside recycling ($b = .397$, $p < .01$) shows a positive and significant relationship with recycling rate. Surprisingly, the political variable, percentage of registered Democrats ($b = -.016$, $p < .01$) has a negative and significant relationship with the dependent variable, compared to percentage of registered Republicans. Finally, age ($b = -.398$, $p < .01$) shows a negative and significant relationship with recycling rate. As a robustness check, I ran the model using population density instead of the urban–rural typology. I found similar results as my final model. The output table can be found in Appendix G. The findings from the final model are discussed in the next section.

The first regression analysis found that, among the programmatic, demographic, and spatial variables, curbside recycling was directly related with recycling rates. Rural, mixed urban, and mixed rural counties were less likely than urban counties to influence recycling. The percentage of registered Democrats and age also show an inverse relationship with recycling.

Among programmatic variables, recycling coordinator and recycling education were found to be statistically insignificant, while curbside recycling shows statistical significance. As noted earlier, studies analyzing the direct effects of a recycling coordinator or supervisor on recycling outcomes cannot be found in the literature, but scholars interested in public service outcomes in the presence of a service manager have found there to be a positive relationship (Bae & Feiock, 2012; Folz & Abdelrazek, 2009). Two underlying reasons could explain these findings. First, it is possible that the phenomenon of recycling has evolved to become the norm; recycling continues to operate, regardless of having an administrator in charge of it. Second, about 66% of the counties have a recycling coordinator, but 93% have at least a solid waste director. Low variation in this variable could have influenced the statistical outcomes.

Recycling education, a widely studied variable (Folz & Hazlett, 1991; Martinez & Scicchitano, 1998; Timlett & Williams, 2009), showed no statistical significance in my final model. This was a surprising outcome because recycling education has been found to play an important role in recycling outreach activities (Folz & Hazlett, 1991; Martinez & Scicchitano, 1998; Timlett & Williams, 2009). However, it is not unfounded in the literature - scholars from the ’80s and ’90s argued that prompts and information on recycling have the weakest effects on recycling outcomes and do not spur long-term behavior changes (De Young, 1986; Hopper & Nielsen, 1991). This is one possible reason for why the results were statistically insignificant. Another possibility is that, as with a recycling coordinator, recycling education has no effect on recycling outcomes owing to pro-recycling behaviors becoming the norm. That is, residents continue to recycle, irrespective of whether they are participating in recycling educational programs. An argument could be made advocating for the messaging of the educational program. Perhaps, the program has lost its effect on residents because the messaging may not be as effective anymore. Over time, message framing, where the focus is on the content of the message and its effects on people’s attitudes and behaviors, has gained popularity over time (Cheng & Yeh., 2013; Davis, 1995; White et al., 2011). However, recycling education was statistically significant in the LR model and the ML regression with year intercept, providing some support for its relevance to recycling outcomes.

An increase in recycling rates as a result of curbside recycling was not surprising and is consistent with previous literature (Dormina & Koch, 1999, 2002; Ewing, 2001; Folz, 1991; Kinnaman & Fullerton, 2000; Park & Berry, 2013; Sidique et al., 2010). The results show that, as a county switched to curbside recycling, the average increase in recycling was about 49%, all else equal. This is a large magnitude. Even with only about 20% of counties indicating the presence of curbside recycling, the statistical results were still positive. This finding implies that curbside recycling is a strong indicator of recycling and is meeting its objective of increased recycling convenience in North Carolina.

Regarding spatial variability in recycling rates, rural, mixed urban, and mixed rural counties on average, demonstrated lower recycling rates than urban counties. Rural counties showed the largest difference in average recycling rates, followed by mixed rural, then mixed urban. These results were expected because population density is highest in urban counties, followed by mixed urban, mixed rural, and rural counties. Previous literature speaks directly to the influence of population density on recycling, arguing that areas with higher density have higher recycling rates. Increased recycling rates are a result of lower operational costs (economies of density[9]), better recycling facilities, and accessibility to services (Dubin & Navarro, 1988; Sidique et al., 2010).

Another spatial variable displaying statistical significance was distance from MRF. My results show that, as the distance between MRFs and county centers increased, recycling rates decreased. Per the data, a 1-mile increase in distance reduced recycling at an average of .001%. Although this effect was small, it is important to understand that the magnitude of the effect can be attributed to the measurement used for distance. Perhaps using actual road networks could have changed the effect sizes. The findings were in agreement with the expectations set in

[9] Cost savings resulting from spatial proximity of suppliers or providers. In this context, lower average cost of garbage collection for each household in high population density areas due to the proximity of both suppliers of recyclables and providers of the recycling service.

previous studies that have advocated for shorter distances between MRFs and recycling service areas resulting in increased recycling collections (Bandheur et al., 2017; Miller et al., 2009).

Among the demographic variables, education was not statistically significant in my final model; however, it was significant at the .01 level in the LR and ML with year intercept model. The positive coefficient for education aligned with the findings of previous studies that have argued for educated citizens being more likely to recycle because of their preference for cleaner environments (Feiock & Kalan, 2001; Kinnaman & Fullerton, 1997). The statistically weak relationship supports arguments against using demographic factors such as education to predict recycling outcomes (Mitchell, 1989; Tilikidou & Delistavrou, 2001; Van Liere & Dunlap, 1980). This could again be explained by recycling having become a mainstream activity across communities in North Carolina, and, regardless of education, residents continue to recycle.

Age and its transformation were both significant in my model. The coefficient on age was negative and statistically significant, indicating that, on average, older people were less likely to recycle. Specifically, on average, a unit increase in age, could reduce recycling by 32%. This magnitude is large and contradicts the idea that demographic factors are invaluable (Mitchell, 1989; Tilikidou & Delistavrou, 2001; Van Liere & Dunlap, 1980). In fact, these results point to age being an important factor when considering recycling outcomes, consistent with some previous studies (Barr et al., 2003; Schultz et al., 1995; Star & Nicolson, 2015; Ungar, 1994). The direction of the coefficient could be explained by the understanding that younger individuals are more likely to be open to new ideas and opportunities and tend to gradually distance themselves from anthropocentric ideas, which might make efforts toward sustainability more appealing (Dunlap & Van Liere, 1978; Roberts et al., 2006).

Finally, when considering local political factors affecting recycling, I hypothesized that counties with more registered Democrats are more likely to have higher recycling outcomes, on average, compared to counties with more registered Republicans. I found that the percentage of registered Democrats in a county had a negative and significant effect on recycling outcomes. Although contrary to what I expected, such a relationship is not unfounded in the literature (Park & Berry, 2013; Seacat & Boileau, 2018). This finding can be attributed to the understanding that there has been a convergence in partisan ideologies with regards to recycling in North Carolina, an argument made by previous scholars in the field. Recycling is not as politicized as we once thought; it could simply be an act of altruism (Carney et al., 2009), or be undertaken based on one's individual assessment of the cost-benefit associated with recycling (Carrus et al., 2008). For instance, from speaking with a representative of a county that has almost an equal number of registered Democrats and Republicans (slightly higher), I gathered that the county, even during challenging times, continues to operate recycling programs because their constituents demand it. This provides evidence for the arguments made by Dunlap et al. (1991) and Carney et al. (2009). The policy implications from these findings are discussed in Chapter 5.

**Environmental and Economic Benefits of Recycling**

To explore the environmental and economic effects of recycling, I assessed the GHG emissions for baseline and alternative management scenarios using the WARM model formulated by the EPA. The baseline management scenario for my study was the current recycling rate, whereas the alternative scenario was whether the same recyclables were being disposed as waste in a landfill. The total results from the baseline and alternative management scenario are provided in Figure 4.1. As can be seen, GHG emissions savings from recycling commingled materials from 2014-2018 were significantly higher, compared to if they had been landfilled. The change in emissions from the alternative to the base management scenario is provided in Figure 4.2. Because a discussion of how and why these outcomes influenced GHG emissions is pertinent to approaching a holistic comprehension of recycling programs, I also explored the effect of recycling on the overall GHG levels and

**Figure 4.1**

*GHG Emissions (MTCO2e): Recycling Versus Landfilling*

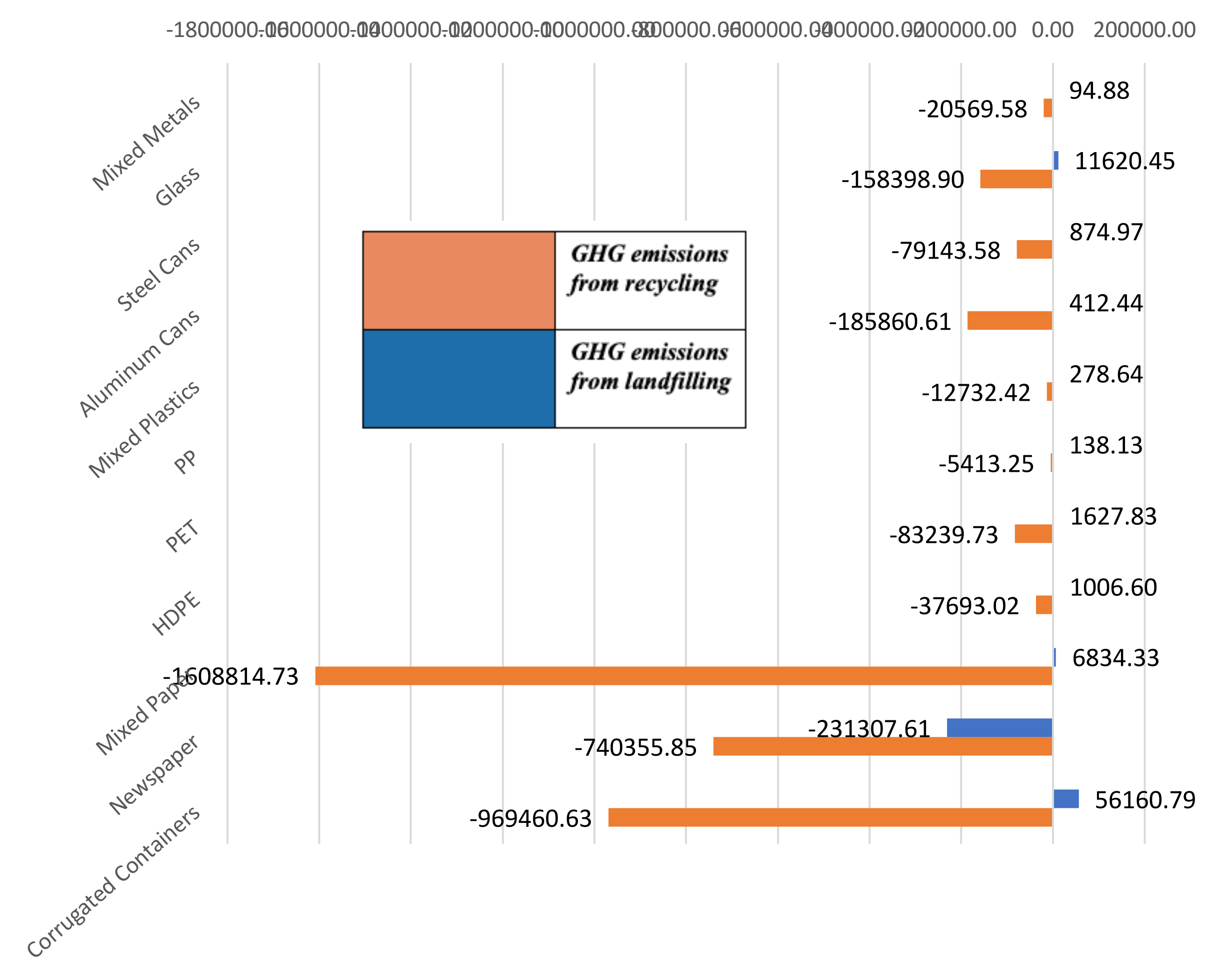
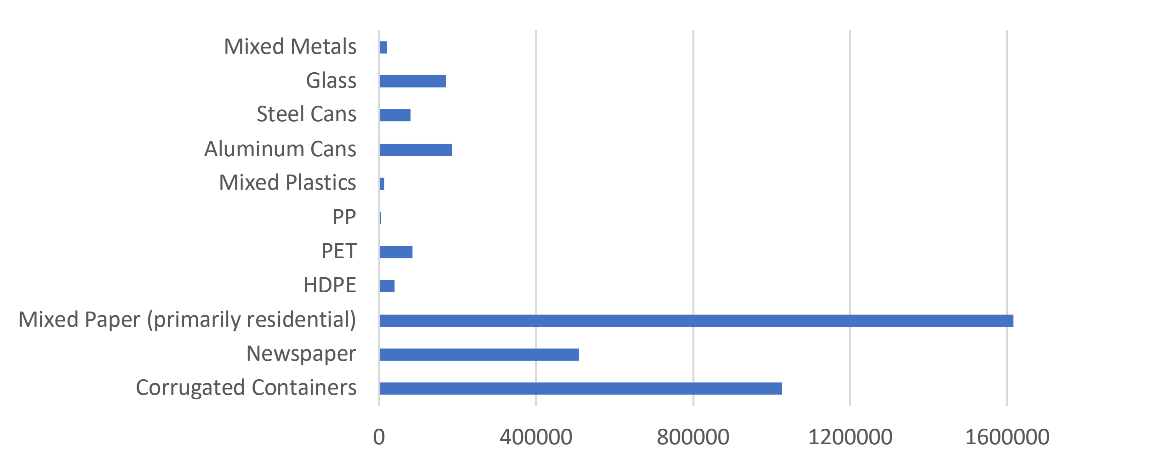


**Figure 4.2**

*Change (Alt – Base) MTCO2e*




employment wages for the state and included other variables that might explain GHG emission changes.

