ABSTRACT

CHRISTOPHER BENDZ: Performance Analysis Of North Carolina County Special Waste Management Programs
(Under the direction of Dr. Richard Andrews)

This exploratory analysis examined the performance of North Carolina county programs that collect and manage two types of special wastes: discarded household appliances (also called "white goods") and scrap tires. Two performance measurements for these programs, pounds collected per county resident and program cost per ton, vary significantly across the state. Linear regression was used to analyze relationships between these measurements and several factors, including exogenous county factors obtained from census sources and endogenous program characteristics collected through phone surveys. Results indicate that the performance of county special waste programs is related to specific features of these programs, including methods used to educate citizens and business about scrap tire disposal, and outsourcing steps of the white goods collection and management process. No factors displayed the same relationship with the same measurement for both types of waste, which suggests determinants of program performance depend on particular characteristics of the special waste. Some evidence indicates product retailers may play an important role in special waste collection.

To Lisa, whose constant encouragement, infinite patience,

and undying love give me strength and hope

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LIST OF ABBREVIATIONS

AFIR	Annual Financial Information Report
ARCA	Appliance Recycling Centers of America, Inc.
ARIC	Appliance Recycling Information Center
BTU	British thermal unit
CFCs	Chlorofluorocarbons
CO	Carbon monoxide
DENR	Department of Environment and Natural Resources
DPPEA	Division of Pollution Prevention and Environmental Assistance
HCFCs	Hydrochlorofluorocarbons
HCl	Hydrogen chloride
HFCs	Hydrofluorocarbons
MARMA	Major Appliance Resource Management Alliance
NA	Not Applicable
NC	North Carolina
NOx	Nitrogen oxides
PAHs	Polynuclear aromatic hydrocarbons
PCBs	Polychlorinated biphenyls
RMA	Rubber Manufacturers Association

SOx	Sulfur oxides
TDF	Tire-derived fuel
US EPA	United States Environmental Protection Agency
VOCs	Volatile organic compounds

LIST OF SYMBOLS

β	Linear regression coefficient
p	P value for linear regression coefficients (probability > F for forward stepwise linear regression analyses)

INTRODUCTION

Concerns about solid waste disposal are increasingly focused on specific components of the municipal solid waste stream. These components are often called "special wastes", and are targeted because they are potentially hazardous when improperly discarded, or because they are highly recyclable. Examples include many types of automotive wastes, such as lead-acid automobile batteries, used motor oil, and scrap tires, in addition to household wastes such as personal computers, other electronics, mercury thermometers, fluorescent light bulbs, and major appliances (referred to as "white goods" because they are often painted white).

Since the late 1980s, many US states have enacted laws designed to increase recovery and recycling of special wastes. These laws often ban special wastes from disposal in landfills, mandate separate collection of these wastes, and usually establish requirements for proper management, disposal, and recycling. Programs setup for managing these wastes are often funded by a special tax or fee that is paid by consumers when purchasing new items (called "privilege taxes", "advanced disposal fees", or "advanced recycling fees") and used to fund collection, processing, and recycling of items returned for disposal.

Special waste management programs established by these laws have diverted large percentages of several wastes from landfills and incinerators. In 2003, over 93% of lead-acid batteries, 35.6% of scrap tires, and 66.7% of major appliances were recovered for recycling across the US (US EPA 2005). When including incineration of tires as a source of fuel in cement kilns, paper mills, boilers, and power plants, the recovery rate for scrap tires reached 80.4% in 2003 (RMA 2004).

The process for collecting many special wastes differs from that of most other solid wastes in the role played by private sector firms. Product retailers and other businesses often take back used products from customers when providing them with replacements. Automotive service stations, for example, frequently collect and discard used oil, batteries, and tires when changing these products for customers. This is often required by law but is also provided by many businesses voluntarily, with or without a surcharge, as an additional measure of customer service. These businesses then become responsible for proper disposal of the used products. Some materials in these products, such as metals from used appliances, have a positive value in scrap markets and can be sold for profit. Others, such as scrap tire rubber, have relatively limited markets, and generators usually must pay to have them processed, recycled, or disposed of properly.

While businesses play a prominent role in the special waste collection process, most local governments also provide services and facilities for collecting, managing, and storing these wastes. These local special waste programs are usually managed by solid waste departments of county or municipal governments, and are needed for several reasons. Residents who generate special wastes at home and do not leave them with retailers need a way to dispose of them safely. Businesses that collect and generate these wastes also seek local disposal options when their special waste materials cannot be sold in scrap markets or when quantities are too small to market cost-effectively. Local governments are traditional providers of solid waste management services, and much of their infrastructure used for collecting, storing, and disposing of solid waste is readily adaptable for managing special wastes. They are also charged with preventing illegal dumping within their service area. Providing special waste collection facilities helps prevent this by making safe disposal options available to citizens and businesses. Through these programs, local governments collect a significant portion of the special wastes generated in their communities. They become "final holders" who must ensure special wastes are properly stored, managed, and sent to recycling or processing facilities.

Faced with limited budgets and a growing list of state and federal mandates, it has become increasingly important for local governments to measure and optimize the performance of their special waste programs. Measurements are used by program administrators to track several aspects of program performance, including cost-effectiveness and per capita collection rates. They also help regulators and policymakers evaluate whether special waste programs are in compliance with requirements and achieving policy goals.

Performance measurements alone, however, cannot be used as a basis for action or change. To improve existing programs or design new policies for managing special wastes, it is necessary to understand what factors influence these measurements. If these factors are exogenous features of the local community served by the special waste program, they can help establish constraints for the program and set realistic expectations. If they are endogenous aspects of the special waste programs themselves, they can help identify specific opportunities to improve special waste collection and management through program or policy changes.

White goods and scrap tires are two types of wastes targeted by special waste laws. Their collection and management presents challenges common to many other types of special wastes. Both are regulated by the State of North Carolina, which requires each county to provide programs for collecting, managing, and recycling these wastes. Funding for these programs is provided by advanced disposal fees charged to consumers when purchasing new appliances and tires. These funds are collected by the state and distributed to each county based on its population. To receive funding, each county is required to report their program operating costs and quantities of white goods and scrap tires collected. These data can be used to calculate two indicators commonly used to measure the performance of recycling programs: the quantity of waste collected per person served by the program, and the program cost per ton of waste managed.

This study explores associations between these performance measurements and factors that are both exogenous and endogenous to county special waste programs. While many of these factors have been studied in relation to conventional household recycling programs, understanding of their impact on special waste programs is limited. Several findings are presented, and possible reasons for each significant finding are discussed. The results provide a few early steps toward understanding determinants of special waste program performance, and present many opportunities for future research.

WHITE GOODS

White goods include a variety of large household appliances. Discarded refrigerators, freezers, ranges, ovens, dishwashers, washing machines, clothes dryers, air conditioners, and water heaters are examples of items typically classified as "white goods". The quantity of appliances discarded in the US has increased from 1.63 million tons in 1960 to 3.48 million tons in 2003, although this amount has remained relatively stable since 1995 (US EPA 2005). In North Carolina, 68,598 tons were collected by county programs in fiscal-year 2003-2004 (NC DENR 2004).

In recent years, disposal of discarded white goods has become increasingly restricted. White goods are made up of significant quantities of metal, primarily iron and steel but also aluminum, copper, and others, all of which can be recycled. A 1997 study found that most types of new appliances are made up of at least 50% ferrous metal (ARIC INFOBulletin #2). When collected and managed properly, discarded appliances can be sold to scrap metal processors and recycled into new metal products, such as automobiles, construction materials, and new appliances. In 2003, 66.7% (2.32 million tons) of discarded major appliances were recycled (US EPA 2003), providing 10% of the steel processed by the recycling industry according to industry sources (ARCA).

A significant portion of the white goods waste stream is made up of discarded refrigeration devices (refrigerators, freezers, air conditioners, and dehumidifiers) which contain gaseous refrigerant compounds such as chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs), hydrofluorocarbons (HFCs), halons, methyl bromide, carbon tetrachloride, and methyl chloroform.. These compounds are widely suspected of depleting the earth's stratospheric ozone layer. While production of these substances is being gradually phased out, many are still present in discarded appliances.

White goods also contain other hazardous materials. Many appliances manufactured before 1979, primarily air conditioners and microwave ovens, used capacitors containing polychlorinated biphenyls (PCBs). Human exposure to PCBs is suspected of interfering with neurological development in children, harming the reproductive, immune, and endocrine systems, and may also cause cancer. Older appliances also have devices containing mercury, primarily in safety devices in pilot-light gas ranges, lid-light switches of chest freezers, and some small fluorescent control panel backlights on ranges and clothes washers manufactured before 1972. Although very small amounts of mercury are used in these devices and their use has been declining in recent years, there is some concern that improper disposal of these devices could release mercury into water supplies and cause chronic problems with nervous and reproductive systems in exposed populations.

To avoid the potential environmental and health hazards associated with improper disposal, and to encourage recycling of the scrap metal, both state and federal governments have acted to restrict disposal of discarded white goods. As of June 2001, 19 states had banned disposal of white goods from landfills and an additional 16 states had imposed restrictions on landfills requiring them to separate white goods for recycling (ARIC 2001). Section 608 of the Clean Air Act, as amended in 1990, requires those engaged in final disposal of refrigeration appliances to extract and recover ozone-depleting CFC and HFC refrigerants. This requirement applies to landfills and scrap metal dealers in all states, not just those who have expressly banned or restricted landfill disposal.

North Carolina's 1989 Solid Waste Management Act (NCGS § 130A-309.09A, also known as Senate Bill 111) banned white goods and several other types of wastes from disposal in landfills. Laws enacted in 1993 prohibit local governments from charging disposal fees and require each county government to provide at least one collection site where citizens can drop off white goods at no charge.[1] An area of the county landfill or transfer station is often set aside for this purpose.

Many county governments also choose to provide additional collection sites that are more conveniently located throughout the county. These "convenience sites" accept household recyclables in addition to white goods and other recyclable materials, and are normally operated by staff who assist residents with unloading and proper sorting of materials. Some counties also host special collection events, such as Earth Day celebrations, Spring cleanings, or household hazardous waste days when residents are encouraged bring their hazardous and recyclable materials, including white goods, for proper disposal or recycling. Cities, towns, and other municipalities within counties occasionally offer regular or scheduled curbside collection of white goods. White goods collected through these channels are typically hauled to the county's central collection site, where they are consolidated before shipment to scrap metal processors.

Discarded white goods brought to central collection sites are processed, managed, and stored in several ways. Some counties separate refrigerators, freezers, and air conditioners

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[1] Most of North Carolina's solid waste programs are administered by county governments. Some counties, however, have agreements with other units of local government, usually cities within the county, in which the local government manages the solid waste program for the entire county. Examples include the cities of Albemarle and Durham, which manage the solid waste program for Stanly and Durham Counties, respectively. These local governments are treated as county governments for the purposes of NC's special waste programs.

from other types of white goods and extract the refrigerant gases on-site. Other counties rely on scrap metal dealers, metal recyclers, or other "final holders" to extract these refrigerants. White goods are usually accumulated and stored in large piles at collection sites. Some counties place piles on wide concrete pads, which minimizes exposure to mud and intercepts spills of oil and other liquids. Other counties place them on cleared sections of bare ground. Some white goods piles are placed under shelter, while others are exposed to the elements. Pieces of heavy equipment (front-end loaders, knuckleboom loaders, skid steers, etc.) are often used to move white goods around these sites and to assist with loading and unloading. Most counties have contracts or agreements with scrap metal dealers to pickup white goods on a regular basis, while some haul white goods themselves directly to metal recycling facilities.