For individual years, the GHG emissions from both scenarios and the total change are given in Table 4.4. The rows labeled 'Recycled MTCO2e' row display the GHG emissions from recycling the tons that are currently being collected for recycling in North Carolina. The negative sign indicates the difference between manufacturing a material from 100% recycled inputs and emissions from manufacturing the same amount of the material from 100% virgin inputs. In other words, recycling materials, relative to source reduction, composting, combustion or landfilling, and using them to produce new materials results in a GHG savings as compared to creating products from virgin extracted materials.

The Landfill MTCO2e row displays the methane emissions, transportation CO2 emissions, carbon storage, and avoided utility GHG emissions from landfilling each material type. Finally, the row Change (alt-base) MTCO2e is the difference between recycling materials versus landfilling them. Because the alternative here is landfilling, the difference is a positive

**Table 4.4**

*GHG Emissions From Recycling (Baseline), Landfilling (Alternative), and Change (Alternative – Baseline) in MTCO2e (2014–2018)*

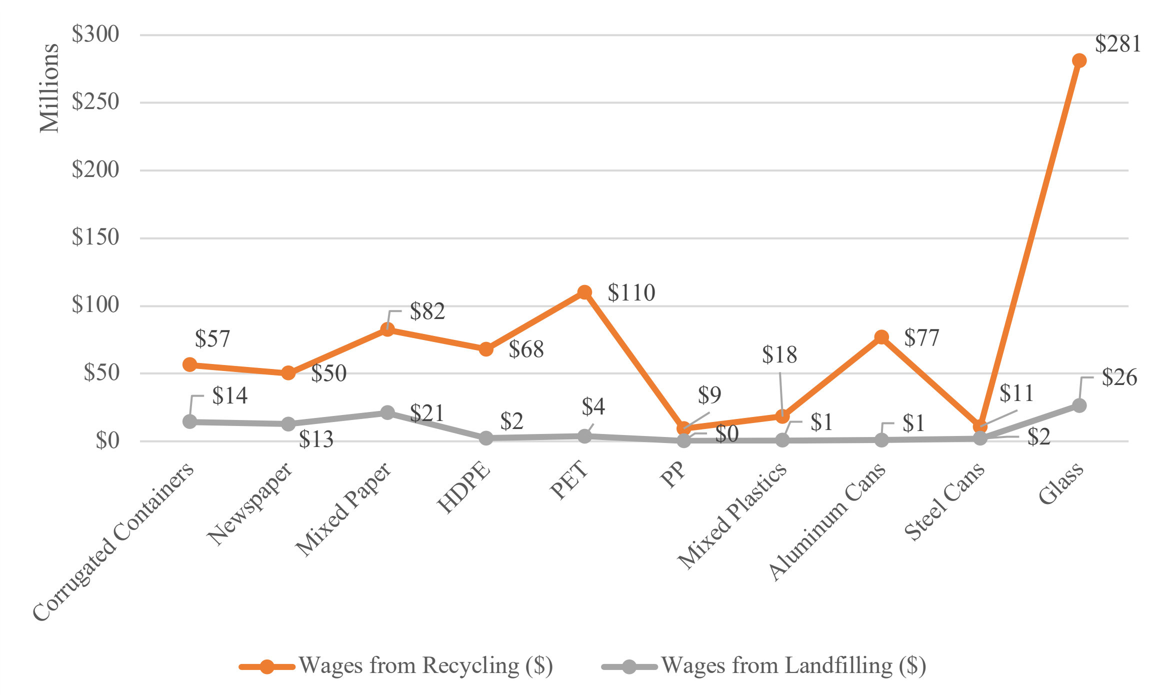
| Material | Scenario | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|
| Corrugated Containers | Recycled MTCO2e | -160,258.11 | -186,213.33 | -170,791.77 | -220,313.35 | -231,884.06 |
| | Landfill MTCO2e | 9,283.7409 | 10,787.3255 | 9,893.95543 | 12,762.7371 | 13,433.0276 |
| | Change (Alt - Base) MTCO2e | 169,541.847 | 197,000.659 | 180,685.727 | 233,076.089 | 245,317.09 |
| Newspaper | Recycled MTCO2e | -200,777.22 | -190,185.85 | -178,683.17 | -129,024.98 | -41,684.632 |
| | Landfill MTCO2e | -62,728.349 | -59,419.311 | -55,825.557 | -40,310.967 | -13,023.43 |
| | Change (Alt - Base) MTCO2e | 138,048.874 | 130,766.538 | 122,857.613 | 88,714.0136 | 28,661.2019 |
| Mixed paper (primarily residential) | Recycled MTCO2e | -223,248.79 | -254,484.74 | -284,905.48 | -387,574.3 | -458,601.42 |
| | Landfill MTCO2e | 948.372777 | 1,081.06479 | 1,210.2937 | 1,646.43636 | 1,948.16336 |
| | Change (Alt - Base) MTCO2e | 224,197.159 | 255,565.808 | 286,115.771 | 389,220.739 | 460,549.586 |
| HDPE | Recycled MTCO2e | -6,937.0145 | -8,625.2321 | -7,955.0959 | -7,187.6747 | -6,988.0074 |
| | Landfill MTCO2e | 185.253949 | 230.338037 | 212.441955 | 191.947865 | 186.615721 |
| | Change (Alt - Base) MTCO2e | 7,122.26848 | 8,855.57017 | 8,167.53784 | 7,379.6226 | 7,174.62314 |
| PET | Recycled MTCO2e | -15,369.483 | -16,706.464 | -18,397.495 | -17,157.769 | -15,608.517 |
| | Landfill MTCO2e | 300.565114 | 326.711065 | 359.780821 | 335.536769 | 305.239654 |
| | Change (Alt - Base) MTCO2e | 15,670.0482 | 17,033.1749 | 18,757.276 | 17,493.3055 | 15,913.7567 |
| PP | Recycled MTCO2e | -1,135.8968 | -1,258.9096 | -1,342.7953 | -1,137.0747 | -538.57106 |
| | Landfill MTCO2e | 28.9853106 | 32.1242952 | 34.2648536 | 29.0153683 | 13.7430173 |
| | Change (Alt - Base) MTCO2e | 1,164.88212 | 1,291.03385 | 1,377.06012 | 1,166.0901 | 552.31408 |
| Mixed plastics | Recycled MTCO2e | -2,620.1549 | -1,998.8548 | -2,473.838 | -3,127.6407 | -2,511.9307 |
| | Landfill MTCO2e | 57.3405032 | 43.7437255 | 54.138446 | 68.4465219 | 54.9720815 |
| | Change (Alt - Base) MTCO2e | 2,677.49542 | 2,042.59848 | 2,527.97644 | 3,196.08721 | 2,566.90277 |
| Aluminum cans | Recycled MTCO2e | -32,938.38 | -37,268.792 | -33,970.002 | -4,2243.341 | -39,440.095 |
| | Landfill MTCO2e | 73.0933947 | 82.7029892 | 75.3826617 | 93.7419857 | 87.5213166 |
| | Change (Alt - Base) MTCO2e | 33,011.4737 | 37,351.4948 | 34,045.3849 | 42,337.0827 | 39,527.616 |
| Steel cans | Recycled MTCO2e | -16,984.699 | -15,208.708 | -15,186.8 | -15,276.041 | -16,487.336 |
| | Landfill MTCO2e | 187.774421 | 168.139954 | 167.89775 | 168.884348 | 182.275826 |
| | Change (Alt - Base) MTCO2e | 17,172.4729 | 15,376.8484 | 15,354.6982 | 15,444.9252 | 16,669.6117 |
| Glass | Recycled MTCO2e | -54,597.854 | -25,509.286 | -25,595.188 | -26,164.492 | -26,532.075 |
| | Landfill MTCO2e | 4,005.4061 | 1,871.41143 | 1,877.71343 | 1,919.47865 | 1,946.44531 |
| | Change (Alt - Base) MTCO2e | 58,603.26 | 27,380.697 | 27,472.9017 | 28,083.9704 | 28,478.5208 |

GHG value. In reality, North Carolina is recycling these materials, and not landfilling them. So the change is actually a negative GHG value, and therefore the net GHG savings from recycling instead of landfilling.

The EPA WARM model also helped calculate the total wages created by either one of the waste management scenarios. For this study, I calculate the wages created from recycling or landfilling materials from 2014 to 2018. The results are provided in Figure 4.3. Whereas both management processes created positive wages, it is evident from the figure that wages created from recycling were far higher than those created from landfilling.

**Figure 4.3**

*Wages From Recycling Versus Landfilling, North Carolina, 2014–2018*




To test for the relationship between recycling and environmental and economic benefits, I ran two linear mixed effect models. The first model used overall GHG emissions in the state as a proxy for the environmental variable. The second set of models used overall employment, measured as number of paid positions across all sectors in North Carolina. Similar to RQ1, I ran a linear regression and variations of generalized linear mixed models (Table 4.5 – 4.9). Table 4.7 is the final model for recycling and GHG emissions, while table 4.9 presents the final model for recycling and employment. Table 4.6 is the final model.

**Table 4.5**

*Linear Regression Log of Greenhouse Gases*

| | | | | | 95% *CI* | |
|---|---|---|---|---|---|---|
| Log of GHG | Coef. | *SE* | *t* | *p* | Lower | Upper |
| Log of recycling | .314 | .183 | 1.72 | .087* | -0.046 | 0.674 |
| Log of disposal | .391 | .12 | 3.27 | .001*** | 0.155 | 0.627 |
| Age | .036 | .249 | 0.14 | .885 | -0.454 | 0.526 |
| Age2 | .000 | .003 | 0.10 | .918 | -0.006 | 0.007 |
| Log of education | -.632 | .463 | -1.37 | .174 | -1.544 | 0.28 |
| Rural | -.742 | .711 | -1.04 | .298 | -2.143 | 0.66 |
| Mixed Urban | -.101 | .428 | -0.24 | .813 | -0.944 | 0.742 |
| Mixed Rural | -1.168 | .572 | -2.04 | .042** | -2.295 | -0.041 |
| % regd. Democrats | -.001 | .008 | -0.10 | .923 | -0.016 | 0.014 |
| Constant | 16.649 | 6.498 | 2.56 | .011** | 3.846 | 29.452 |

*Note*. *M* of DV = 12.737; *SD* of DV = 1.491; $R^2$ = 0.107; number of observations = 243; *F* = 2.793; prob > *F* = .003; Akaike information criterion = 877.225; Bayesian information criterion = 915.648.

**p* < .10. ***p* < .05. ****p* < .01.

**Table 4.6**
*Mixed-Effects Regression Year Intercept*

| | | | | | 95% *CI* | |
|---|---|---|---|---|---|---|
| Log of GHG | Coef. | *SE* | *t* | *p* | Lower | Upper |
| Log of recycling | .314 | .179 | 1.76 | .079* | -0.036 | 0.664 |
| Log of disposal | .391 | .117 | 3.35 | .001*** | 0.162 | 0.62 |
| Age | .036 | .243 | 0.15 | .882 | -0.44 | 0.512 |
| Age2 | .000 | .003 | 0.11 | .916 | -0.006 | 0.006 |
| Log of education | -.632 | .452 | -1.40 | .162 | -1.518 | 0.254 |
| Rural | -.742 | .695 | -1.07 | .286 | -2.104 | 0.621 |
| Mixed Urban | -.101 | .418 | -0.24 | .808 | -0.921 | 0.718 |
| Mixed Rural | -1.168 | .559 | -2.09 | .037** | -2.263 | -0.072 |
| % regd. Democrats | -.001 | .007 | -0.10 | .921 | -0.015 | 0.014 |
| Constant | 16.649 | 6.35 | 2.62 | .009*** | 4.204 | 29.094 |

*Note*. *M* of DV = 12.737; *SD* of DV = 1.491; number of observations = 243; $\chi^2$ = 29.251; prob > $\chi^2$ = .001; Akaike information criterion = 881.225.

**p* < .10. ***p* < .05. ****p* < .01.

**Table 4.7**

*Mixed-Effects Regression County Intercept Year Slope*

| Log of GHG | Coef. | *SE* | *t* | *p* | 95% *CI* Lower | 95% *CI* Upper |
|---|---|---|---|---|---|---|
| Log of recycling | .202 | .067 | 2.99 | .003*** | 0.070 | 0.334 |
| Log of disposal | -.011 | .037 | -0.29 | .770 | -0.083 | 0.061 |
| Age | .352 | .208 | 1.69 | .091* | -0.056 | 0.760 |
| Age2 | -.004 | .002 | -1.67 | .094* | -0.009 | 0.001 |
| Log of education | -.654 | .271 | -2.41 | .016** | -1.186 | -0.123 |
| Rural | -.326 | 1.293 | -0.25 | .801 | -2.860 | 2.208 |
| Mixed Urban | .186 | .88 | 0.21 | .833 | -1.539 | 1.911 |
| Mixed Rural | -.369 | .997 | -0.37 | .711 | -2.323 | 1.585 |
| % regd. Democrats | .003 | .01 | 0.29 | .768 | -0.017 | 0.023 |
| Constant | 6.696 | 7.367 | 0.91 | .363 | -7.742 | 21.134 |

*Note*. *M* of DV = 12.737; *SD* of DV = 1.491; number of observations = 243; $\chi^2$ = 20.499; prob > $\chi^2$ = .025; Akaike information criterion = 194.093.

*$p$ < .10. **$p$ < .05. ***$p$ < .01.

**Table 4.8**

*Linear Regression Log of Employment*

| Log of employment | Coef. | *SE* | *t* | *p* | 95% *CI* Lower | 95% *CI* Upper |
|---|---|---|---|---|---|---|
| Log of recycling | -.027 | .134 | -0.20 | .838 | -0.291 | 0.237 |
| Age | .165 | .199 | 0.83 | .406 | -0.225 | 0.555 |
| Age2 | -.002 | .002 | -0.64 | .524 | -0.006 | 0.003 |
| Log of education | .749 | .334 | 2.24 | .025** | 0.093 | 1.405 |
| Rural | -.239 | .632 | -0.38 | .705 | -1.481 | 1.002 |
| Mixed Urban | -.082 | .475 | -0.17 | .863 | -1.015 | 0.851 |
| Mixed Rural | -.053 | .504 | -0.11 | .916 | -1.043 | 0.936 |
| Constant | -8.401 | 4.728 | -1.78 | .076* | -17.690 | 0.888 |

*Note*. *M* of DV = 10.893; *SD* of DV = 2.293; $R^2$ = 0.392; number of observations = 500; $F$ = 39.608; prob > $F$ = .000; Akaike information criterion = 2,016.704; Bayesian information criterion = 2,054.636.

*$p$ < .10. **$p$ < .05. ***$p$ < .01.

For employment and recycling, I used overall jobs in the state as a proxy for the economic variable. The results of the final model are provided in Table 4.9.

**Table 4.9**

*Mixed Effects Regression Year Intercept*

| Log of employment | Coef. | *SE* | *t* | *p* | 95% *CI* Lower | 95% *CI* Upper |
|---|---|---|---|---|---|---|
| Log of recycling | .139 | .026 | 5.37 | .000*** | 0.089 | 0.190 |
| Age | .245 | .038 | 6.39 | .000*** | 0.170 | 0.320 |
| Age2 | -.003 | .000 | -6.16 | .000*** | -0.004 | -0.002 |
| Log of education | .115 | .065 | 1.78 | .075* | -0.012 | 0.242 |
| Rural | -.541 | .122 | -4.45 | .000*** | -0.780 | -0.303 |
| Mixed Urban | -.314 | .091 | -3.43 | .001*** | -0.493 | -0.135 |
| Mixed Rural | -.350 | .097 | -3.61 | .000*** | -0.540 | -0.160 |
| Constant | -6.308 | 1.206 | -5.23 | .000*** | -8.672 | -3.943 |

*Note*. *M* of DV = 10.893; *SD* of DV = 2.293; number of observations = 500; $\chi^2$ = 8,223.940; prob > $\chi^2$ = .000; Akaike information criterion = 422.256.

*$p < .10$. **$p < .05$. ***$p < .01$.

Table 4.7 shows a significant relationship between recycling rates ($b = .202$, $p < .01$) and GHG emissions. The relationship is positive. Disposal rates ($b = .391$, $p < .01$) and GHG emissions show no statistically significant relationship with one another. Age ($b = .352$, $p < .1$) exhibits a positive and direct relationship with the dependent variable, while education ($b = -.654$, $p < .05$) shows a negative relationship with GHG emissions. All other variables in the model were insignificant.

In Table 4.9, all variables have a statistically significant relationship with employment. As expected, recycling rate has a statistically significant and positive relationship with employment ($b = .139$, $p < .01$). Age ($b = .245$, $p < .01$), education ($b = .115$, $p < .1$), and population ($b = 1.029$, $p < .01$) also show statistically significant and positive relationships with employment rate, on average. Rural ($b = -.541$, $p <.01$), mixed urban ($b = -.314$, $p < .01$), and mixed rural ($b = -.35$, $p < .01$) counties, on average, are likely to have lower employment rates than urban counties.

The results from the WARM model indicated that, at its recycling rate for 2014 to 2018, North Carolina achieved positive GHG savings. For 2014 to 2018, the total GHG savings from recycling materials found in the commingled stream was 3,728,759 MTCO2e. This was an expected outcome of recycling; however, these numbers represent materials collected for recycling and not materials that make it through the recycling process. Contamination has been a big challenge for North Carolina, resulting in less than 100% of recycling. According to county and MRF sources, contamination has increased from an average of about 12–13% to 17–20% in the last 2–3 years. This number is large, and depending on the composition of the contaminated materials, has the potential to significantly reduce GHG savings. In contrast, these numbers represent only part of the total recyclables collected, meaning that the total GHG savings might be higher. Thus, it is possible that the missing GHG savings could cancel out the loss of savings from contaminated materials. If the same materials were landfilled, then the added GHG emissions would amount to 152,258 MTCO2e. This is a small amount compared to the GHG savings from recycling but landfilling also requires land space and involves wastage of precious materials that could be circulated back into the economy.

From 2014 to 2018, North Carolina produced about $763 million in incomes from recycling its commingled materials. In comparison, landfilling the same amount would have resulted in $84 million in incomes from landfilling its commingled materials. This difference is significant and supports the concept of green economic development, which advocates for environmental protection and economic development going hand in hand. Green economic development supporters argue that there is no trade-off between the two and that, in fact, green industries could be more labor-intensive, thereby offsetting job losses from traditional sectors to achieve net employment gains (Fankhauser et al., 2008; Feiock & Coutts, 2013; Fitzgerald, 2010; Cortney, 2009). Therefore, if North Carolina recycles all its collected materials, the state will have a massive opportunity for economic gains in this sector.

In testing the hypothesis that recycling creates environmental and economic benefits, I found that, on average, a unit increase in recycling rate increased GHG emissions by about 37%. This effect was statistically significant but contrary to my hypothesis. As a robustness check, I ran a log log OLS regression between my dependent variable and my key explanatory variable—recycling rate. I found that adding disposal rates to check for spurious relationships in the equation changed the direction of the relationship between recycling and GHG from positive to negative. These results were very similar to Makridis and Dawson's (2018) and Makridis's (2020) respective studies of California, where they found a positive effect of recycling rates on broad environmental indicators - energy consumption and specific pollution emissions. Omitted variable bias could be one possible explanation for this. Another possibility for these findings is that the measurement for GHG emissions does not directly correspond to recycling activities or the recycling sector. On the other hand, it is possible that recycling activities, in their current form, are actually increasing GHG emissions because either not enough material is being recycled, or the right materials (low GHG emissions when recycled) are not making it to the MRF for recycling, to offset the GHG emissions from producing virgin materials.

In terms of recycling rates and economic benefits, I found that recycling rates positively influence employment across the state. This aligns with my hypothesis regarding green development. It appears that recycling is in fact positively benefitting the economy by creating new employment opportunities, and these effects are widespread across all sectors.

## Uncovering Challenges and Missed Opportunities in the Recycling Process

In Chapter 3 I detailed the methodology used to recruit participants for the interview. The results and findings from the interviews have important implications for solid waste management and recycling policy. These findings could assist policy makers and leaders, as well as all other stakeholders in the recycling industry, to design more effective recycling policies. Participants were introduced to the study, and the findings of the quantitative analysis were revealed only when asked. Most of the participants expressed interest and asked for the study to be shared with them upon completion. The results and the findings from the interviews are discussed below. For the sake of comprehension, all responses are synthesized together under a common theme.

### County and State Officials

#### *Overview of Recycling Programs*

All officials reported that they had been operating recycling programs for a very long time. Recycling programs began as dual-stream or mixed-stream collection, which required residents to sort their recyclables at the source. Upon recognizing the need to increase recycling collection, program administrators increased the convenience for households by shifting to single-stream collection from households. When talking about curbside and drop-off, one official reported no provision of curbside recycling in unincorporated areas. Another official reported that some municipalities within the county were managing their own programs. One county indicated that, in light of China withdrawing from collecting plastics, the MRF associated with the county had to stop operations. This resulted in the county having nowhere in the immediate geography to send its plastics, some metals, and paper products. Because of the sudden service gap, they were able to acquire permits to incinerate these materials.

#### *Target Achievements*

The state official reported that the state's recycling targets were outdated and needed to be updated, which made it difficult to determine if the state was achieving its recycling targets. Regardless of a target, in the past 3 years, the state's recycling rate has plateaued. The state has continued to undertake actions to improve its collections, with the expectation that more convenient recycling will lead to not just increased recycling collections but also increased diversion of materials to the landfill. Efforts to further improve recycling collections are underway given the new EPA recycling target of 50%. An official from one county indicated that they were achieving their recycling targets in accordance with state mandates. Another county official said they were not achieving their targets due to low participation rates. This latter official suspected that low participation rates were due to people not willing to separate their recyclables from their trash and because there is no way of knowing how many recyclables go into the trash instead of the recycling bin.

***How Much of Collected Material Is Recycled***

An official from the county that did not have access to a local MRF stated that the plastics, some paper, and some metals do not make it to the MRF and are instead incinerated. They do however continue to run recycling programs for tires and glass. An official from another county said that their contamination rates have been relatively low compared to the rest of the state, claiming a contamination rate of about 8%. At the state level, contamination rates on average have increased from 12–15% in 2018 to 17% in the following years. Most of the contamination is attributable to people not disposing their recyclables correctly. Some of it was due to increased amounts of trash during the pandemic, resulting in people running out of space in their trash cans and dumping surplus trash in the recycling bin.

***Challenges in the Recycling Process***

Several challenges were highlighted during the interviews.

**Budgets.** Local and state governments often do not have the budgets to ensure that residents are recycling correctly. Although switching to single stream has increased recycling collections, sorting the materials after collection is often challenging and labor intensive. As one official explained,

> We're in a situation right now where, really, if you break it down, the cost of recycling is often more than the cost to landfill. So, if you're a local government with a strapped budget, you're making tough decisions, sometimes you may decide that it is not worthwhile to continue or to initiate a recycling program.

The pandemic, combined with China's National Sword policy, has exacerbated the situation, compelling many local governments to altogether do away with their program.

**Recycling participation.** From speaking with the officials, I inferred that residents in urban parts of the county are more enthusiastic to recycle than are residents of rural areas. Getting rural residents to recycle remains a challenge. Some officials voiced that, although participation remains high, "wishful recyclers" cause some obstacles in ensuring that collected materials are ultimately recycled.

**Recycling education.** Officials were unanimous about the effectiveness of recycling education. Although recycling education programs exist, consideration needs to be given to the content of the messaging. Additionally, one official said, the demographics and population density need to be considered when creating educational content. Some officials advocated for messaging that encourages consumption of certain products and, consequently, their recycling. The rationale for this was that some products, such as aluminum cans, when recycled, save 95% of their energy, as compared to making them from raw materials. This is both an environmental and economic advantage. Messaging needs to also focus on the environmental and economic gains from recycling. Two officials argued for the standardization of educational materials, making it easier for people to recycle as they move from one place to another.

**Recycling markets.** Some officials highlighted challenges rooted in the diminishing markets for recycling due to China's policy and the US still lacking in infrastructure. However, they were positive that the US is responding to these changes by building more recycling infrastructure to be able to continue to carry out recycling activities.

**Single-stream recycling.** Although officials understood the need to move to single-stream recycling, they reported finding it challenging to keep contamination rates low. They agreed that, although curbside recycling made it more convenient for residents to recycle, in some instances, it incentivized residents to dispose items that are not recyclable or were deemed unfit for recycling at an MRF.

### ***Why Counties Have Recycling Programs***

One official stated that they continued to operate recycling programs due to the environmental benefit associated with it. The county does not economically profit from it, so that is not a motivation. On the contrary, another county official said that they operate recycling programs because they do not have a landfill, so not having to pay other counties to use their landfill is economically beneficial. Recycling minimizes items going to the landfill. All officials reported that a partial motivating factor for continuing to operate recycling programs is that residents demand it.