The scrap metal in white goods is readily recyclable and can be sold to scrap metal dealers, recyclers, and steel mills for a profit. This enables counties to receive revenue for each ton of white goods they collect and ship. Payments for scrap metal change over time based on steel commodity prices, and have been growing in recent years. The amount of scrap metal revenue, however, is usually exceeded by a county's total costs for labor, equipment, materials, refrigerant removal, and other services related to white goods management. As a result, county white goods programs typically operate with a net cost.

County white goods program costs are funded by a privilege tax or advanced disposal fee paid by consumers when purchasing a new appliances in the North Carolina. The fee was originally established by the 1989 Solid Waste Management Act and set at $10 per new appliance, but it was reduced to $3 per appliance in 1998. It is collected by retailers and remitted to the State Department of Revenue. Seventy-two percent of these fees are distributed to each of North Carolina's 100 counties based on the percent of the state population living in the county. These funds are distributed quarterly, and must be used for management of discarded white goods. Twenty percent is placed in a White Goods Management Account, and the remaining eight percent is placed in the Solid Waste Trust Fund.[2] To receive their quarterly advanced disposal fee distribution, counties must report the quantity of white goods collected and the net costs for operating their white goods program, in addition to any funds used for capital improvements or illegal dumpsite cleanup. This information is included in the county's Annual Financial Information Report (AFIR), submitted each year to the NC State Department of Revenue and shared with the Division of Waste Management.

North Carolina's white goods laws have significantly increased the annual quantity of white goods collected, and some evidence suggests they have reduced illegal disposal. Figure 1 shows the quantity of white good collected by NC county programs has increased by almost 41,000 tons per year since they were banned from landfills in 1991. Before white goods were regulated, the state regulators assumed most of these additional quantities were mishandled and either landfilled or discarded in illegal rural dump sites (NC DENR 2000). After the regulations went into effect, their field operations observed a decrease in illegal dumping, which they attributed to free disposal available at collection sites in every county in the state.

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[2] The funds in the White Goods Management Account are used to provide 3 types of grants to NC counties. Cost overrun grants are available for counties whose costs for managing white goods exceed the amount they are allocated based on their population. Capital improvement grants are available for capital projects or investments (e.g. concrete pads, trucks, etc.) that counties can undertake to improve their white goods management program, and illegal dumpsite cleanup grants are available to fund removal of white goods from illegal dumps. To receive these grants, counties must apply to the Solid Waste Section of the State Division of Waste Management. The Solid Waste Trust Fund is administered by the NC Division of Pollution Prevention and Environmental Assistance (DPPEA) and is used to provide small grants for waste reduction technical assistance projects, educational activities, and local waste reduction and recycling programs.

Figure 1: White Goods Collected in North Carolina

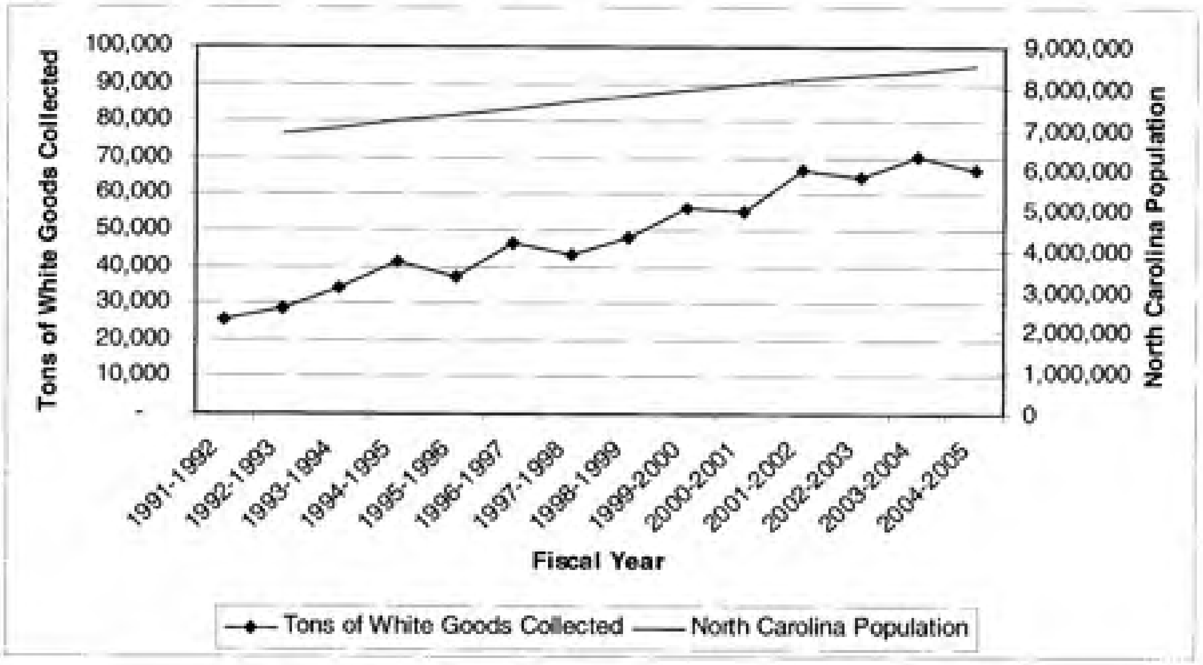
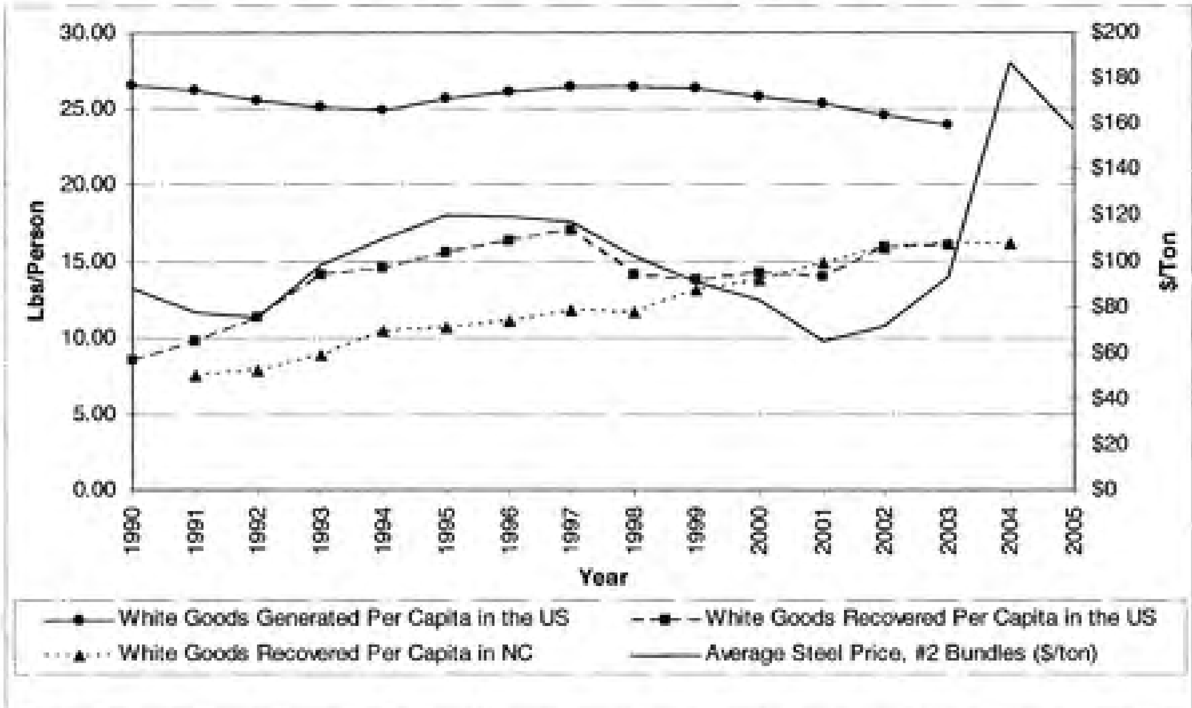


Figure 2 shows quantities of white goods generated and collected per capita in the United States and in North Carolina. The US quantities were provided by appliance industry sources and reported in the US EPA's annual reports on Municipal Solid Waste in the United States (US EPA, 1996-2005). Quantities of white goods recovered in North Carolina were obtained from Annual Financial Information Reports submitted by each county. These data were divided by census population estimates to obtain generation and recovery rates per capita each year. The quantities recovered across the US include white goods collected by both public and private sector programs (i.e. both local government collection programs and private sector take-back programs). Quantities recovered in North Carolina, however, only include white goods collected by public-sector county white goods programs; they do not include white goods recovered and recycled independently by appliance retailers, junkyards, and scrap metal dealers. Average steel prices for no. 2 bundles (a grade of steel scrap whose value is commonly used as a basis for appliance scrap metal prices) each year are also shown on the graph, as reported by the metal recycling industry (American Metals Market 2006).

Figure 2: White Goods Generated and Collected Per Capita



The quantity of white goods generated per capita across the US has remained relatively stable, and has even declined slightly, since 1990. In past years, average per capita recovery rates across the US were higher than North Carolina rates by 20%-60%, or 2.0-5.5 pounds per person. This difference could have been due to a period of "ramping up" where counties were expanding their white goods collection infrastructure, or due to greater collection by private sector firms while high scrap metal price were relatively high. Beginning around 1998, however, per capita recovery rates for North Carolina increased to within 5% of the US average, where they have remained since. This increase coincided with a decline in steel prices, which reached a low in 2001 and did not fully recover until 2004. While US average recovery rates remained flat throughout this period of relatively low scrap metal prices, per capita recovery rates from North Carolina county counties continued to increase. In recent years, NC county programs have collected as many white goods per capita as both public and private sector firms across the US. This suggests that public sector white goods collection programs in North Carolina play an important role in maintaining high recycling rates in the state, even when scrap metal market prices are low.

SCRAP TIRES

Scrap tires include discarded tires from passenger vehicles, trucks, off-road vehicles, industrial and farm equipment, and other vehicles. In 2003, approximately 290 million scrap tires were generated in the US, or about 1 tire per person. This is equivalent to 4,770,000 tons of scrap tires, which has remained relatively stable since 2000 but is up from 1,120,000 since 1960 (US EPA 2005). In North Carolina, 143,000 tons were generated in fiscal-year 2003-2004 (NC DENR 2004).

Prior to the late 1980s, scrap tires were usually discarded in landfills along with other solid waste, or placed in large open piles on the ground. When buried in landfills, tires are bulky and difficult to compact, which traps air and wastes landfill space. When stored in large open piles, scrap tires pose a number of health and environmental hazards. They collect rainwater and provide breeding sites for mosquitoes, which can contribute to the spread of vector-borne viruses such as West Nile and encephalitis. They also provide shelter for rats and other rodents that can be carriers of disease. Apperson et al conducted a state-wide survey of mosquito species at 38 tire disposal sites in 36 North Carolina counties. Almost 90% of their samples included known vectors of viruses causing encephalitis, including *Aedes albopictus* and *Aedes triseriatus*. In addition, the range of *Aedes albopictus* had expanded from 6.1% to 76.3% of tire disposal sites sampled between 1987 and 1993.

Tire piles are also formidable fire hazards. The rubber, fibers, and other materials found in tires are combustible and have high energy content (14-15 thousand BTUs per pound, compared to 8-12 thousand for coal). When tires are stacked in piles they also trap significant amounts of air. Once ignited, burning tire pile fires are extremely difficult to extinguish and can continue to burn for months. They also produce large plumes of thick, black smoke that includes pollutants such as polynuclear aromatic hydrocarbons (PAHs), volatile organic compounds (VOCs), carbon monoxide (CO), nitrogen oxides (NOx), sulfur oxides (SOx), dioxins, furans, hydrogen chloride (HCl), benzene, polychlorinated biphenyls (PCBs), and metals such as arsenic, cadmium, nickel, zinc, mercury, chromium, and vanadium. These fires convert tire rubber into a thick, oily sludge with many of the same pollutants, which leaks onto the ground and can be carried through runoff into water bodies. One of the largest tire fires in US history took place in 1983 at the Rhinehart tire dump in Winchester, VA. Five million tires at this 4 acre site burned for nine months, producing a black smoke plume 3000 feet high and nearly 50 miles long. Air samples from the plume indicated potentially hazardous levels of CO and PAHs (NC DPPEA), and runoff from the site polluted nearby water sources with lead and arsenic. It is currently being cleaned up as a Superfund site (US EPA, *Tire Fires*). Seven million tires burned in another large tire pile fire in Tracy, California, between 1998 and 2000 (Blackman and Palma, 2002). In a comparative analysis of environmental and health risks associated with scrap tire stockpiles on the US-Mexico border, Blackman and Palma found that the risks associated with air pollution from tire pile fires outweighed those from mosquito-borne diseases or combustion of tires as a fuel in kilns (Blackman and Palma 2002).

To avoid these hazards, many states have banned scrap tires from landfills, initiated cleanup of existing scrap tire piles, and require segregation and proper disposal of newly generated scrap tires. Forty-eight states have laws regulating disposal of scrap tires (all states except for Alaska and Delaware). Thirty-nine of these states ban whole tires from landfills, thirty-five states collect taxes or advanced recycling fees to pay for management of discarded tires, and thirty-six have programs to clean up old stockpiles of scrap tires. These cleanup programs contributed to significant reductions in the number of tires in stockpiles across the US, from 1 billion tires in 1990 to around 160 million in 2003 (RMA 2004).

Restricting disposal and regulating management of scrap tires have contributed to the growth of end-markets for scrap tires. In 2003, nearly 45% of the scrap tires generated in the US were used as a source of fuel (called tire-derived fuel, or TDF) in cement kilns, pulp and paper mills, industrial and utility boilers (RMA 2004). Almost 20% of scrap tires were used in civil engineering applications, such as road and landfill construction and septic tank leach fields, and about 10% were used in ground rubber applications, such as new rubber products, rubber modified asphalt, and playground and sports surfacing. Overall, 80.4% of the scrap tires generated in the US in 2003 were sent to end-markets, compared to only 11% in 1990 (RMA 2004).

Laws regulating scrap tires in North Carolina are similar to those regulating discarded white goods. The 1989 Solid Waste Management Act banned scrap tires from disposal in landfills and required each county to provide a collection site where citizens can drop off scrap tires at no charge. A portion of the county landfill or transfer station is usually set aside for this purpose. Some county governments also collect scrap tires at convenience sites and special collection events, and a few municipalities offer curbside collection of tires. Private businesses, such as tire dealers and automotive service stations, also collect scrap tires that must be managed by county programs. In some counties, tire dealers haul scrap tires to the county's central collection site, where they are combined with tires from other sources. In other counties, particularly those with businesses that generate large volumes of scrap tires, tire dealers accumulate scrap tires on-site and haul them directly to processing facilities.

Scrap tires are usually stored in large trailers that loaded from the top (if open) or from the rear (if closed). Some counties sort tires based on type and size (e.g. passenger tires, truck tires, off-road tires, etc.) while others mix all types together in the same trailer. "Lacing" is a stacking technique used when hand-loading tires to maximize the number that will fit in a trailer. This technique can make a significant difference in the number of tires shipped in a truckload, and is used by some counties and scrap tire haulers to minimize unit hauling costs (hauling costs per ton or per tire). Other counties, however, load scrap tires haphazardly, which reduces the density of each shipment but also reduces the amount of labor required for loading. Some counties do not use trailers and store scrap tires in large piles on the ground. Special rules apply to scrap tires stored outdoors regulating the dimensions of tire piles, the length of time they can remain on-site, and measures to prevent fires, control pests and prepare for emergencies.

The cost of processing scrap tires, unlike white goods, exceeds the value of recycled products. As a result, counties are charged by recycling companies to dispose of their scrap tires. These charges typically range from $70 to $100 per ton, although some counties are charged based on the number of tires or the number of truckloads (NC DENR 2004). Most NC counties have contracts with one of two major tire recyclers in the state: US Tire Recycling located in Concord, NC and Central Carolina Tire Disposal located near Sanford, NC. These companies typically offer "turnkey" agreements in which they provide counties with both hauling and disposal services. At these facilities, tires are normally shredded and used in one of the end-markets described previously. Tires that cannot be used in these markets are landfilled, but only at tire monofills permitted by the state.

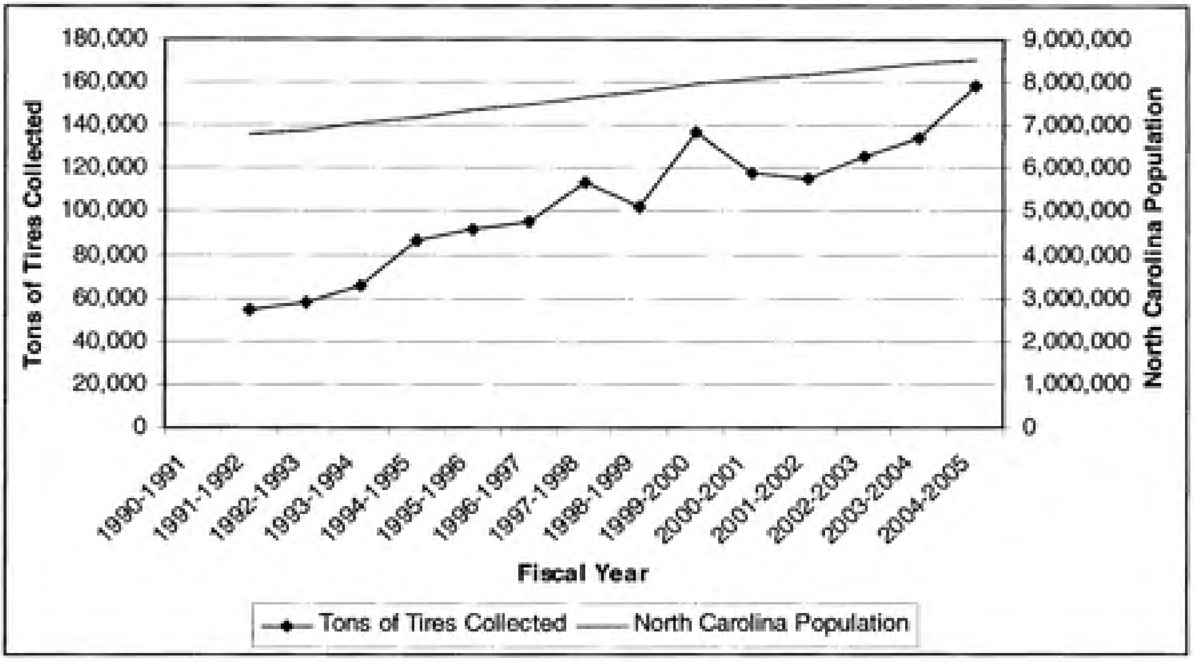
To fund proper collection, management and disposal of tires, the 1989 Solid Waste Management Act established a 1% privilege tax on the sale of new tires. Tire retailers collect this fee at the point of sale and remit the funds to the State Department of Revenue. In 1993 the fee was increased to 2% by House Bill 83. Sixty-eight percent of collected fees are distributed quarterly to each of NC's 100 counties based on population, twenty percent is placed in a Scrap Tire Disposal Account, and the remaining five percent is placed in the Solid Waste Trust Fund.[3] To receive quarterly per-capita tax distributions for scrap tire programs, counties must report quantity and cost data that is similar to information reported for their white goods programs. The data includes the quantity of tires collected in addition to costs for operating the program, cleaning up nuisance tire sites, and funding capital improvements. It is reported in a Scrap Tire Management Annual Report submitted each year to the Solid Waste Section.

The effects of North Carolina's scrap tire laws have been similar the impacts of its white goods laws. Since the regulations were enacted, quantities of scrap tires collected each year have increased and many illegal dumpsites have been cleaned up. Figure 3 shows the quantity of scrap tires collected statewide has increased by over 100,000 tons since fiscal

[3] Of the funds deposited in the Scrap Tire Disposal Account, 50% are used to provide cost overrun grants, 10% are provided as grants for cleanup of nuisance tires, and 40% are used for processed tire market development grants. The latter grants are provided to public and private entities to develop technologies and markets for processed scrap tire material, such as tire chips, crumb rubber, and carbon black for use in fuel, playground & sports surfaces, new tires, and other commercial and consumer products. To receive these grants, counties and private firms seeking market development grants must apply to the Solid Waste Section of the State Division of Waste Management.

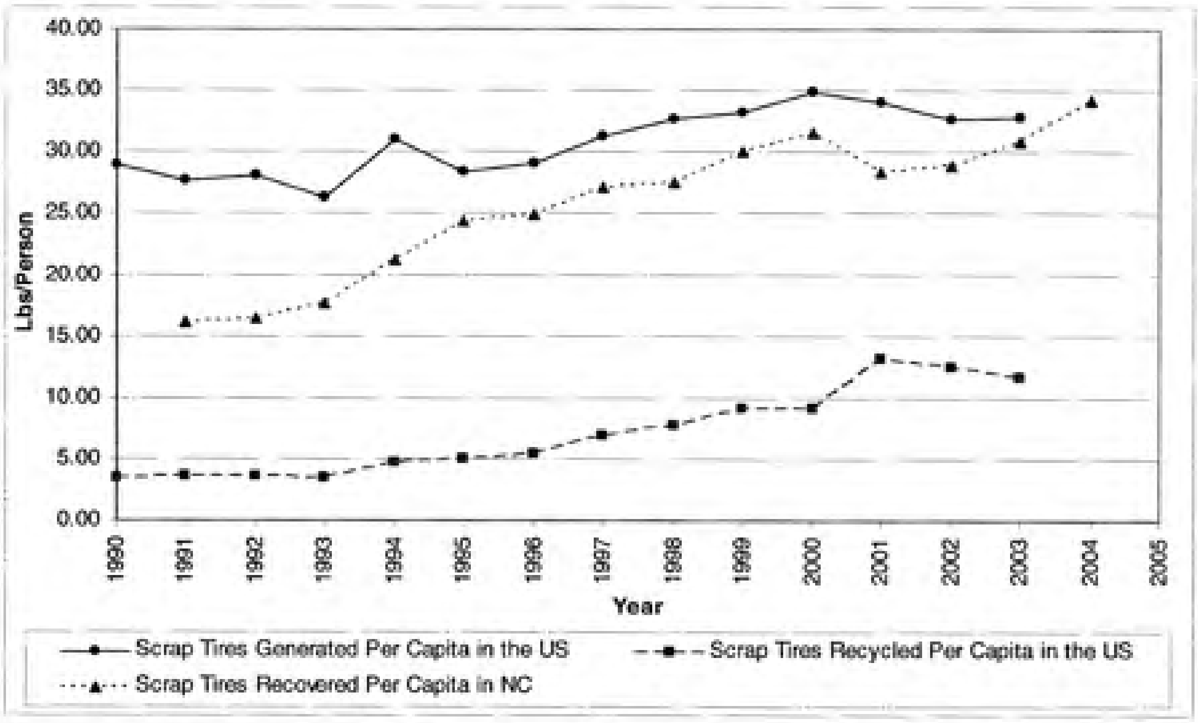
year 1990-1991. As of fiscal year 2003-2004, 335 nuisance tire disposal sites, including over 7.6 million tires, had been cleaned up throughout the state (NC DENR 2004).