## **MRF Managers**

### ***Achieving Targets and Challenges***

When asked about achieving recycling targets, representatives from both MRFs said that they were achieving their targets, even though they were operating single-stream recycling. However, one MRF representative reported a contamination rate of about 20%. Both agreed that contamination in single-stream recycling is challenging. Both said that MRFs are labor intensive, and the reduced ability to attract labor to work at MRFs was contributing to higher contamination rates. Both managers believed that building and strengthening the recycling infrastructure would help improve the state of recycling.

***What Local Governments Can Do to Keep Recycling Rates High***

Both managers supported local government efforts to educate residents. However, they emphasized the need for the right messaging, one that incorporates local contextual factors in the message design. Both managers highlighted the need to understand the different “types” of recyclers—wishful recyclers, uninterested recyclers, and those who recycle because they think they must. This understanding would help in message design. One manager advocated for shifting some of the costs associated with recycling from MRF and local government, onto to the residents. In times when markets are crashing, especially in the context of China’s policy, it is helpful to have residents bare more of the recycling cost. One manager suggested going back to the system of tagging recycling bins and carts. If the person on the collection truck sees that the resident has placed incorrect items in the bin, they should have the discretion to not collect those items. Instead, they would tag the bin/cart to inform the resident of the incorrectly places items.

Both county officials and MRF managers were on the same page regarding issues with recycling education messaging and the need for better recycling infrastructure. However, they face different day-to-day challenges. County officials emphasized the need for larger budgets to be able to not only continue to provide recycling services but also to be able to improve current recycling practices. Local government budget constraints are reflected in the ability to hire recycling managers and coordinators, operate curbside recycling programs, provide recycling education programs, and access MRFs, even if they are farther. In general, the econometric models in RQ 1 revealed that these are important indicators of recycling outcomes. Interviews with county officials are consistent with Hypotheses 1, 2, 3 and 8.

The final model in RQ 1 showed no significant relationship between recycling education and recycling rates. This finding could be explained by both counties and MRF managers, who pointed out that, although education programs exist, it is the messaging that needs attention. From this one can infer that educational programs, although being implemented, are not effective because their content does not reach or resonate with every type of recycler. Most interviewees also agreed that contextual factors, such as demographics and population density, should be taken into consideration, especially when designing educational programs. This is important in interpreting the findings from the models in RQ 1. Residents' educational attainment, political affiliation, and residential area (urban vs. rural) showed significant relationships across all models in RQ 1. Therefore, taking into consideration these effects is pertinent to designing effective recycling educational programs.

As highlighted in the interview responses, China's stance on receiving certain types of waste from other countries has affected recycling operations in North Carolina. Moving forward, it would be vital to build and improve the recycling infrastructure to adjust to the evolving situation.

The findings from the quantitative and qualitative analyses are crucial to better understanding recycling programs across North Carolina. These findings have important theoretical and policy implications for practitioners and scholars engaged in recycling activities. The next chapter discusses these implications while also describing the study's limitations and what future scholars and practitioners can do to overcome them.

# CHAPTER 5: LIMITATIONS AND IMPLICATIONS

The scope of this study was to assess recycling programs in the state of North Carolina. Owing to the complexity associated with recycling, I selected three approaches to evaluate recycling programs at the county level in North Carolina. The first part explored local-level variables that influence recycling outcomes. The variables selected included programmatic factors and demographic and spatial variables. The results demonstrate that curbside recycling had a direct relationship with recycling rates. Rural, mixed urban, and mixed rural counties showed a lower likelihood than did urban counties to influence recycling. The percentage of registered Democrats and age showed an inverse relationship with recycling. This provides support for theories advocating for recycling being a consensual and non-divisive issue, far removed from partisan differences (Carney et al., 2009; Dunlap et al., 2001). These findings are consistent with studies that have undertaken similar analyses.

In the second part of the quantitative analysis, I showed the direct GHG emissions (in MTCO2e) and wages (in dollars) produced because of recycling in North Carolina from 2014 to 2018. The total GHG emission savings from avoiding using virgin materials for corrugated containers, newspapers, mixed paper, glass, PET, HDPE, PP, mixed plastics, aluminum cans, and steel cans for those years was 296,233,843 MTCO2e. Additionally, recycling these materials instead of landfilling them, led to a GHG emission savings of 3,728,759 MTCO2e. To put it in more relevant terms, the reduction in these emissions is the equivalent of taking approximately 810,600 cars off the road in a year.[10]

[10] Based on the U.S. EPA estimate that the typical automobile has tailpipe emissions of 4.6 metric tons of carbon (Environmental Protection Agency, 2018)

The total wages created from recycling the same materials was $763,421,413. I then conducted an econometric analysis to test for a statistical relationship between recycling rates and these two parameters. For recycling rates and GHG emissions, I found that an increase in recycling increased GHG emissions, whereas all other variables except education and age showed no statistically significant relationship with GHG emissions. These effects could be the result of omitted variable bias. For employment and recycling rate, I found a statistically significant relationship between recycling rates and employment, suggesting that recycling has had positive effects on employment creation across the state of North Carolina from 2014 to 2018. This analysis was the first of its kind for the state of North Carolina. Even with its limitations, the study provides a clear path to future scholars and practitioners looking to answer questions related to recycling and its impact on the environment and the economy.

As a final approach, I interviewed county officials and MRF managers in charge of recycling across North Carolina. My selection included counties that ranked high and low on mainly two metrics—recycling rates and education. I found that, overall, budgets, recycling education messaging, and recycling infrastructure were key challenges in North Carolina's recycling industry. Although overcoming budget challenges remains an open question, some solutions and guidance for recycling education messaging and recycling infrastructure are offered under policy implications. The interview findings were helpful in understanding and validating the results from the quantitative analysis.

While these findings are important for policy makers and future scholars, like most research in the social sciences, the present study is not without its limitations. To ensure best practices, all limitations must be given equal consideration as the results when designing future research and management of recycling programs. In this chapter, I identify the limitations of my research and possibilities on how they can be addressed in the future. I conclude the chapter with theoretical and policy implications based on my findings. Recommendations on possible ways to overcoming data limitations and ways to make recycling more effective are provided in each section.

## Study Limitations

North Carolina captures its recycling rate as simply the traditional items collected for processing at the MRF. Recycling rates can be better understood as a proportion of the total MSW collected from waste management programs. Some states and local governments measure the recycling rate as a proportion, reflecting materials recovered from total waste. This measurement provides a better judgement of how much recycling is taking place within the context of how much waste is being produced. Even though the alternative way to measure recycling is preferred, the specification used in this study allowed the results to speak to the factors that influence recycling and whether recycling has any environmental and economic impacts, regardless of total waste disposal. Future studies could also use recycling rates at the municipality level. This would increase the population/sample size and could provide insights at lower levels of government. Related variables at the municipal level, such as recycling coordinators, curbside recycling provisions, recycling education, and so forth, could be sought for future analysis.

MRF distance measurement was calculated as the nearest Euclidean distance between a county centroid and the closest MRF. Perhaps using a measurement of the actual travel distance by road networks would provide more accuracy. This could also enable an understanding of the costs of and GHG emissions associated with transporting recyclables.

The GHG emission data used for this study factored in all point sources across the state to include any upstream and downstream benefits possibly induced by the recycling industry. While this provides a good approximation for conducting this type of analysis and is a first step in exploring any causal mechanisms, accuracy could be achieved by identifying industries that are, in fact, impacted by recycling. Similarly, when assessing recycling impacts on jobs, using more accurate variables in place of overall employment in the state could result in better findings.

Disposal rates used in the analysis measured total waste disposal for each county, regardless of its source, which does not proportionately correspond to the recycling rate, which was calculated as recycling of only traditional household materials. Consequently, the disposal rate used was significantly larger, but I used it because it was the only data available and provided a satisfactory proxy for consumption patterns. Having a more accurate measure of disposal rate would allow for a more sophisticated analysis and provide a true understanding of recycling performance, in comparison to disposal.

Finally, because all North Carolina counties were analyzed, this study offers high internal validity. However, generalizing the results of the study might be limited because states differ in their recycling policies and approaches to measuring recycling.

## Theoretical Implications

From a theoretical perspective, this study has several implications. First, in agreement with previous literature, I found that curbside recycling, a service providing increased convenience, influences recycling outcomes positively. I also found that the more urban an area is, the higher its recycling collection. Distance from MRF also influenced recycling outcomes: The farther a county was from an MRF, it was, on average, more likely to have lower recycling rates. Previous studies have not included this variable in their analysis. Therefore, this finding is important for future scholars and researchers interested in investigating recycling. Given the growing national trend to push for improving recycling infrastructure, MRFs and their locations would be vital in supporting the endeavor.

Although this study did not find recycling education to be statistically significant in its final model, as I had posited based on previous literature and as articulated by interviewees, it is an important component of recycling, and one that should not be overlooked. However, the results from this study highlight the extent to which educational programs influence recycling outcomes. From a theoretical standpoint, more emphasis should be given to the contents of the education program rather than the presence of a program itself. Message framing (Cheng et al., 201; Davis, 1995; White et al., 2011) could be used to replace recycling educational programs in future analyses.

Educational attainment, another important variable when studying recycling outcomes, was statistically insignificant in my final model. Previous findings have been mixed on the effects of educational attainment on recycling. This study provides evidence in support of education not being very important in determining recycling success. Perhaps future scholars should be more cautious in using education in their analysis. It is possible that recycling has found its way into mainstream residential behavior, regardless of one's educational attainment. This new understanding should be taken into consideration in future analyses.

Political affiliation was found to be statistically significant in my model, but the direction of the relationship was negative. This is consistent with findings from other studies that have shown that recycling has moved away from being a partisan issue. However, despite this trend, I argue that it is possible that disparities remain in access to recycling, seated in individuals' race and, consequently, their political preferences. A deep body of literature has linked race to political preferences and environmental concern, postulating that minority populations tend to lean Democratic and/or tend to have higher environmental concern than those in the majority (Kanagy et al., 1994; Jones & Dunlap, 1992; Mohai & Bryant 1998; Van Liere & Dunlap 1980; Whittaker et al., 2005). This raises questions regarding minority access to recycling activities: Do minorities, although more inclined to recycling, lack access to recycling? Future work should explore this relationship, either by incorporating race variables or by using other proxies for accessibility, such as where minorities are located. The question of accessibility also extends to urban–rural dynamics of counties and recycling accessibility in these areas.

## Policy Implications

The empirical findings from this study highlight a few noteworthy implications for policy and practice. These findings are relevant for public administrators, policy makers, private stakeholders, and future scholars looking to increase the effectiveness of recycling programs. As mentioned earlier in this study, the exit of countries such as China from collecting the developed world's waste has compelled the latter to find innovative strategies to either continue or sustain existing collection efforts. Recycling now faces additional challenges with the arrival of a global pandemic brought about by COVID-19. As informed by one of the interviewees and the plethora of news articles revolving around this subject, the pandemic has resulted in increased consumption of packaging materials consisting primarily of plastic and paper. The growing stream of plastics and paper has increased pressure on current recycling systems, further highlighting the urgency in rethinking the recycling process. A few measures could be taken to achieve improvements in the recycling process. These are discussed ahead.

First, inconsistencies in data collection, combined with possibly less reliable reports from local governments, affects data quality and, consequently, both the accuracy and interpretations of the results. Because the recycling process is so complex, more sophisticated data could provide scholars, policy makers, and program administrators with new ways to measure recycling program success, using several indicators beyond simply recycling collection, which is the current practice. Recycling performance indicators could include programmatic variables, such as the provision of curbside recycling, the effectiveness of and access to recycling educational programs, officials dedicated to solid waste management, GHG emissions, diversion rate, and disposal rate. Additionally, analyses should consider not only how much is collected for recycling but also what is being collected. Finally, recycling performance measures should account for how much of collected recyclables is actually recycled. Reporting the actual number of materials recycled allows for a better understanding of the effectiveness of recycling programs as a whole. Contamination rates at the MRF would reflect the effectiveness of education strategies. Lower contamination rates imply highly effective recycling educational programs. Furthermore, accounting for materials recycled allows for more accurate life-cycle analysis and GHG accounting in the recycling process.

Second, although recycling education programs should consider the demographic context within which the program is being executed, they should also focus the contents of the messaging to encourage residents to put more specific materials into the stream. For example, if aluminum and plastics have higher economic and environmental value, residents could be encouraged to utilize and recycle more of these materials, rather than paper and glass, which are less valuable and require more energy to be recycled. Experimental and qualitative assessments at the community level could help decision makers understand what incentives people respond to so that they can select message narratives accordingly.