Figure 3: Scrap Tires Collected in North Carolina



Per capita trends in the quantities of scrap tires generated and recovered are shown in Figure 4. US quantities were also obtained from the US EPA's annual reports on Municipal Solid Waste in the United States (US EPA, 1996-2005), and quantities of tires recovered in North Carolina were obtained from county Scrap Tire Management Annual Reports. These amounts were again divided by census population estimates to obtain per capita generation and recovery rates.

Figure 4: Scrap Tires Generated and Collected Per Capita



The quantities of tires collected per capita in NC are much higher than per capita quantities recycled in the US because the NC quantities include all tires collected by NC counties, regardless of whether they were recycled into new products or used as tire-derived fuel in cement kilns, paper mills, and utility boilers. The US quantities, on the other hand, only include tires recycled into new products, such as roads and sports surfaces, and do not include any tires combusted as a source of fuel. Figure 4 shows that quantities of tires collected per capita by NC county programs have increased steadily since scrap tire programs were first established in the state in 1989. The quantities collected per capita in NC represent an increasing percentage of the average quantities generated per capita in the US, from 58% in 1991 to 94% in 2003. If per capita generation in NC is close to the US average, this trend suggests scrap tire programs operated by NC counties are successfully collecting a large percentage of tires generated across the state.

PERFORMANCE MEASUREMENTS

The success of recycling policies and programs is frequently evaluated through the use of performance measurements. These measurements are often used to define quantitative policy goals, such as recycling rates or waste reduction targets. Two measurements commonly used to assess the performance of recycling programs are the quantity of material collected per person served by the program, which will be referred to as program "effectiveness," and the cost of managing each unit of material, which will be referred to as program "efficiency".

Effectiveness indicates how well a recycling program collects recyclable wastes from the citizens and businesses it serves. When applied to conventional household recycling programs, this measurement can indicate how well the program has solicited public participation and how much waste is being diverted from landfill disposal. When applied to special waste recycling programs, it can also indicate how well the program prevents illegal dumping, or how effectively the program encourages citizens to discard old, unused products stored in attics, sheds, and garages.

Efficiency measures how cost-effectively a recycling program is operating. The market value of most recycled materials is often insufficient to completely cover all of the costs for recycling them, and volatile markets for these materials cause net recycling costs to fluctuate over time. Solid waste departments often pay for recycling services based on the quantity of material recycled, and this market volatility can cause their recycling costs to change from month to month. With budgets that are limited and fixed for most solid waste programs, operating with high efficiency (i.e. minimal costs per ton) is important to ensure that recycling continues to be affordable and sustainable.

Taking action or making changes to programs or policies based on these measurements requires an understanding of their primary determinants. Analyzing factors that contribute to program effectiveness can help identify ways to increase collection in communities faced with low recycling rates or problems with illegal disposal. Evaluating factors that affect program efficiency can help communities establish investment priorities or find cost savings opportunities. Together, tracking these measurements and understanding what influences them can help recycling program managers and administrators achieve the twin goals of recycling as much as possible while minimizing the costs associated with recycling.

LITERATURE SUMMARY

While programs for managing white goods and scrap tires have been established in many states for several years, the performance of these programs has received little scholarly attention. A 1997 publication by the Major Appliance Resource Management Alliance (MARMA 1997) provides an informative overview of the appliance collection and recycling process in the US. In 2002 the Midwest Assistance Program, Inc. conducted a study to identify the primary barriers to recycling white goods in Missouri and propose solutions for overcoming these barriers (Midwest Assistance Program, Inc. 2003). The study collected input from a variety of stakeholders including local governments, appliance dealers and repairers, solid waste specialists, scrap metal dealers, and recycling centers. They identified low scrap metal prices, regulations requiring refrigerant removal, and labor required to prepare white goods for recycling as primary barriers to increasing recycling of white goods. Their recommendations included providing municipalities and citizens with more information on white goods disposal options, educating consumers about the costs of white goods disposal, providing more collection points for rural areas, increasing recycling subsidies, and promoting scrap metal markets.

An article by Jeff Hughes provides an informative summary of North Carolina's white goods and scrap tire programs, including an overview of the regulations and a synopsis of how disposal taxes are collected, distributed, and used by counties. He notes that one performance measurement, per-capita annual program costs, varies significantly across the state for both programs for "at least three reasons. First, counties provide different levels of service, ranging from a single collection point to multiple collection points and sophisticated in-house processing facilities. Second, the amounts of waste the counties process do not correspond to population figures. Third, the cost of managing materials varies significantly in different parts of the state, depending on the availability and the prices of commercial processors." While these factors probably do impact a county's annual operating costs, he does not attempt to quantify the relative impact of each factor nor does he account for county demographics or other reasons why the quantity of waste collected in a county would not correspond to its population. He acknowledges that errors in cost accounting or reporting could account for some variation, saying "[a]lthough differences in costs are expected, some of the discrepancies in the annual reports are so extreme that they probably are due to reporting errors or poor recordkeeping" (Hughes 2003).

In the absence of findings directly related to white goods and scrap tire recycling programs, studies of other special wastes could provide insight into the types of exogenous and endogenous factors that affect program performance. Using results of a 2004 mail survey of 3000 California households, Saphores et. al. (2005) assessed the willingness of households to recycle used electronic devices. They found that females, people with a college education, and those with stronger environmental beliefs were more willing to drop off electronic waste at recycling centers, while income and political affiliation did not have a significant influence. The convenience of the collection system also had a significant impact; respondents expressed significantly more willingness to drop off used electronics for recycling if they lived within 5 miles of the nearest drop-off center. Bach et al (2003) developed a multivariate regression model to predict the amount of waste paper collected using sample data from 649 municipalities in Austria. They found that significantly more waste paper was collected in municipalities with more tourists and business travelers, a higher percentage of private sector employees, and fewer agricultural firms, and significantly less waste paper was collected on a per-capita basis in municipalities with higher average purchasing power and a greater percentage of housewives. The density of drop-off collection sites was associated with higher quantities of waste paper collected in their study, supporting their hypothesis that the convenience of a collection system improves its performance.

The vast majority of recycling literature focuses on conventional household recyclables, which include plastic, glass and metal containers used for foods and beverages, in addition to commonly used paper products such newspaper, office paper, and cardboard. They are often collected along with trash through regular curbside pickup or dropped off at collection sites located throughout a community. Programs for separate collection of these materials have been established in many communities since the 1980's and 1990's. As of 2002, 8,875 curbside household recycling programs were operating across the US (US EPA 2003). They are the most recognizable form of recycling and the greatest source of recyclable materials in most communities that recycle. Factors linked to the performance of these programs, whether they are features of the communities themselves or the recycling programs that serve them, could suggest the types of exogenous and endogenous factors that might also influence the performance of special waste recycling programs.

Many studies of conventional household recycling have found relationships between subject or community demographics and outcome measurements such as recycling behavior, participation, or recycling rates. Bacot et al (1993) conducted opinion surveys of 844

Tennessee residents and found greater willingness to drop-off recyclables at a collection center among older, white, and home-owning residents living in smaller, rural communities. Derksen and Gartrell (1993) found that both age and education had a weak but positive relationship with self-reported recycling behavior among residents of Alberta, Canada. Gamba and Oskamp (1994) found that larger household size and income were significantly associated with commingled curbside recycling participation using recycling behavior observations and mail survey results from 456 California households. Oskamp et al (1998) measured the quantity of materials recycled by 262 California homes and found that larger households recycled significantly more each time they participated in the local curbside collection program. Owens et al (2000) measured quantities of household waste discarded and recycled among a random sample of 87 residences in Athens-Clarke County, Georgia, and found higher annual household income, greater education, and home ownership were significantly associated with higher household recycling rates. Based on data collected from 43,000 Canadian households, Berger (1997) found that size of residential area, type of dwelling, education, and income were significant determinants of whether recycling facilities were available and used. Peretz et al (1995) found higher mean household income was associated with higher rates of citizen participation in city recycling programs, and larger cities with greater non-minority populations experienced higher participation rates. Kinnaman and Fullerton (2000) found that communities where households are older, larger, more educated, and own more of their own homes recycled significantly more per person using data from 658 communities with recycling programs.

While these studies have established links between community or individual demographic characteristics and recycling, they are somewhat less clear about exactly how these factors affect recycling behavior or program performance. Most scholars agree that demographic characteristics are only antecedents to other behaviors or socio-economic circumstances, such as concern for the environment, access to recycling options, knowledge of the recycling process, and other factors that directly impact recycling. Bacot et al (1993) found that membership in an environmental group was more consistently and strongly associated with preferences for more extensive recycling programs (fee-based, mandatory, curbside programs that require households to separate recyclables) than most of the demographic characteristics of the individuals they surveyed. In Berger's study (1997) the influence of community demographics (education, income, size of service area, and type of dwelling) on recycling usage was significantly reduced when recycling access was included as a predictor, suggesting that demographics determine access to recycling, which then facilitates use of recycling services. Among single-family homes with access to curbside recycling, Derksen and Gartrell (1993) found significantly more items were recycled by households that reported greater concern for the environment. Kinnaman and Fullerton (2000) suggest that retired persons may have more time to separate and store recyclable waste, educated individuals may be more aware of recycling opportunities and prefer a cleaner environment, and owner-occupants of homes may generate more waste overall and therefore recycle more.

Other explanations are also possible. While older people may have more time to separate and recycle wastes, younger people may have more education on environmental issues or a better appreciation for the benefits of recycling. Higher income or home ownership could be linked to greater property ownership, which could motivate waste reduction as a way to reduce local environmental impacts and thereby protect property values. Larger household size may indicate presence of more families, who might wish to protect the environment and conserve resources for future use. The Democratic Party is traditionally associated with more environmental advocacy, and communities with a greater proportion of registered Democrats could be hypothesized to recycle more. Race and gender are interrelated with education and income, albeit in complex ways, which may explain findings linking them to recycling participation and behavior. Regardless the mechanism, research has shown that community demographics are important exogenous factors affecting the performance of household recycling programs. In some cases, demographic variables have been shown to be the most significant influence on performance. In a study of Florida county recycling programs, Feiock and Kalan (2001) found higher income, more educated counties had significantly higher recycling rates, but did not find that public support for environmental protection or recycling program design characteristics had a significant influence.

The ways community demographics influence recycling are important for understanding the constraints on recycling programs and for setting realistic expectations for program performance. However, these factors are generally not under the control of policymakers and program managers. To these stakeholders, it is usually of greater interest to understand how policies should be designed and how programs should be established in ways that maximize the amount of recyclable material collected while minimizing program unit costs. If features of the recyclable collection and management system itself, including local recycling policies, program designs, education strategies, collection systems, management practices, and other endogenous program factors are directly linked to the program performance, then understanding these features and their relative degree of influence can guide program and policy improvements to maximize opportunities for success.

Some research has shown that these types of endogenous program characteristics play a role in the success of recycling programs. Much of this research has been conducted by David Folz using the results of a 1990 survey of 264 municipal recycling coordinators across the US. In one analysis of these results, Folz (1991) examined the effects of the program design process and public education methods on the rate of citizen participation in recycling programs. Among curbside recycling programs, he found significantly higher participation in municipalities that established a recycling goal with a target year and involved citizens in the design of the program. Higher participation was also correlated with municipalities who reported that local government staff analysis, citizen opinion surveys, advice from private industry representatives, meetings with community groups, and assistance from nonprofit or volunteer recycling organizations were important to their program design decisions. Several public education strategies were significantly correlated with curbside recycling participation, including pamphlets, brochures, or bumper stickers; neighborhood or community information meetings; paid newspaper advertisements; and speeches by officials to schools or local groups about recycling. The importance of educating the public about recycling is echoed by the findings of others. Gamba and Oskamp (1994) found that relevant recycling program knowledge was the most significant predictor of observed recycling behavior. In a meta-analysis of 67 empirical studies of consumer recycling behavior, Hornik and Cherian (1995) found that consumer knowledge (of the importance of recycling and the recycling programs available to them) and social influence are among the best predictors of consumer propensity to recycle.