Third, in response to China’s National Sword policy, a push to improve and expand existing recycling infrastructure is pertinent. Vertically integrated recycling businesses, where the manufacturers established MRFs as a way to feed the materials back into the manufacturing process, have great potential in overcoming some of the current challenges. Relatedly, countries in Europe and some parts of Asia, have implemented Extended Producer Responsibility programs, where producers are partially responsible for collecting used goods and having them recycled. Such policies pressure producers of consumer goods to take responsibility for the products they output into the economy. The United States does not have any such mechanisms in place, leaving all responsibility on state and local governments. With the EPA pushing for a 50% recycling target by 2030, programs such as Extended Producer Responsibility would help in the attainment of these targets.

Fourth, some of the interviewees suggested introducing a container deposit legislation or bottle bill in North Carolina that would include not only glass but also aluminum and steel bottles. Policies such as the bottle bill and other economic incentives have shown to increase recycling rates (Everling, 2018; Kaden & Preston, 2010; Cheng & Yeh, 2013). Unfortunately, few states have incorporated these mechanisms that have been proven to not only positively influence recycling outcomes but also boost government revenue.

Fifth, another view shared during the interview process was that some of the recycling costs need to be shifted to consumers. This study presents some evidence that consumers recycle, regardless of any perceived altruistic or economic benefit attached to it. If this is true, residents might be willing to pay to recycle. Although this is practiced in some communities across the world, more communities should implement small fees. This would not only be a source of revenue for the governments but might also incentivize residents to reduce their overall consumption.

Finally, all data sources and articles made very little mention (if any) of strategies to reduce and reuse, which fall higher than recycling in the hierarchy of the 3 Rs. Local governments and stakeholders could invest more resources in encouraging people to reduce their overall consumption. A deeper investigation into this might reveal that it is cheaper and more effective to design programs to incentivize residents to reduce consumption than programs that invest time and resources in encouraging recycling and the recycling process itself.

In conclusion, I found that recycling is moving away from being a behavior based in individual taste and preferences to a mainstream behavior—part of everyday life. Recycling must be viewed not only as an individual altruistic action but also as a means to decrease the cost of goods, lower landfill costs, combat climate change, and reduce resource and energy use while engaging the community as a whole. Most important is the need for standardized measures for recycling, new ways to measure recycling performance, and greater consistency in solid waste management policies so that scholars and program analysts can conduct more comparative studies. In addition to these efforts, some cities have undertaken waste characterization studies to determine residents' consumption patterns to better inform local policy. More communities should invest resources in these studies if the nation is to increase efficiency in recycling practices. With the EPA recently announcing its objectives to achieve 50% recycling by 2030, the next 9 years will be crucial as well as exciting for the recycling industry as a whole.

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APPENDIX A: DEFINITIONS

| | |
|---|---|
| **Rural county:** | (1) The county's population density is less than 500 people per square mile, and (2) 90 percent of the county population is in rural areas or the county has no urban area with a population of 10,000 or more. The density requirement is the same used to distinguish urban and rural census blocks, and the urban area threshold mimics the urban cluster requirement that defines micropolitan core areas. The 90 percent requirement screens out low-density counties with substantial urban populations, but it has no official precedent or standing. |
| **Urban county:** | (1) The county's population density is at least 500 people per square mile, (2) 90 percent of the county population lives in urban areas, and (3) the county's population in urbanized areas is at least 50,000 or 90 percent of the county population. The density and the 90 percent requirement serve as above, and 50,000 is the urbanized area threshold for the nucleus of a metropolitan county. The second part of the third criterion is only necessary because independent Virginia cities are treated as counties statistically; it designates as urban counties some independent cities that have fewer than 50,000 residents but are entirely or almost entirely within larger urbanized areas that spill over their borders. |
| **Mixed rural county:** | (1) The county meets neither the urban nor the rural county criteria, and (2) its population density is less than 320 people per square mile. That density is two acres per person; it has no official standing but seems reasonable. |
| **Mixed urban county:** | (1) The county meets neither the urban nor the rural county criteria, and (2) its population density is at least 320 people per square mile. Thus, mixed urban counties are almost two-thirds of the way from no population to the urban density threshold of 500 people per square mile. |

APPENDIX B: GLADDER RESULTS FOR THE INDEPENDENT VARIABLES

**Figure B1**

*Histograms by Transformation, Density by Median Age*

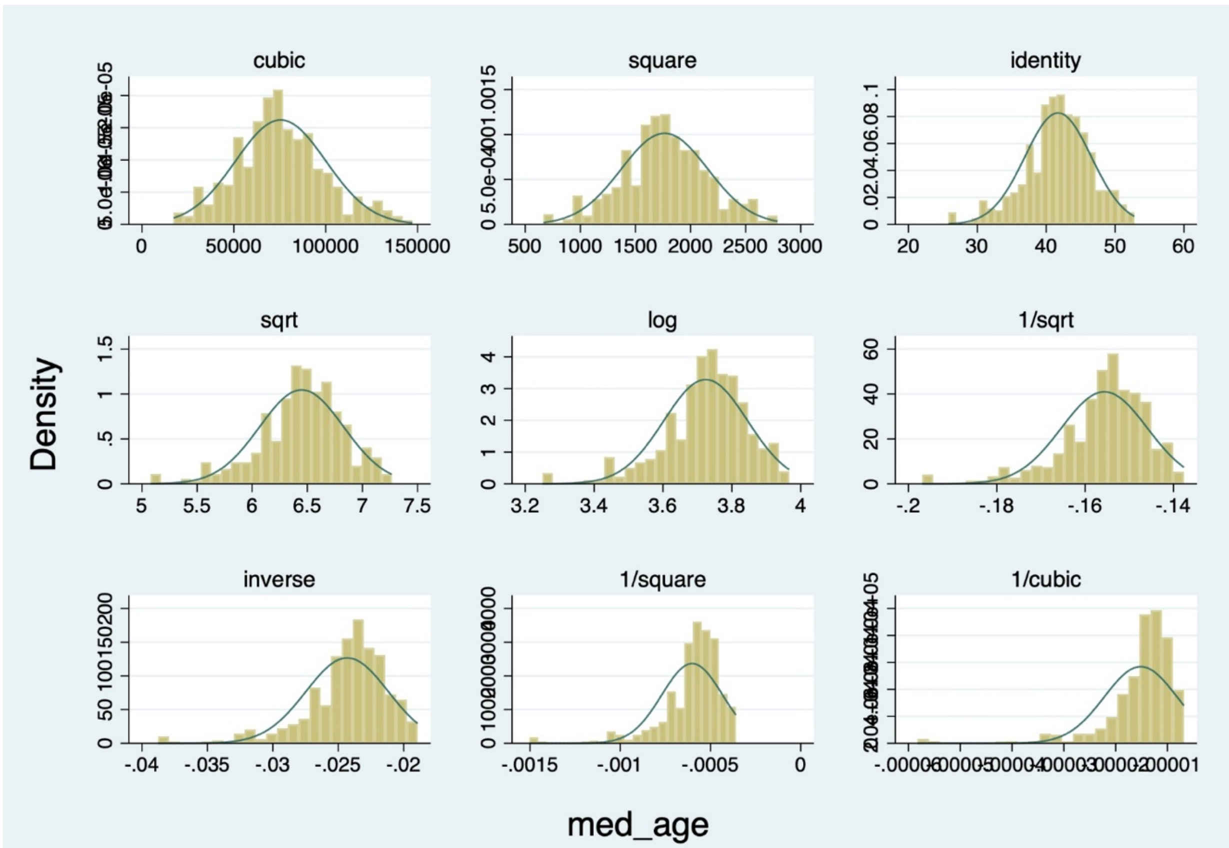


**Figure B2**

*Histograms by Transformation, Distance From Nearest MRF*

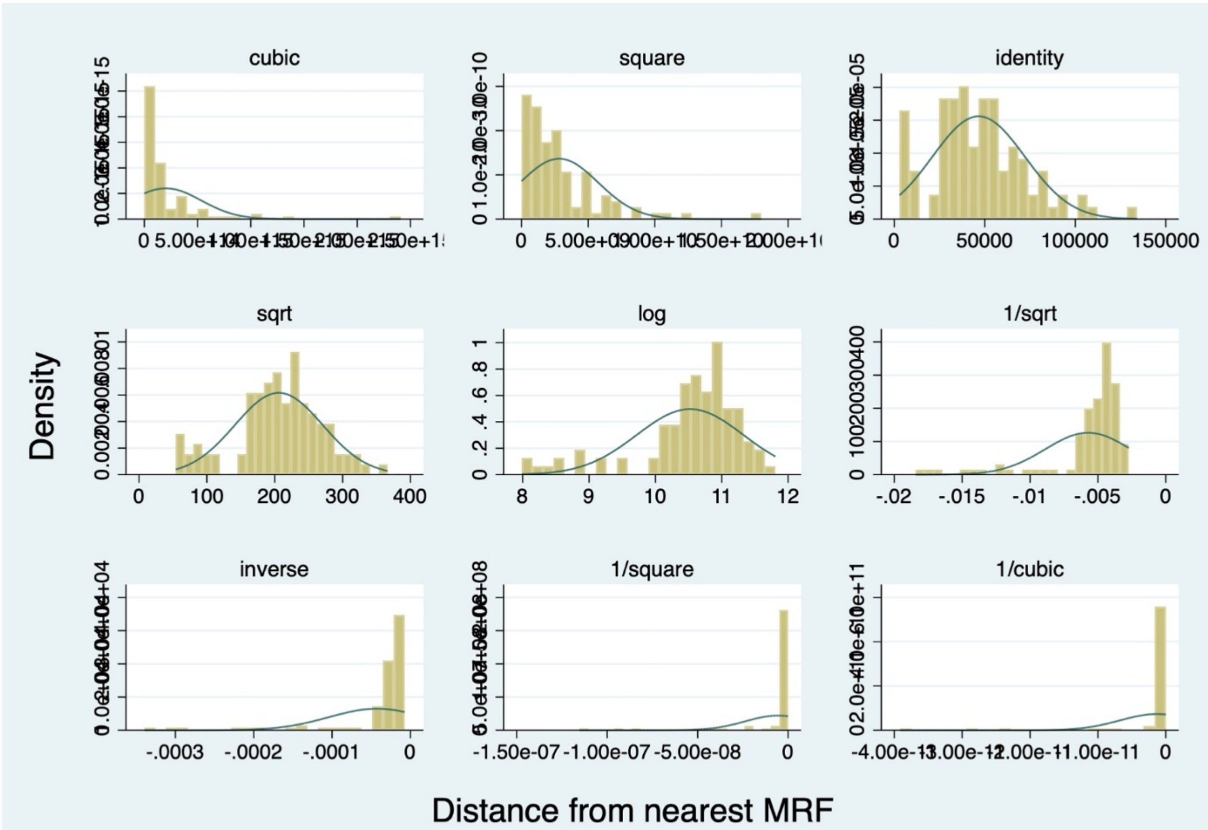


**Figure B3**

*Histograms by Transformation, Density by Percentage of Residents With at Least a 4-Year Degree*

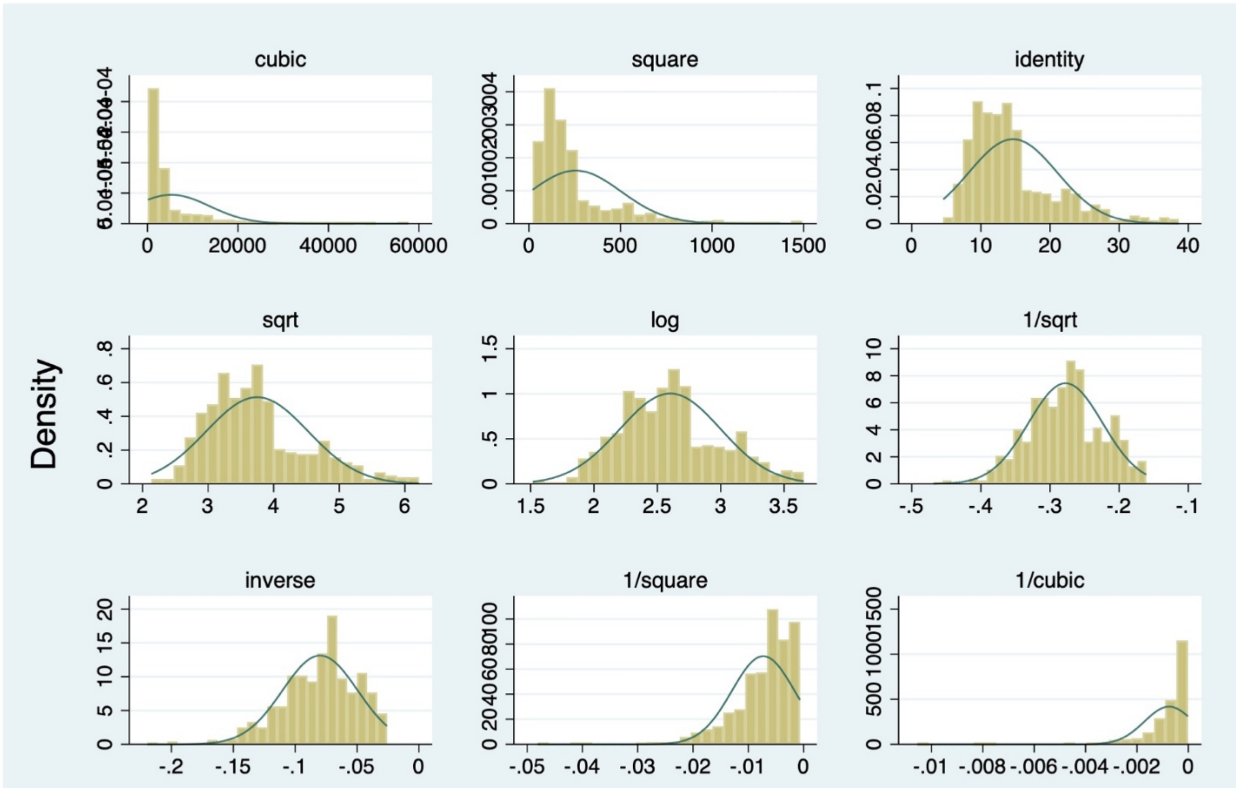


**Figure B4**

*Histograms by Transformation, Density by Percentage of Voters Registered as Democrats*

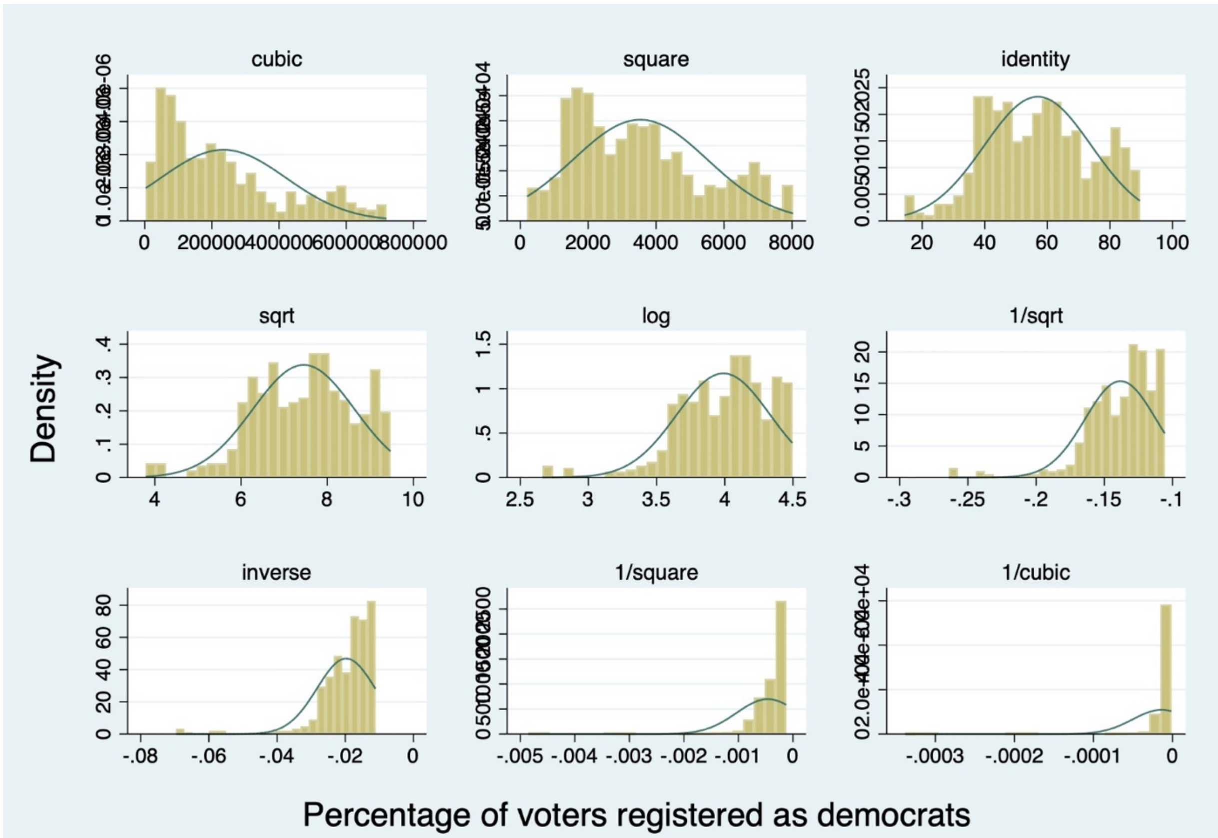
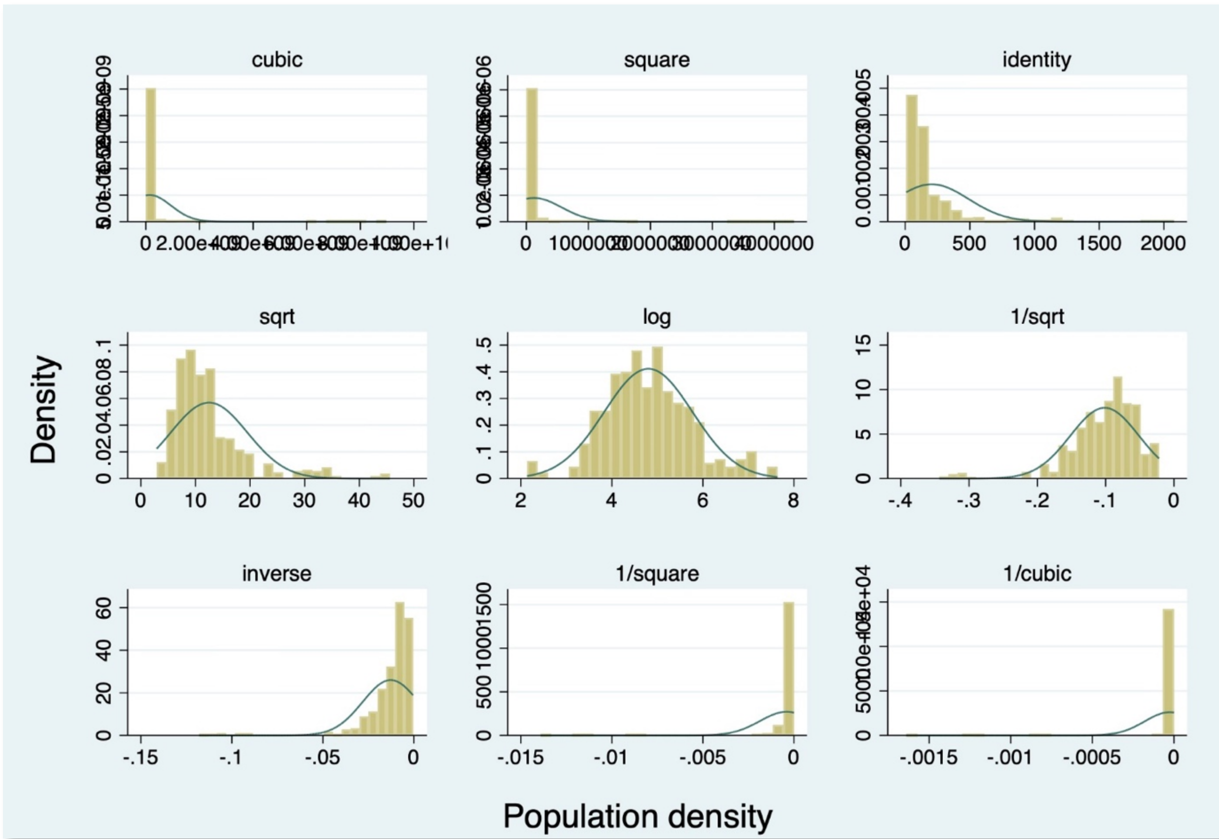