In another analysis of the same national survey data, Folz and Hazlett (1991) explored several other potential determinants of recycling program performance. Specifically, they investigated the effects of community demographic characteristics and recycling program features on two performance indicators: citizen participation in recycling and waste diversion rates. Among voluntary recycling programs that use drop-off facilities (which are also used in most special waste collection systems) older median age was significantly associated with both greater citizen participation and total waste diversion. Other features of the programs themselves, however, had more significant effects. Disposal of solid waste in a landfill outside of the county was associated with higher citizen participation and greater waste diversion in these communities, which suggests that higher solid waste transportation costs provide an incentive to reduce landfill disposal by increasing recycling. Higher citizen participation was also found among communities with more experienced recycling coordinators, and greater waste diversion rates were found in communities that used advertising firms and community information meetings to promote recycling. They conclude that endogenous program factors, and not demographic variables, are the most important determinants of household recycling program performance.

A large body of research has found associations between the convenience of recyclable collection systems and the resulting program performance. Hornik and Cherian (1995) found that frequency of collection was among the best predictors of consumer propensity to recycle. Derksen and Gartrell (1993) found that people with access to a structured recycling program (measured by the availability to households of a blue-box curbside recycling program on the same day as trash pickup) have much higher levels of recycling. Berger found that convenient access to a recycling program mediated the influence of socio-economic factors on recycling behavior. Peretz et al (2005) used a convenience scale for collection of household recyclables that considered collection frequency, required separation by households, availability of curbside collection, and collection on the same day as trash to develop an overall measurement for convenience. They found this measurement of program convenience has a very strong influence on citizen participation rate for both large and small communities.

The research reviewed thus far has focused on determinants of recyclable quantities collected by a program, or antecedent factors such as recycling behavior or citizen participation. Cost is another important indicator used to measure recycling program performance, and has been analyzed in several studies. Some research has found relationships between demographic variables and recycling program costs. Hyde and Lovejoy (1995) found that Indiana communities with more than 5000 households experienced lower per-household recycling costs, suggesting that recyclable collection efficiency is subject to economies of scale. Folz (1995) found both total and net recycling costs per ton decreased as community population increased up to 100,000, and increased again for cities with more than 100,000 people, suggesting similar economies of scale that are optimal in communities with 50,000-100,000 people. Carroll (1995) did not find similar economies of scale among 57 Wisconsin cities with curbside collection programs, but did find significant economies of density (lower average per-household collection costs in communities with higher population densities) when recycling collection is provided by a single firm or agency, either public or private.

Folz (1995) used his national survey data to analyze whether endogenous recycling program characteristics were related to reported costs of household recycling programs. He suggested that the process of designing conventional household recycling systems and public outreach can influence the reported operating costs per ton of material recycled. In this analysis he found that voluntary programs collecting recyclables using only drop-off sites incurred lower costs when using an open, consultative, democratic process for program design, specifically by placing more importance on citizen surveys, meetings with community groups, local government staff analysis, advice from other local officials or staff with recycling program experience, and assistance from local nonprofit or volunteer recycling organizations. Several decentralized, community-based education strategies were also associated with lower unit costs, including programs in local schools, speeches by local officials, neighborhood meetings, and pamphlets, brochures, and bumper stickers. Lower costs were also found among municipalities who solicited participation from commercial and industrial firms as well as by public institutions, and who set a specific recycling goal with a target year. Using results of a 1996 follow-up survey, Folz (1999) found communities that recycled more in 1996 had significantly decreased their total per ton recycling costs since 1989. These communities increased their recyclable volumes at a greater rate than their total program costs, which suggests they were able to take advantage of economies of scale in recyclable collection.

The degree of outsourcing or privatization may also have an effect on the performance of household recycling programs. Folz (1991) found higher citizen participation in recycling when private contractors collect recyclables, and suggests this could be due to revenue sharing or other contract incentives. Hyde and Lovejoy (1995) found that privatization has lowered per-household costs of refuse services and has greatly lowered costs associated with recycling. Carroll (1995) found that private firms working under city contracts are significantly more cost effective than municipal collection agencies.

While examining the findings of prior research focused on conventional household recyclables, it is important to consider several important differences between these materials and the special wastes targeted by this study. Conventional household recyclables are usually generated in greater quantities than scrap tires or white goods. In 2003, for example, over 16.8 million tons of glass, steel, aluminum, and plastic food and beverage containers were generated in the US, compared to only about 3.5 million tons of white goods and 4.8 million tons of scrap tires (US EPA, 2005). Households typically generate conventional recyclables more frequently, usually on a daily basis, while they might only discard used appliances or tires once every few years. A higher level of service is often provided for collecting household recyclables, often including weekly curbside pickup, while used tires and appliances must often be left with product retailers or transported to special drop-off locations. Many states allow landfill disposal of household recyclables but have banned for scrap tires and white goods from municipal solid waste landfills, and often require "final holders" of these wastes to follow special storage and handling requirements.

These differences may affect the relationships between exogenous factors, endogenous program characteristics, and resulting performance outcomes. Regular community education programs and convenient curbside pickup services, for example, might have a greater influence on the performance of programs collecting household recyclables generated on a daily basis than on the performance of programs collecting appliances discarded once every few years or scrap tires generated primarily at retail automotive stations. Differences in where, how much, and how frequently wastes are generated and variation in the collection and management processes must all be considered carefully when applying findings of household recycling program research to special waste collection and management programs..

METHODS

This exploratory analysis of North Carolina special waste program performance was conducted in two phases, with the first phase primarily focused on exogenous county characteristics and the second phase focused on endogenous features of county special waste programs. The first phase analyzed county demographic, social, and geographic characteristics seeking relationships between these factors and program performance measurements. In the second phase, phone surveys were conducted with selected counties to collect details about their special waste collection and management programs. This information was analyzed to determine which program characteristics were associated reported measurements of special waste program effectiveness (lbs/person) and efficiency (cost/ton).

These measurements are calculated for North Carolina white goods and scrap tire programs using quantity and operating cost data reported annually by each county. Historically, these measurements have varied significantly across the state. In fiscal year 2003-2004, for example, the effectiveness of NC county white goods programs ranged from 2.19 lbs/person to 170.25 lbs/person and the efficiency ranged from \$0.56 per ton to \$343.77 per ton. For county scrap tire programs, the effectiveness ranged from 14.51 lbs/person to 91.50 lbs/person with efficiency ranging from \$24.46 per ton to \$173.92 per ton.

The data used to calculate these measurements (i.e. waste quantities and operating costs) are influenced by a variety of factors that are both exogenous and endogenous to a recycling program. Exogenous factors include characteristics of a program's service area that are beyond the direct control of policymakers or program managers. These might include physical features (e.g. geographic location, land area, topography, etc.), demographic characteristics (e.g. population, population density, education, income, etc.), economic conditions (e.g. commercial facilities that produce large amounts of waste), and other circumstances. Endogenous factors are those that are readily influenced through changes to policies and programs. These include the structure and design of the program, public education and outreach initiatives, collection systems and infrastructure, management practices, degree of outsourcing or privatization, and other features or characteristics of the program itself.

The ways county special waste programs calculate and report their quantities and costs are also likely to have a significant influence on the variation of performance measurements. Many counties, for example, collect other types of scrap metal in addition to the metal present in discarded white goods, and ship all of their scrap metal to the same recycling facility. When reporting annual quantities to the state, some counties include all of their scrap metal tonnage without estimating the portion contributed by white goods. In most cases, this amount is likely to be small since most other major sources of scrap metal (such as junked automobiles and building materials) are collected and managed independently of county collection programs. However, the relative quantity of these other scrap metal sources could not be verified since they were not tracked separately.

The way counties are charged for scrap tire disposal can also affect the accuracy of reported quantities. When charged by the ton, the quantities reported are directly measured on truck scales and are relatively accurate. When charged based on the number of tires or number of truckloads, counties can only estimate the tonnage collected per year, and the accuracy of these estimates are highly sensitive to the assumptions used to produce them.

Methods used to calculate operating costs can also be a source of variation and potential error in efficiency measurements. The NC Solid Waste Section provides counties with some guidance on the types of costs that are eligible to fund from quarterly distributions of the white goods and scrap tire disposal taxes. Eligible costs include labor, equipment maintenance and operation, hauling, and disposal/recycling costs. The basic rule in these guidelines is that operating costs are reportable if they support a person or piece of equipment that physically touches the waste. Administrative costs, such as portions of solid waste director salaries, are not typically reportable or covered by disposal tax funding.

Each year, however, significant variation is observed in reported operating costs for white goods and scrap tire programs. In fiscal-year 2003-2004, these costs ranged from ranged from $414 to $269,108 for county white goods programs, and in fiscal-year 2004-2005 they ranged from $5,538 to $924,624 for county scrap tire programs. This high degree of variation, coupled with the fact that these costs are not normally audited for compliance with state guidelines, suggests they may be calculated somewhat inconsistently from county to county. In some cases, it may be difficult for counties to estimate costs even when using the guidelines. This is especially true in counties with comprehensive solid waste management contracts, where the county pays a private contractor a fixed monthly fee to provide all solid waste and recycling services for the county, including management of white goods and scrap tires. In other cases, costs may be determined by financial officials who are not involved with the county's solid waste programs, or by technical staff who have little financial accounting experience.

The process of selecting counties for each step of this analysis attempted to control for several of these potential sources of reporting errors. All counties that failed to report special waste quantities, program costs, or both were excluded. Counties that reported the number of tires or tire loads collected instead of their weight were also excluded from the analysis of scrap tire programs, since weight estimates based on the number of tires or loads requires assumptions involving significant uncertainty and potential error. Of those counties that did report the required information, the top and bottom 10% of counties were also excluded. This was done to minimize the chance of selecting counties whose performance measurements were excessively high or low because of potential reporting errors or other data anomalies, as described previously.

Of the 100 counties in North Carolina, this process excluded 34 counties from white goods program effectiveness analyses, 38 counties from white goods program efficiency analyses (4 counties reported quantities collected but not program costs), and 35 counties from scrap tire effectiveness and efficiency analyses. Excluding these counties reduced the standard deviation of program effectiveness measurements from 25.4 lbs/person to 13.8 lbs/person for white goods, and from 11.9 lbs/person to 5.8 lbs/person for scrap tires. It also reduced the standard deviation of program efficiency measurements from $76.30/ton to $35.84/ton for white goods, and from $26.59/ton to $12.74/ton for scrap tires.

Among the counties that were not excluded based on these criteria, there was no additional information available to detect and quantify the amount of error in reported performance data. While remaining errors may compromise the precision of performance measurements, there is no evidence to suggest the measurements are entirely inaccurate. For the purposes of this analysis, the measurements are assumed to provide rough indicators of how effectively and efficiently each North Carolina county special waste program operates. If the measurements are even partly accurate in representing program performance, then a significant portion of the differences among county measurements must be due to variations exogenous and endogenous factors; that is, the characteristics of the counties themselves and their programs for collecting these wastes.

The recycling research reviewed previously identified several demographic characteristics associated with recycling behavior, participation, and other determinants of performance measurements. These included population, population density, gender, age, non-minority population, education, income, home ownership, household size, and political affiliation. These demographic data were collected for North Carolina counties from the sources identified in Appendix A, and were used in the first phase of this analysis.