**Figure B5**

*Histograms by Transformation, Density by Population Density*



APPENDIX C

ORIGINAL (IDENTITY) VARIABLE, AND TRANSFORMATIONS

**Figure C1**

*Histograms by Transformation, Density by Greenhouse Gas Transmissions*

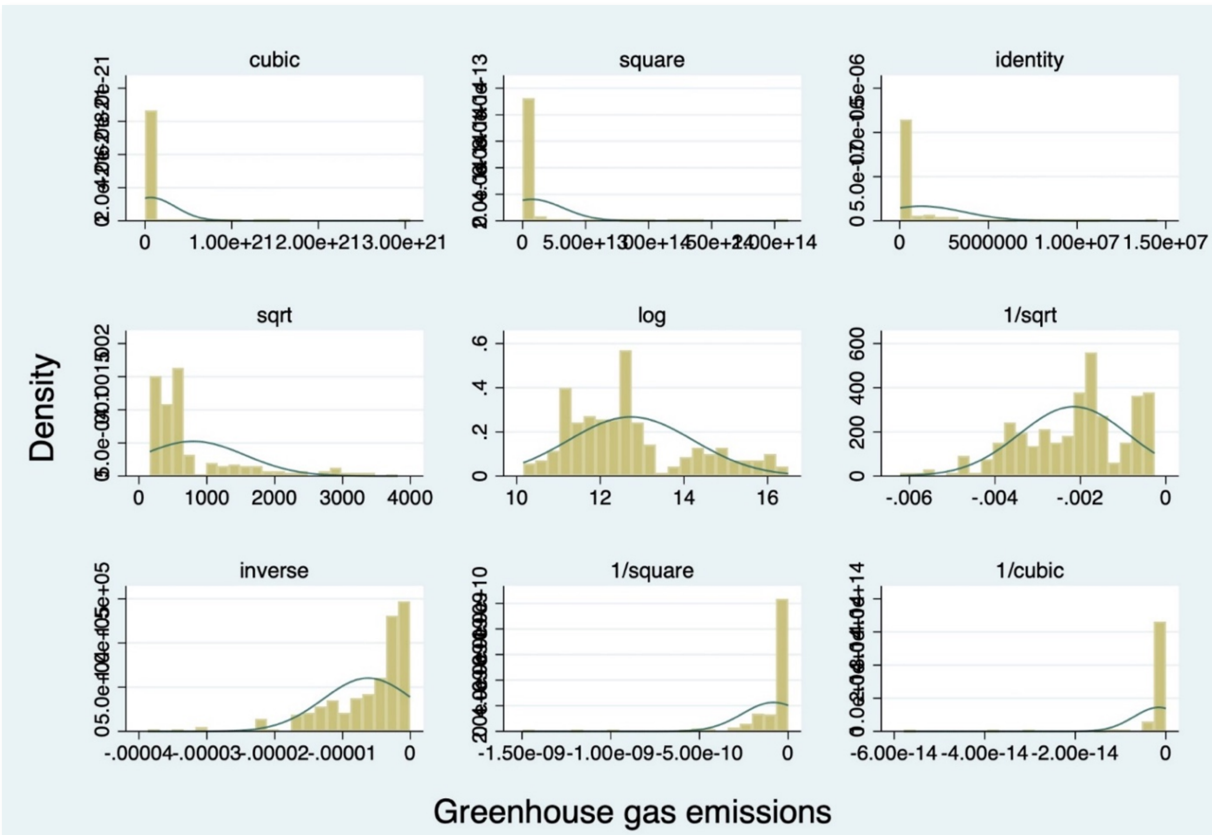


**Figure C2**

*Histograms by Transformation, Density by Disposal Rate*

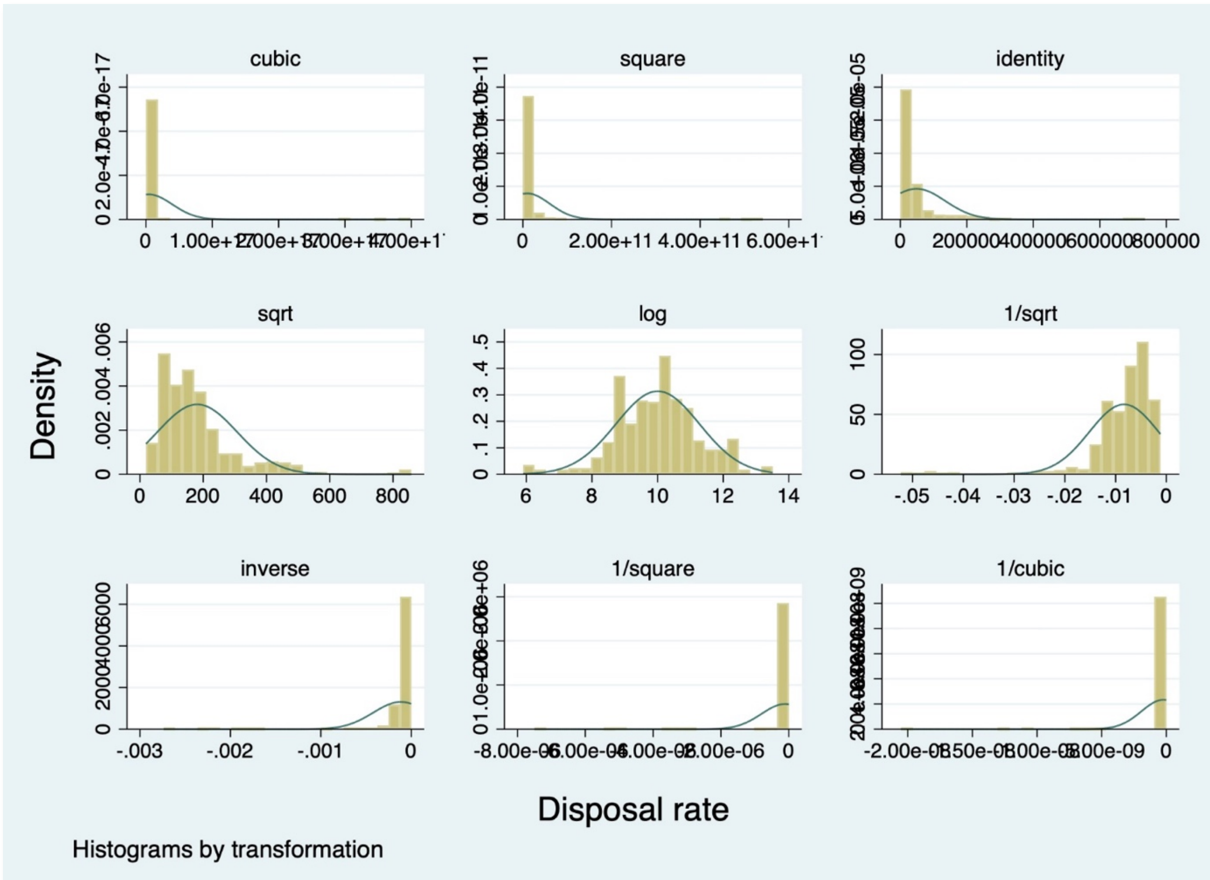
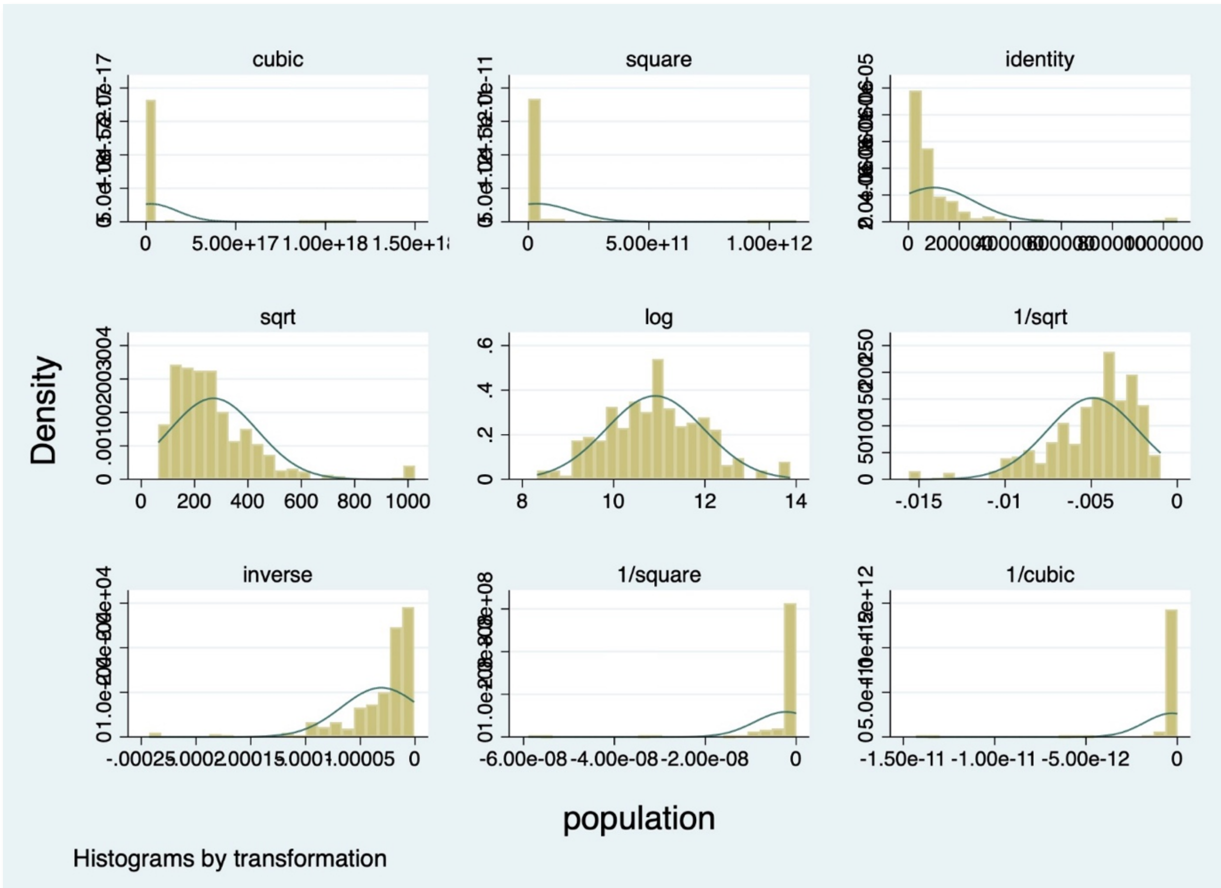


**Figure C3**

*Histograms by Transformation, Density by Population*



APPENDIX D: PER TON ESTIMATES OF GHG EMISSIONS FOR BASELINE AND ALTERNATIVE MANAGEMENT SCENARIOS

## Table D1

*Per Ton Estimates of GHG Emissions for Baseline and Alternative Management Scenarios*

| | GHG emissions per ton of material | | | | | | |
|---|---|---|---|---|---|---|---|
| Material | Produced (MTCO2e) | Reduced (MTCO2e) | Recycled (MTCO2e) | Landfilled (MTCO2e) | Combusted (MTCO2e) | Composted (MTCO2e) | Anaerobically digested (MTCO2e) |
| Corrugated containers | 5.58 | (5.58) | (3.14) | 0.18 | (0.47) | NA | NA |
| Magazines/third-class mail | 8.57 | (8.57) | (3.07) | (0.43) | (0.34) | NA | NA |
| Newspaper | 4.68 | (4.68) | (2.71) | (0.85) | (0.54) | NA | NA |
| Office paper | 7.95 | (7.95) | (2.86) | 1.13 | (0.45) | NA | NA |
| Phonebooks | 6.17 | (6.17) | (2.62) | (0.85) | (0.54) | NA | NA |
| Textbooks | 9.02 | (9.02) | (3.10) | 1.13 | (0.45) | NA | NA |
| Mixed paper (general) | 6.07 | (6.07) | (3.55) | 0.07 | (0.47) | NA | NA |
| Mixed paper (primarily residential) | 6.00 | (6.00) | (3.55) | 0.02 | (0.47) | NA | NA |
| Mixed paper (primarily from offices) | 7.37 | (7.37) | (3.58) | 0.11 | (0.43) | NA | NA |
| Food waste | 3.66 | (3.66) | NA | 0.50 | (0.13) | (0.12) | (0.04) |
| Food waste (non-meat) | 0.76 | (0.76) | NA | 0.50 | (0.13) | (0.12) | (0.04) |
| Food waste (meat only) | 15.10 | (15.10) | NA | 0.50 | (0.13) | (0.12) | (0.04) |
| Beef | 30.09 | (30.09) | NA | 0.50 | (0.13) | (0.12) | (0.04) |
| Poultry | 2.45 | (2.45) | NA | 0.50 | (0.13) | (0.12) | (0.04) |
| Grains | 0.62 | (0.62) | NA | 0.50 | (0.13) | (0.12) | (0.04) |
| Bread | 0.66 | (0.66) | NA | 0.50 | (0.13) | (0.12) | (0.04) |
| Fruits and vegetables | 0.44 | (0.44) | NA | 0.50 | (0.13) | (0.12) | (0.04) |
| Dairy products | 1.75 | (1.75) | NA | 0.50 | (0.13) | (0.12) | (0.04) |
| Yard trimmings | NA | NA | NA | (0.20) | (0.16) | (0.05) | (0.09) |
| Grass | NA | NA | NA | 0.12 | (0.16) | (0.05) | 0.01 |
| Leaves | NA | NA | NA | (0.53) | (0.16) | (0.05) | (0.14) |
| Branches | NA | NA | NA | (0.54) | (0.16) | (0.05) | (0.22) |
| HDPE | 1.42 | (1.42) | (0.76) | 0.02 | 1.33 | NA | NA |
| LDPE | 1.80 | (1.80) | NA | 0.02 | 1.34 | NA | NA |
| PET | 2.17 | (2.17) | (1.04) | 0.02 | 1.27 | NA | NA |
| LLDPE | 1.58 | (1.58) | NA | 0.02 | 1.34 | NA | NA |
| PP | 1.52 | (1.52) | (0.79) | 0.02 | 1.34 | NA | NA |
| PS | 2.50 | (2.50) | NA | 0.02 | 1.70 | NA | NA |
| PVC | 1.93 | (1.93) | NA | 0.02 | 0.68 | NA | NA |
| Mixed plastics | 1.87 | (1.87) | (0.93) | 0.02 | 1.29 | NA | NA |
| PLA | 2.45 | (2.45) | NA | (1.64) | (0.61) | (0.09) | NA |
| Desktop CPUs | 20.86 | (20.86) | (1.49) | 0.02 | (0.66) | NA | NA |
| Portable electronic devices | 29.83 | (29.83) | (1.06) | 0.02 | 0.66 | NA | NA |
| Flat-panel displays | 24.19 | (24.19) | (0.99) | 0.02 | 0.03 | NA | NA |
| CRT displays | NA | NA | (0.57) | 0.02 | 0.45 | NA | NA |
| Electronic peripherals | 10.32 | (10.32) | (0.36) | 0.02 | 2.09 | NA | NA |
| Hard-copy devices | 7.65 | (7.65) | (0.56) | 0.02 | 1.20 | NA | NA |
| Mixed electronics | NA | NA | (0.79) | 0.02 | 0.39 | NA | NA |
| Aluminum cans | 4.80 | (4.80) | (9.13) | 0.02 | 0.03 | NA | NA |
| Aluminum ingot | 7.48 | (7.48) | (7.20) | 0.02 | 0.03 | NA | NA |
| Steel cans | 3.03 | (3.03) | (1.83) | 0.02 | (1.59) | NA | NA |
| Copper wire | 6.72 | (6.72) | (4.49) | 0.02 | 0.03 | NA | NA |
| Mixed metals | 3.65 | (3.65) | (4.39) | 0.02 | (1.02) | NA | NA |
| Glass | 0.53 | (0.53) | (0.28) | 0.02 | 0.03 | NA | NA |
| Asphalt concrete | 0.11 | (0.11) | (0.08) | 0.02 | NA | NA | NA |
| Asphalt shingles | 0.19 | (0.19) | (0.09) | 0.02 | (0.35) | NA | NA |
| Carpet | 3.68 | (3.68) | (2.38) | 0.02 | 1.12 | NA | NA |
| Clay bricks | 0.27 | (0.27) | NA | 0.02 | NA | NA | NA |
| Concrete | NA | NA | (0.01) | 0.02 | NA | NA | NA |
| Dimensional lumber | 2.13 | (2.13) | (2.66) | (0.92) | (0.56) | NA | NA |
| Drywall | 0.22 | (0.22) | 0.03 | (0.06) | NA | NA | NA |

| | GHG emissions per ton of material | | | | | | |
|---|---|---|---|---|---|---|---|
| Material | Produced (MTCO2e) | Reduced (MTCO2e) | Recycled (MTCO2e) | Landfilled (MTCO2e) | Combusted (MTCO2e) | Composted (MTCO2e) | Anaerobically digested (MTCO2e) |
| Fiberglass insulation | 0.38 | (0.38) | NA | 0.02 | NA | NA | NA |
| Fly Ash | NA | NA | (0.87) | 0.02 | NA | NA | NA |
| Medium-density fiberboard | 2.41 | (2.41) | NA | (0.85) | (0.56) | NA | NA |
| Structural steel | 1.67 | (1.67) | (1.93) | 0.02 | NA | NA | NA |
| Vinyl flooring | 0.58 | (0.58) | NA | 0.02 | (0.29) | NA | NA |
| Wood flooring | 4.03 | (4.03) | NA | (0.86) | (0.71) | NA | NA |
| Tires | 4.30 | (4.30) | (0.38) | 0.02 | 0.50 | NA | NA |
| Mixed recyclables | NA | NA | (2.85) | 0.03 | (0.41) | NA | NA |
| Mixed organics | NA | NA | NA | 0.18 | (0.14) | (0.09) | (0.06) |
| Mixed MSW | NA | NA | NA | 0.31 | 0.02 | NA | NA |