In addition to these demographic data, several other exogenous factors were considered to examine potential effects of special wastes transported into North Carolina counties from outside sources. Receiving special wastes from other counties or other states would increase the quantity collected by a county, inflating measurements for program effectiveness (lbs/person) and deflating measurements for efficiency (cost/ton). Three potential sources considered in this analysis are location of the county along a state border, presence of a regional landfill, and presence of an interstate highway.

State law requires each county in North Carolina to provide at least one site where white goods and scrap tires can be discarded and prevents counties from charging disposal fees at these sites. The states bordering North Carolina (Virginia, Tennessee, and South Carolina) also require their counties to provide collection sites for scrap tires, and South Carolina requires collection sites for white goods. Unlike North Carolina, however, these states allow their counties to charge fees at the time of disposal. This has led some citizens and businesses to transport special wastes, particularly scrap tires, from these other states into North Carolina border counties to take advantage of free disposal. To determine whether this problem was significant, a binary variable was included in this first phase of the analysis to indicate whether the county was located along a state border (1=located on a state border, 0=not located on a state border).

Presence of a regional landfill is another factor that could attract waste from external sources. Several counties in North Carolina host large, regional landfills that accept solid waste from other counties and even other states. If white goods or scrap tires are included in loads of waste sent by these external generators, they would have to be separated by the host county and recycled along with locally-generated special wastes to comply North Carolina's ban on landfill disposal of these wastes. To determine whether this was significant, a list of landfills in North Carolina was used to identify counties that hosted regional landfills and populate another binary variable (1=regional landfill present, 0=no regional landfill).

Interstate highways increase vehicle traffic through the counties where they are located. If the presence of interstate highway traffic also increases the number of events or activities producing scrap tires (such as flat tires, car accidents, or service stations offering tire changing services) over counties lacking interstate highways, their presence would be expected to increase generation of scrap tires in those counties. A state roadmap was used to identify counties that interstate highways passed through and to code a third binary variable (1=interstate highway present, 0=no interstate highway).

Linear regression was used to analyze the impact of these demographic and other exogenous variables on reported special waste program performance measurements. Results are presented in Table 1. Only 2 demographic variables were significant predictors of the white goods program effectiveness: population density and political affiliation. The regression coefficients for both variables were negative, suggesting that less dense counties and those with a smaller percentage of Democratic registered voters reported collecting more white goods per-capita. Population density narrowly missed significance for scrap tires program effectiveness ($p = 0.08$) and carried positive coefficient, suggesting that more dense counties collected more scrap tires per person. County population was a significant predictor of scrap tire program efficiency, and with a negative regression coefficient this finding suggests counties with larger populations had lower scrap tire costs per ton. None of the demographic or other exogenous factors were significantly associated with reported white goods program costs per ton.

Table 1: Regression results for exogenous factors and special waste program measurements

Parameter	White Goods Lbs/Person		Scrap Tires Lbs/Person		White Goods Cost/Ton		Scrap Tires Cost/Ton	
	β	p	β	p	β	p	β	p
Intercept	106.5775	0.4759	90.2122	0.1526	83.0471	0.8316	-104.77	0.4533
County population					3.11E-05	0.5841	-4.6E-05	0.0299*
County population density (persons per square mile)	-0.0410	0.0097*	0.0100	0.0776				
Gender (males per 100 females 18 years and over)	-0.1577	0.5339	-0.1210	0.2725	-0.9559	0.2173	0.3683	0.1519
Age (median age in years)	-0.1251	0.9232	-0.0769	0.8962	-2.4190	0.4902	1.8235	0.1964
Non-minority population (% White)	-0.4832	0.0970	0.0054	0.9662	-0.4892	0.5022	0.2102	0.4833
Education (% with bachelor's degree or higher)	0.5077	0.3938	-0.2269	0.3686	1.4666	0.3679	0.8349	0.1078
Income (median household income estimate)	-0.0006	0.4888	-0.0002	0.5074	-0.0005	0.8335	-0.0005	0.5036
Home ownership (% of housing units owned)	0.2662	0.6654	-0.1593	0.5865	1.2827	0.4660	-0.5742	0.3095
Average household size	0.5126	0.9912	-8.4241	0.6578	39.2933	0.7491	47.2317	0.2508
Political affiliation (% Democratic registered voters)	-57.1074	0.0305*	-6.2742	0.5847	-27.3685	0.6483	7.1273	0.7602
Regional landfill? (1=Yes, 0=No)	9.4079	0.0951	-0.3210	0.9109	-16.7379	0.3587	0.7988	0.8339
County on state border? (1=Yes, 0=No)	4.3646	0.2644	0.6694	0.6780	10.1463	0.3359	3.0118	0.4271
Interstate highway? (1=Yes, 0=No)	NA	NA	-0.9357	0.5642	NA	NA	-10.2455	0.5101
R^2	0.2732		0.2153		0.2105		0.2023	

* $p < 0.05$
NA = Not applicable

Discussion of these results is provided in the next section.

The second phase of this analysis targeted the endogenous characteristics of county special waste programs and their relationship with reported measurements of effectiveness and efficiency. Details of the collection process, infrastructure, management practices, and other aspects of NC county special waste programs are not available in any single, consolidated data source. Many counties provide this information to businesses and residents through a variety of media (handouts, brochures, websites, etc.), but the amount and availability of information varies significantly from county to county. To collect this information in a consistent format usable for analysis, a survey of county solid waste departments was required. A phone survey was selected as the data collection instrument to help maximize the response rate (non-responding counties could be called back until a response was received). This method also allowed for open discussion and probing for details of county programs that were not anticipated in the design of the survey questions.

To comprehensively describe relationships between features of county special waste programs and resulting performance measurements, information about white goods and scrap tire programs could be collected from all 100 counties in North Carolina. This option, however, would require a labor intensive process of contacting 100 counties by phone and surveying each one about both types of special waste programs. Theoretically, a representative sample of counties could be selected and surveyed about their special waste programs. However, the number and variety of factors that could potentially affect waste quantities and program operating costs (including exogenous characteristics such as population density and endogenous program features such as program design, outreach, collection infrastructure, management practices, etc.) would make it difficult to select a sample that is truly "representative" of all counties in the state. While both of these options would provide a comprehensive understanding of the determinants of county special waste program performance statewide, both involve a very difficult process for either collecting data or selecting counties to survey. It was desirable to use a simpler process for selecting and surveying counties, specifically one involving a smaller number of counties that focused on information most useful for identifying future research needs, enhancing special waste programs, and improving public policy.

When analyzing recycling program performance, researchers, program managers, and policymakers are interested in knowing which policy elements and program features are most significant in promoting or hindering program success. Identifying these factors can provide targets for future research involving all counties, or samples of counties that are representative in the areas of concern. Knowing what the best performers may be doing right and what the worst performers may be doing wrong may also provide focus areas for county solid waste managers and state policymakers to explore how existing programs and policies could be enhanced. Many of these factors can be identified by contrasting features of county programs reporting high measurements with those reporting low measurements. If endogenous program factors are consistently associated with measurements of program performance, these associations should be strongest in samples of programs whose measurements are among the highest and lowest of all similar programs. This second phase of the analysis, therefore, focuses on counties whose recent measurements of program effectiveness (lbs/person) and efficiency (cost/ton) were among the highest and lowest reported across the state, for both white goods and scrap tire programs.

In the first phase of this analysis, county population density was found to be significantly associated with the effectiveness of white goods programs, and approached significance in its relationship with the effectiveness of scrap tire programs. Higher county population was also significantly associated with lower scrap tire costs per ton. Since the second phase of this analysis was focused on the endogenous characteristics of special waste programs, it was desirable to control for the effects of these known relationships. This was attempted in the process used to select counties for participation in the detailed phone surveys. Before selecting counties to participate, the exclusion criteria used in the first phase of this analysis were applied to the list of counties once again (i.e. excluded counties failing to report quantity and cost data, counties reporting scrap tire numbers or loads instead of tons, and the top and bottom 10% of the remainder). Counties were then stratified based on population density and total population, ranked by their program effectiveness measurement (lbs/person) within each stratum of population density, and ranked by their program efficiency measurement (cost/ton) within each stratum of total population. The top- and bottom-ranked counties in each stratum were selected to participate in detailed phone surveys. More details about the stratification and selection process are provided in Appendix B. Selecting counties from each strata of population density and population improved chances any significant findings in the second phase of this analysis are would be associated with differences in the design and operation of the special waste programs themselves, rather than population density or population which were already found to have an effect. The counties surveyed for each program are listed in Tables 2 and 3 and shown in Figures 5 and 6.

Table 2: Counties surveyed for white goods management programs

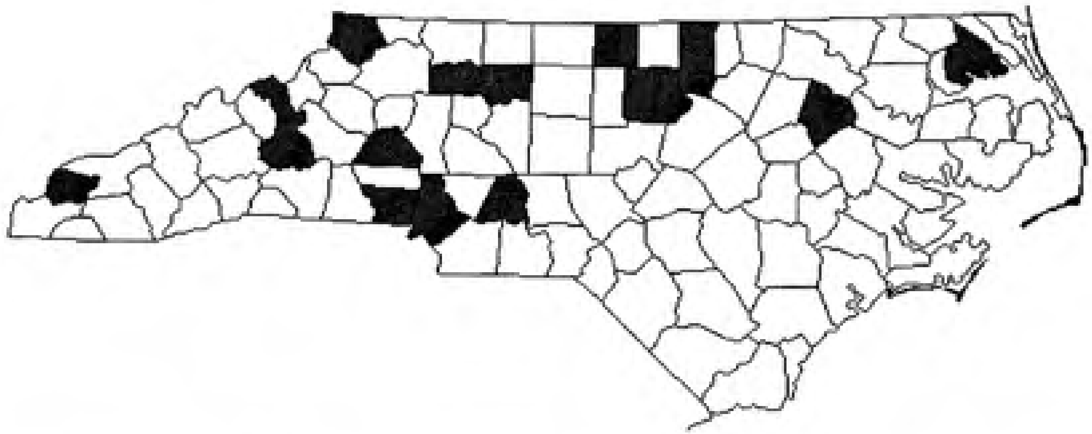
County	White Goods Lbs/Person	White Goods Cost/Ton	2003 Population	2003 Population Density (persons / mi^2)
Anson	58.40	$0.56	25,238	47.48
Avery	57.53	$68.38	18,076	73.18
Caldwell	39.57	$18.89	78,188	165.79
Cherokee	15.26	$19.97	25,290	55.56
Clay	31.97	$22.75	9,384	43.71
Davidson	11.60	$33.92	151,942	275.18
Davie	8.49	$86.09	37,240	140.43
Guilford	7.06	$10.97	431,247	664.05
Halifax	28.02	$17.98	56,822	78.34
Harnett	8.66	$131.61	97,710	164.22
Henderson	43.17	$18.13	94,547	252.80
Johnston	8.67	$63.22	136,394	172.25
Jones	15.68	$47.69	10,201	21.62
Lenoir	52.25	$62.27	58,904	147.32
Lincoln	46.01	$14.68	67,374	225.49
Onslow	12.46	$45.51	156,550	204.15
Northampton	23.16	$149.48	21,762	40.56
Pitt	33.02	$21.71	138,958	213.26
Richmond	8.30	$29.02	46,481	98.07
Vance	10.94	$146.74	43,856	172.99
Wake	5.01	$134.47	701,052	842.69

Table 3: Counties surveyed for scrap tire management programs

County	Scrap Tires Lbs/Person	Scrap Tires Cost/Ton	2004 Population	2004 Population Density (persons / mi^2)
Ashe	41.77	$60.00	25,104	58.91
Caswell	20.44	$96.98	23,670	55.74
Catawba	42.30	$69.66	147,789	369.50
Durham	28.39	$90.57	238,865	822.76
Edgecombe	35.59	$72.07	53,916	106.76
Forsyth	39.09	$75.98	320,764	783.12
Gaston	24.49	$79.32	192,044	539.13
Graham	35.33	$64.50	8,074	27.64
Granville	20.74	$118.20	52,942	99.68
Mcdowell	37.71	$92.20	43,247	97.91
Mecklenburg	34.90	$68.91	768,789	1,460.80
Mitchell	56.28	$108.77	15,992	72.22
Orange	20.36	$110.30	120,965	302.53
Pasquotank	40.88	$107.45	37,606	165.75
Perquimans	19.76	$84.71	11,840	47.90
Stanly	31.24	$111.30	59,078	149.54
Yadkin	25.15	$66.57	37,054	110.43

Figure 5: Counties surveyed for white goods management programs

Figure 6: Counties surveyed for scrap tire management programs



Once counties were selected for the survey, their solid waste directors were contacted by phone. All counties reached by phone agreed to participate, although some solid waste directors delegated participation to another member of their department who was more familiar with the details of their white goods or scrap tire program. Of the 38 counties selected, only one of the originally selected counties (Tyrrell) could not be reached by phone and the next-ranked county was selected and surveyed in its place.