## Per Ton Estimates of Wages for Baseline and Alternative Management Scenarios

| Material | Wages per Ton of Material Source Reduced ($) | Wages per Ton of Material Recycled ($) | Wages per Ton of Material Landfilled ($) | Wages per Ton of Material Combusted ($) | Wages per Ton of Material Composted ($) | Wages per Ton of Material Anaerobically Digested ($) |
|---|---|---|---|---|---|---|
| Corrugated Containers | NA | $157.27 | $46.15 | $46.15 | NA | NA |
| Magazines/third-class mail | NA | $157.27 | $46.15 | $46.15 | NA | NA |
| Newspaper | NA | $157.27 | $46.15 | $46.15 | NA | NA |
| Office Paper | NA | $157.27 | $46.15 | $46.15 | NA | NA |
| Phonebooks | NA | $157.27 | $46.15 | $46.15 | NA | NA |
| Textbooks | NA | $157.27 | $46.15 | $46.15 | NA | NA |
| Mixed Paper (general) | NA | $157.27 | $46.15 | $46.15 | NA | NA |
| Mixed Paper (primarily residential) | NA | $157.27 | $46.15 | $46.15 | NA | NA |
| Mixed Paper (primarily from offices) | NA | $157.27 | $46.15 | $46.15 | NA | NA |
| Food Waste | NA | NA | $46.15 | $46.15 | $25.84 | $35.32 |
| Food Waste (non-meat) | NA | NA | $46.15 | $46.15 | $25.84 | $35.32 |
| Food Waste (meat only) | NA | NA | $46.15 | $46.15 | $25.84 | $35.32 |
| Beef | NA | NA | $46.15 | $46.15 | $25.84 | $35.32 |
| Poultry | NA | NA | $46.15 | $46.15 | $25.84 | $35.32 |
| Grains | NA | NA | $46.15 | $46.15 | $25.84 | $35.32 |
| Bread | NA | NA | $46.15 | $46.15 | $25.84 | $35.32 |
| Fruits and Vegetables | NA | NA | $46.15 | $46.15 | $25.84 | $35.32 |
| Dairy Products | NA | NA | $46.15 | $46.15 | $25.84 | $35.32 |
| Yard Trimmings | NA | NA | $46.15 | $46.15 | $25.84 | $32.36 |
| Grass | NA | NA | $46.15 | $46.15 | $25.84 | $32.31 |
| Leaves | NA | NA | $46.15 | $46.15 | $25.84 | $31.85 |
| Branches | NA | NA | $46.15 | $46.15 | $25.84 | $32.96 |
| HDPE | NA | $1,364.89 | $46.15 | $46.15 | NA | NA |
| LDPE | NA | NA | $46.15 | $46.15 | NA | NA |
| PET | NA | $1,364.89 | $46.15 | $46.15 | NA | NA |
| LLDPE | NA | NA | $46.15 | $46.15 | NA | NA |
| PP | NA | $1,364.89 | $46.15 | $46.15 | NA | NA |
| PS | NA | NA | $46.15 | $46.15 | NA | NA |
| PVC | NA | NA | $46.15 | $46.15 | NA | NA |
| Mixed Plastics | NA | $1,326.33 | $46.15 | $46.15 | NA | NA |
| PLA | NA | NA | $46.15 | $46.15 | $25.84 | NA |
| Desktop CPUs | NA | $2,437.51 | $46.15 | $46.15 | NA | NA |
| Portable Electronic Devices | NA | $2,437.51 | $46.15 | $46.15 | NA | NA |
| Flat-Panel Displays | NA | $2,437.51 | $46.15 | $46.15 | NA | NA |
| CRT Displays | NA | $2,437.51 | $46.15 | $46.15 | NA | NA |
| Electronic Peripherals | NA | $2,437.51 | $46.15 | $46.15 | NA | NA |
| Hard-Copy Devices | NA | $2,437.51 | $46.15 | $46.15 | NA | NA |
| Mixed Electronics | NA | $2,437.51 | $46.15 | $46.15 | NA | NA |
| Aluminum Cans | NA | $3,756.94 | $46.15 | $46.15 | NA | NA |
| Aluminum Ingot | NA | $3,756.94 | $46.15 | $46.15 | NA | NA |
| Steel Cans | NA | $252.90 | $46.15 | $46.15 | NA | NA |
| Copper Wire | NA | $3,756.94 | $46.15 | $46.15 | NA | NA |

| | | | | | | |
|---|---|---|---|---|---|---|
| Mixed Metals | NA | $1,470.15 | $46.15 | $46.15 | NA | NA |
| Glass | NA | $490.22 | $46.15 | $46.15 | NA | NA |
| Asphalt Concrete | NA | $36.92 | $46.15 | NA | NA | NA |
| Asphalt Shingles | NA | $36.92 | $46.15 | $46.15 | NA | NA |
| Carpet | NA | $497.74 | $46.15 | $46.15 | NA | NA |
| Clay Bricks | NA | NA | $46.15 | NA | NA | NA |
| Concrete | NA | $36.92 | $46.15 | NA | NA | NA |
| Dimensional Lumber | NA | $36.92 | $46.15 | $46.15 | NA | NA |
| Drywall | NA | $36.92 | $46.15 | NA | NA | NA |
| Fiberglass Insulation | NA | NA | $46.15 | NA | NA | NA |
| Fly Ash | NA | $36.92 | $46.15 | NA | NA | NA |
| Medium-density Fiberboard | NA | NA | $46.15 | $46.15 | NA | NA |
| Structural Steel | NA | $245.70 | $46.15 | $46.15 | NA | NA |
| Vinyl Flooring | NA | NA | $46.15 | $46.15 | NA | NA |
| Wood Flooring | NA | NA | $46.15 | $46.15 | NA | NA |
| Tires | NA | $407.59 | $46.15 | $46.15 | NA | NA |
| Mixed Recyclables | NA | $221.28 | $46.15 | $46.15 | NA | NA |
| Mixed Organics | NA | NA | $46.15 | $46.15 | $25.84 | $33.94 |
| Mixed MSW | NA | NA | $46.15 | $46.15 | NA | NA |

APPENDIX E: RECRUITMENT EMAIL, CONSENT FORM, AND INTERVIEW QUESTIONS

**Recruitment Email Draft**

Dear ___,

You have been identified as a potential participant for a study titled "Why Waste? Local Factors and Recycling Outcomes. A case study of North Carolina counties." This study evaluates recycling programs in the state of North Carolina – the policies chosen, how they are selected, and how they are implemented. The study is being conducted as a part of academic research at UNCC.

Your insight is valuable to understand performance indicators for recycling programs. The study hopes to uncover existing factors, challenges, and opportunities in the recycling industry in North Carolina.

If you consent to participate in this study, you will be contacted to set up a 20-30 minute phone interview. The consent and confidentiality agreement form is attached to this email.

I look forward to hearing from you. Please let me know if you have any questions or concerns.

Thank you

Sincerely,

UNC CHARLOTTE

Ph.D. Public Policy Program
9201 University City Boulevard, Charlotte, NC 28223-0001

**Consent to be Part of a Research Study**

Why Waste? Local Factors and Recycling Outcomes.
A case study of North Carolina counties

Principal Investigator: Titiksha Fernandes, Ph.D. Candidate, Public Policy
Faculty Advisor: Dr. Suzanne M. Leland, Professor, Public Policy

You are invited to participate in a research study entitled "Why Waste? Local Factors and Recycling Outcomes. A Case Study of North Carolina Counties." Participation in this research study is voluntary. The information provided is to help you decide whether or not to participate. If you have any questions, please ask.

**Important Information You Need to Know**

- The purpose of this study is to improve our understanding of how recycling programs operate in North Carolina.
- You will be asked to participate in a audio-recorded phone interview.
- If you choose to participate it will require 20-30 minutes of your time.
- There are no known risks to participation in this study.
- There are no direct benefits to participants in this study.
- The decision to participate in this study is completely up to you. If you decide to be in the study, you may stop at any time. You will not be treated any differently if you decide not to participate or if you stop once you have started.

Please read this form and ask any questions you may have before you decide whether to participate in this research study.

**Why are we doing this study?**
The purpose of this study is to improve our understanding of how recycling programs operate in North Carolina. This includes the understanding of what factors affect recycling and evaluating the outcomes of these programs. Additionally, this study evaluates the policies chosen, how they are selected, and how they are implemented. Its primary purpose is for academic research.

**Why are you being asked to be in this research study.**
You are being asked to be in this study because you are an identified individual above the age of 18, who has a role in city/county/state government or organizations/companies that conduct recycling activities.

**What will happen if I take part in this study?**
If you choose to participate in this study, you will be asked to complete a 20-30 minute phone interview, at a time convenient to you, about recycling programs and their operations. Interviews will be audio recorded so they can be transcribed at a later time.

You time commitment will be about 30-40 minutes including the phone interview and follow up email/phone calls (if needed).

**What benefits might I experience?**
You will not benefit directly from being in this study. However, others might benefit by gaining insight regarding recycling programs and their performance.

**What risks might I experience?**
There are no known risks to participation in this study. However, there may be risks which are currently unforeseeable.

**How will my information be protected?**
We plan to publish the results of this study. To protect your privacy we will not include any information that could identify you. Interviews will provide material which will be published only in the aggregate and no specific counties or recycling facilities will be identified, only that it took place in North Carolina. Interviewers will be recorded using audio recording devices. Interviews will be transcribed. No names or identifiers will be published or disclosed to anyone outside the research team. Audio recordings will be destroyed once the study is complete.

**How will my information be used after the study is over?**
After this study is complete, the audio recordings will be destroyed. The information we share with other investigators will not contain information that could directly identify you. There still may be a chance that someone could figure out that the information is about you.

**What are my rights if I take part in this study?**
It is up to you to decide to be in this research study. Participating in this study is voluntary. Even if you decide to be part of the study now, you may change your mind and stop at any time. You do not have to answer any questions you do not want to answer.
If you decide to withdraw from the study, the data/information collected from you will not be included in the study. However, the principal investigator possesses the right to terminate your participation at their discretion. In this case, you will be notified about the termination along with the reason for the decision.

**Who can answer my questions about this study and my rights as a participant?**
For questions about this research, you may contact Titiksha Fernandes (tfernan7@uncc.edu) and Dr. Suzanne M. Leland (smleland@uncc.edu).

If you have questions about your rights as a research participant, or wish to obtain information, ask questions, or discuss any concerns about this study with someone other than the researcher(s), please contact the Office of Research Compliance at 704-687-1871 or uncc-irb@uncc.edu.

**Consent to be audio recorded**
To assist with accurate recording of participant responses, interviews may be audio recorded
Participants have the right to refuse to allow such recording without penalty. Please select one of the following options:

________I consent to the use of audio recording.______
________I do not consent to the use of audio recording.

_______________________________________________
Signature                                                            Date

**Consent to Participate**
By signing this document, you are agreeing to be in this study. Make sure you understand what the study is about before you sign. You will receive a copy of this document for your records. If you have any questions about the study after you sign this document, you can contact the study team using the information provided above.

I understand what the study is about, and my questions so far have been answered. I agree to take part in this study.

Name (PRINT)

Signature Date

[redacted] 01/29/2021

Name and Signature of person obtaining consent Date

**Phone interview questions for North Carolina Recycling study**

**County questions**

Thank you for agreeing to participate, your insight is valuable to the study.

I will ask you a few questions about recycling programs in your county and your perception of them.

Could you give me a brief overview of the recycling program in your county? How long have you had a recycling program? Who handles the program/who's in charge?

According to you, is your county's recycling program achieving its targets?
Probe: If yes, why? If no, what are some challenges you face?

Do you know how much of the recyclables you collect actually get recycled?
Probe: (If answer to above is less than 100%) Why do you think all of it doesn't get recycled? What happens to the stuff that doesn't get recycled?

What would you do to improve your recycling programs?

Finally, why does your county have a recycling program? Is it because you've always had one, it's environmental, or is it a source of revenue for the county?

Is there anything else you would like to tell me about your county's recycling program?

Thank you so much for speaking with me and providing me with your thoughts.

**Material Recovery Facility Questions**

Thank you for agreeing to participate, your insight is valuable to the study.

I will ask you a few questions about recycling programs in the areas you service and your perception of them.

Could you give me a brief overview of your operations and the services you provide to counties?

Are you achieving your recycling targets?
Probe: Why, or why not?

What is your residual or contamination rate?

What are some challenges you face?
Probe: Why do you think these challenges occur? Do these challenges arise from local government performance or resident behavior? Or are there challenges from the market for recycling?

What do you think local governments or county/municipality residents can do to improve recycling performance?

Is there anything else you would like to tell me about recycling programs and their operations?

Thank you so much for speaking with me and providing me with your thoughts.