The phone surveys requested detailed information about many aspects of each county's special waste collection and management program. These aspects were grouped into the following categories for the survey and subsequent analyses:

- Participants in the design of the special waste program: Survey participants were asked which of the following participated or provided input in the design of the county's special waste program: county government staff, staff of other units of local government staff (i.e. towns or cities), state agency staff, private industry representatives, nonprofit or volunteer organizations, published reports or studies, and private citizens.
- Education and outreach methods: In this section, participants were asked which of the following methods the county used to educate citizens and businesses about special waste disposal in the county: posting signs at public places, meeting with product dealers/retailers, mailing information to product dealers/retailers, mailing inserts or newsletters to county residents, handing out pamphlets/brochures/bumper stickers, presenting at community meetings, describing programs in speeches by local or state officials, advertising programs through newspapers, radio, television, or billboards, or providing program information through websites.
- Collection methods and convenience: Participants were asked to provide the number of collection sites available for drop off of special wastes in the county, any towns or cities in the county that offered curbside collection of special wastes, and the number of special collection events hosted annually where special wastes can be dropped off. In the survey of scrap tire programs they were asked whether any tire dealers hauled scrap tires directly to processing facilities.

- <u>Outsourcing of special waste management:</u> In this section, participants were asked whether each of the following steps in the special waste management process was performed by local government staff or by contractors: staffing convenience sites, hauling to the central collection site, managing the central collection site, loading trucks, and hauling to processing facilities.
- <u>Efforts to minimize cost and maximize revenue:</u> Participants were asked whether the county used a competitive bid process before signing their contract for processing of special wastes. In the survey of scrap tire programs, participants were asked to provide the county's scrap tire disposal cost per ton. In the survey of white goods programs, participants were asked whether the county receives revenue for their scrap metal, and whether this revenue remains in the county solid waste department budget (called an "enterprise fund" if the department is allowed to keep revenue)
- <u>Management practices:</u> In this section participants were asked how the county manages special wastes at the central collection site, specifically whether special wastes were stored under shelter and whether they used a dock or loading platform when loading special wastes into trucks. In the survey of white goods programs, participants were asked whether the county separates refrigeration devices from other white goods, removes refrigerant gases, or stores white goods are stored on a concrete pad. In the survey of scrap tire programs, participants were asked whether the county separates tires by type, store tires in a trailer, "lace" tires when loading them into trucks, or use heavy equipment (bulldozers, grapplers, loaders, etc) for moving and loading scrap tires

- Hauling distance: Participants were asked to provide the physical address of their central collection site and the location of the facility where their white goods or scrap tires are hauled for processing.

While counties were selected for the survey based on a single performance measurement (effectiveness or efficiency), all counties were asked the same set of survey questions about their special waste program. This allowed use of all county responses in the subsequent analyses of each program measurement, increasing the sample size. Extreme performance measurements (those that fell within the top 10% or bottom 10% of all counties in the state) were still excluded from each analysis. As a result, for each performance measurement in each program, at least half of the counties analyzed had very high or very low measurements, and the other counties had measurements that fell somewhere in between.

Results of the phone surveys were coded and analyzed using SAS JMP™ Release 6.0.0. Forward stepwise linear regression was used to examine relationships between special waste program characteristics and resulting performance measurements. This is a statistical technique that creates a linear model iteratively by inserting the most significant predictors of an outcome variable within a specified range of significance while removing predictors that fall outside the range. Default settings for the forward stepwise regression analyses were used in all cases. The probability to enter the model was set at 0.25, and the probability to leave was set at 0.10.

The analysis was performed using a two stage process. First, separate stepwise regressions were constructed for each category of variables listed above using all of the variables in that category (e.g. all design participants, all outreach techniques, all collection methods, etc.). These regressions were run to select the individual variables in each category with the most statistically significant regression coefficients. Second, all variables with coefficients where $p<0.10$ were grouped into a final regression model, using the same forward stepwise technique. This model was run to evaluate the relative influence of all significant variables on overall special waste program performance. Lists of these variables and regression results are provided in the next section.

RESULTS AND DISCUSSION

The analysis of demographic and other exogenous predictors of program performance, described in the previous section, found that more densely populated counties reported collecting lower quantities of white goods per person, but greater quantities of scrap tires per person (although the latter finding narrowly missed significance). The opposite effects of population density on the regression coefficients for white goods and scrap tire programs may be explained by the relative value of recycled materials between these two products. More densely populated regions typically include urban areas that have greater concentrations of retail businesses, including appliance retailers. These retailers often take used appliances back from customers when delivering new ones. This service not only provides more convenience for customers, it also enables retailers to sell used appliances directly to scrap metal dealers as an additional source of revenue. Higher independent recovery and recycling of used appliances by retailers in more densely populated counties could reduce the quantity of white goods collected by county government programs. Tires, on the other hand, are significantly more expensive to recycle than white goods due to lower market values for recycled rubber products. Generators must usually pay recyclers to accept and process scrap tires. North Carolina state law, however, mandates free disposal of tires at county collection sites statewide and provides funding for managing these tires from the 2% privilege tax. As a result, tire retailers typically haul their used tires where they are accepted at no charge. While some tire retailers haul their scrap tires directly to processing facilities, tire disposal charges are still billed to the solid waste department of the county where the retailer is located. As a result, the presence of more tire retailers in more densely populated counties could increase the quantity of scrap tires collected by county government programs. Unfortunately, comprehensive data on the locations and practices of retailers were not available so further research is needed to explore and confirm these possibilities.

It is also possible that more densely populated counties increase opportunities to reuse appliances rather than discard them. Appliances are often discarded and replaced not because they are broken down, but simply because they are old. Appliance owners that live in more densely populated counties may have more opportunities to sell these old but functional appliances through garage or yard sales, or to donate them to thrift stores. Increased reuse of white goods in these counties could reduce the quantities collected by county white goods programs.

The observed relationship between counties with lower percentages of voters registered as Democrats and those that collected greater quantities of white goods per capita may also be due to the influence of population density. A separate linear regression found a weak but significant inverse relationship between population density and the percentage of registered Democrats ($\beta = -1.76e\text{-}04$, $p = 0.02$). In other words, more densely populated counties also have a smaller proportion of voters registered as Democrats in North Carolina. This suggests that the relationship between the quantity of white goods collected per capita and the percentage of voters registered as Democrats may be an artificial result of its relationship with population density, and not a direct impact of the county's political affiliation on white goods collection. Removing the percentage of registered Democratic

Party voters from the linear regression analysis of all exogenous factors did not change the statistically significant finding that counties with lower population densities collected more white goods per capita. Removing the population density from this analysis, however, eliminated the significance of the relationship with the percentage of voters registered as Democrats. Because of its close relationship with population density, county political affiliation was not considered further in this study.

Higher county population was significantly associated with lower scrap tire costs per ton. This suggests the costs of managing scrap tires may be subject to economics of scale, which would be consistent with the findings of Hyde and Lovejoy (1995) related to household recycling. Larger counties that generate more tires may be able to use their greater quantities as leverage to negotiate lower per ton disposal charges with tire recyclers. These counties may also employ more administrative staff for solid waste management. While costs for these staff are not reportable to the state, their knowledge and services may still help to keep scrap tire costs low on a per ton basis.

As described previously, counties were sorted and stratified by these significant demographic characteristics (population density and total population). Within each stratum, counties with the highest and lowest performance measurements were selected to participate in detailed phone surveys about the design and operation of their special waste management program. To test whether this stratification process successfully reduced the effects of these demographic variables among selected counties, a regression analysis was run to test the effects of population and population density on each performance measurement for each program. Results of this analysis are presented in Table 4.

Table 4: Regression results for exogenous factors on selected counties

Parameter	White Goods Lbs/Person		Scrap Tires Lbs/Person		White Goods Cost/Ton		Scrap Tires Cost/Ton	
	β	p	β	p	β	p	β	p
Intercept	41.22	0.0084	30.11	<0.0001	52.43	0.0012	90.61	<0.0001
County population					9.24e-5	0.2194	-2.88e-5	0.2271
County population density (persons per square mile)	-0.0385	0.2223	0.0031	0.5807				
Political affiliation (% Democratic registered voters)	-17.4418	0.4324						
R^2	0.0989		0.0223		0.0926		0.1101	

The results of this regression show that county population density and political affiliation were not significantly associated with program effectiveness (pounds of white goods and scrap tires collected per county resident) and total county population was also not significantly associated with program efficiency (cost per ton) among selected counties. The stratification process used to select counties successfully reduced the known effects of these exogenous demographic characteristics, so they are no longer significant determinants of program performance among selected counties. Subsequent analyses were performed using forward stepwise linear regression on each category of responses collected during the surveys.

The first variables analyzed were the participants that provided input to counties in the design of special waste programs. Survey participants were asked whether county government staff, staff of other units of local government (i.e. towns or cities), state agency staff, private industry representatives, nonprofit or volunteer organizations, published reports or studies, and/or private citizens participated in the design of the county white goods or scrap tire collection program. These design participants were used as predictors of each performance measurement (lbs/person and cost/ton) for each special waste program. Results of this regression analysis are provided in Table 5.

Table 5: Regression results for design participants

Parameter	White Goods Lbs/Person (n=20)		Scrap Tires Lbs/Person (n=16)		White Goods Cost/Ton (n=18)		Scrap Tires Cost/Ton (n=15)	
	β	p	β	p	β	P	β	p
Intercept	14.03	1.0000	24.20	1.0000	74.50	1.0000	88.93	1.0000
County government staff provided program design input (0=No, 1=Yes)	19.26	0.0285*	0 †	0.6386	‡	‡	-18.74	0.0376*
Other local government staff provided program design input (0=No, 1=Yes)	0 †	0.9025	0 †	0.5752	0 †	0.6573	0 †	0.3602
State agency staff provided program design input (0=No, 1=Yes)	0 †	0.6542	0 †	0.8537	0 †	0.5049	8.99	0.0588
Private industry provided program design input (0=No, 1=Yes)	12.18	0.0044*	-5.65	0.0159*	17.00	0.1503	0 †	0.9201
Nonprofit / volunteer organizations provided program design input (0=No, 1=Yes)	7.39	0.1390	‡	‡	0 †	0.3616	‡	‡
Published reports or studies provided program design input (0=No, 1=Yes)	-7.50	0.0654	-4.70	0.2202	15.16	0.2184	-12.61	0.1198
Private citizens provided program design input (0=No, 1=Yes)	0 †	0.6184	0 †	0.4845	0 †	0.6803	0 †	0.5428
R^2	0.4953		0.3941		0.2237		0.4627	

* $p < 0.05$
† Regression coefficients are set to zero when dropped from the stepwise linear regression model
‡ No variation observed in responses to these questions

These results show that input from county government staff and private industry representatives were both associated with higher effectiveness of white goods programs. Several possibilities are suggested by this result. County government staff may use their understanding of citizen needs, preferences, and behaviors to find the most convenient locations for establishing white goods collection sites. Representatives from private industries, such as appliance retailers or scrap metal dealers, might contribute their awareness of major sources of white goods in the county, possibly including commercial or industrial sources. Soliciting input from these stakeholders when designing white goods collection programs could help counties establish optimal systems that help to maximize quantities collected. This is consistent with the correlations observed by Folz (1991) between higher participation in recycling and importance of local government staff analysis and advice from private industry representatives

The opposite sign of the regression coefficient for scrap tire programs indicates that input from private industry representatives was associated with lower program effectiveness. When tire dealers are involved with the design of county scrap tire programs, they may encourage county governments to provide a more extensive collection system so that fewer tire businesses need to collect, store, and haul scrap tires themselves. If county-sponsored tire collection options are less convenient than tire retailer collection, a possibility suggested by evidence presented later, county residents may store more used tires in their garages or discard them illegally. This would reduce the per-capita quantity of scrap tires collected by county programs. Retailers that refuse to accept used tires for disposal, however, may also receive less business from consumers who value the convenience of this service. More research is needed on the possible causes of this finding.

Input from county government staff was significantly associated with lower scrap tire costs per ton, suggesting that using in-house local knowledge of the county when designing scrap tire programs could be a way to keep costs low. This would support one relationship found by Folz (1995), that municipalities placing more importance on local government staff analysis incurred lower costs per ton for conventional household recyclables. Input from state agency staff was associated with higher costs per ton for scrap tire programs, although this narrowly missed achieving significance (p=0.06). It differs from Folz's finding that input from input state agency staff was associated with lower household recycling units costs (1995). When providing input to counties on the design of their scrap tire programs, state agency representatives are probably not making recommendations that result in more expensive programs. It is more likely that counties with extensive, more costly programs solicit help from state agency representatives, possibly to help them reduce costs.

Other associations found by Folz (1991, 1995) are also unsupported by these results. Program design input from nonprofit or volunteer organizations, published reports or studies, or private citizens in program design were not significantly associated with either performance measurement. Key differences between special wastes and conventional household recyclables, such as reduced frequency of generation or lower total quantities, could reduce the impact of these stakeholders' input on resulting performance measurements of county special waste programs.

To assess the effect of county education and outreach efforts on program performance, phone survey participants were asked whether they educated citizens and businesses about the special waste program by posting signs at public places, meeting with product dealers or retailers, mailing information to product dealers or retailers, mailing inserts or newsletters to county residents, handing out pamphlets, brochures, or bumper stickers, presenting at community meetings, describing programs in speeches by local or state officials, advertising programs through newspapers, radio, television, or billboards, or providing program information through websites.

North Carolina's 1989 Solid Waste Management Act requires the state Department of Environment and Natural Resources to provide public education programs to encourage recycling through public workshops, brochures, reports, and public service announcements. It also requires the Department of Public Instruction to develop curriculum materials and resource guides for recycling education, and requires school districts required to promote recycling awareness. Recycling is broadly defined by these portions of the law, however, and there are no requirements for public education specifically targeting white goods or scrap tires. State agencies have responded by developing lesson plans and activity books for use in schools, an advertising campaign using cartoon characters called the "Recycle Guys", resources for local governments, and recycling information and brochures for members of the public. Some of these resources include information about recycling white goods and scrap tires.

Most survey participants indicated their county's methods for education and outreach covered both household recyclables and special wastes. They were asked to specify only those methods that included information about white goods or scrap tire disposal, and were conducted by the county government. While county governments probably used some state resources in their recycling education and outreach programs, it was not possible to completely assess the extent of their use through this brief survey of county solid waste directors. In most cases, state resources would be incorporated into larger recycling education programs directed by county governments. While the independent effects of state education resources are not analyzed here, significant associations between specific education methods and performance outcomes could highlight targets for future study of how state education resources contribute to the performance of NC county special waste programs.

Regression results for special waste education and outreach methods used by North Carolina counties are provided in Table 6.

Table 6: Regression results for education and outreach methods

Parameter	White Goods Lbs/Person (n=20)		Scrap Tires Lbs/Person (n=16)		White Goods Cost/Ton (n=18)		Scrap Tires Cost/Ton (n=15)	
	β	p	β	p	β	p	β	p
Intercept	18.94	1.0000	21.21	1.0000	85.86	1.0000	103.37	1.0000
Posted signs used to educate (0=No, 1=Yes)	0 †	0.4936	0 †	0.6672	0 †	0.8666	0 †	0.9816
Meeting with product dealers / retailers used to educate (0=No, 1=Yes)	0 †	0.9016	6.44	0.0029*	30.55	0.0869	-7.63	0.0053*
Letters to product dealers / retailers used to educate (0=No, 1=Yes)	‡	‡	0 †	0.5773	‡	‡	-11.02	0.0022*
Mailing inserts / newsletters to county residents used to educate (0=No, 1=Yes)	0 †	0.6681	0 †	0.9952	0 †	0.7409	0 †	0.4451
Pamphlets, brochures, or bumper stickers used to educate (0=No, 1=Yes)	0 †	0.6984	0 †	0.7651	0 †	0.2599	10.21	0.0027*
Presentations at community meetings used to educate (0=No, 1=Yes)	-10.11	0.0708	0 †	0.4218	‡	‡	-12.56	0.0037*
Speeches by local/state officials used to educate (0=No, 1=Yes)	0 †	0.4894	-3.91	0.1483	0 †	0.3660	18.95	0.0025*
Newspaper advertisements used to educate (0=No, 1=Yes)	0 †	0.9378	‡	‡	0 †	0.8727	‡	‡
Radio or television advertisements used to educate (0=No, 1=Yes)	0 †	0.3825	0 †	0.8418	0 †	0.6363	7.10	0.0678
Billboards used to educate (0=No, 1=Yes)	‡	‡	-7.07	0.0564	‡	‡	8.81	0.1076
Website used to educate (0=No, 1=Yes)	0 †	0.9395	0 †	0.3195	0 †	0.4913	0 †	0.4381
R^2	0.1700		0.5589		0.1722		0.9265	

* $p < 0.05$
† Regression coefficients are set to zero when dropped from the stepwise linear regression model
‡ No variation observed in responses to these questions

Several education and outreach methods were associated with the performance of scrap tire programs. Counties that met regularly with tire retailers collected significantly more pounds of scrap tires per person. Most counties indicated that meetings with tire dealers were used to keep them informed about scrap tire regulations and options for disposing of scrap tires in the county. They were also used to ensure tire retailers were completing and submitting scrap tire certification forms, which certify that the scrap tires were generated in North Carolina, and are required for loads of more than 5 tires to be eligible for free disposal. This finding could suggest that engaging retailers in collection of scrap tires results in a more convenient collection system. By serving as additional collection sites, tire dealers may help counties to collect more scrap tires on a per-capita basis. It is also possible, however, that this outreach method is positively correlated with the number or size of tire dealers operating in the county. In other words, meetings with tire dealers may occur more often in counties with a greater number of retailers, or in counties with large retailers that are significant sources of scrap tires. Retailers in these counties could attract customers from outside of the county, and cause the county to generate disproportionately large quantities of scrap tires.

Use of billboards was associated with lower scrap tire effectiveness. While this finding did not attain significance ($p=0.06$), it could be due to a perception of billboards as unfriendly to the environment and aesthetically displeasing, which could have a negative impact on scrap tire recycling. This was also suggested by Folz (1991) to account for a negative correlation between citizen participation in household recycling and municipalities that advertised recycling using billboards.

Educating tire dealers by meeting with them and by mailing information to them were both significantly associated with lower scrap tire costs per ton. This finding could suggest that engaging retailers in collection of scrap tires from their customers could be more cost-effective than using only collection options provided by county or local governments. Retailers that collect scrap tires typically pay for storage at their facilities and hauling to county collection sites, effectively creating staffed convenience sites at no additional cost to county scrap tire programs. However, as described previously, these outreach methods could also be associated with the number or size of tire retailers operating in the county. Counties with larger tire dealers or a greater density of these businesses could attract customers from outside of the county. By collecting scrap tires from these customers, these retailers would increase the quantity of scrap tires collected in the county, which would decrease overall costs per ton.

Presenting information at community meetings was associated with lower costs per ton for scrap tire programs. Most counties using this method indicated special waste recycling information was presented at local schools, civic organizations, and county commissioner meetings. This approach may be an effective way to educate the public about scrap tire recycling and reduce total costs per ton by minimizing the need for a more extensive collection system. This would support the finding by Folz (1995) that using decentralized, community-based education strategies were associated with lower unit costs among municipal recycling programs.

The use of pamphlets, brochures, or bumper stickers and speeches by local or state officials was significantly associated with greater costs per ton for scrap tire programs. Use of radio or television advertisements also approached significance in its association with higher scrap tire costs per ton. While outreach and advertising campaigns can be expensive, it is unlikely these higher costs include expenses for producing brochures, hosting speakers, or paying for radio or television ads. These are considered administrative costs and are not reportable to the state or covered by advanced disposal fee funding. Typically, these forms of advertising are used to provide information about a county's entire recycling program, including collection options for household recyclables, scrap tires, and other materials. Counties that use pamphlets, brochures, radio and TV ads, and similar media in their education strategies might also tend to provide more extensive recycling programs (e.g. programs with more collection sites and better management of recyclable materials). These counties might also support scrap tire recycling programs that are more costly on a per ton basis, which might explain the observed association. Funding for these more expensive recycling programs would probably require support from local leadership, which may be expressed through speeches. This association contrasts with the finding of Folz (1995), who discovered that pamphlets, brochures, and bumper stickers were associated with lower recyclable unit costs.

None of the education and outreach methods reached conventional levels of significance in their relationships with the effectiveness or efficiency of white goods programs. Counties that presented information at community meetings were associated with lower effectiveness ($p=0.07$). These presentations may help to improve citizen awareness about the importance of white goods recycling and encourage increased collection. However, if citizens respond by utilizing more convenient pickup services offered by appliance retailers instead of county collection programs, they may actually decrease the quantity of white goods collected by county government programs.

Meetings with retailers were associated with higher cost per ton among white goods programs, although this relationship failed to achieve significance ($p=0.09$). Instead of encouraging retailers to ship white goods to county collection sites, these meetings might make them aware of increasing scrap metal value that they could recover by independently collecting and recycling used appliances. They may respond by starting to collect white goods independently of county programs, possibly by picking up used appliances when delivering new ones, to recover the scrap metal value. This would reduce the amount of scrap metal revenue received by county white goods programs, which would also reduce the amount of scrap metal revenue received by counties and possibly increase net costs per ton.

Posting signs, mailing inserts or newsletters to county residents, newspaper advertisements, and websites were also not significantly associated with either performance measurement of either program. These methods are somewhat more passive than the other outreach methods examined in this study, and it is possible that when used they are more likely to be ignored by citizens.

To measure the effect of special waste collection infrastructure on program performance, survey participants were asked to provide the number of collection sites where residents and businesses can drop off special wastes, towns or cities where curbside collection of special wastes are available, the annual number of special collection events where special wastes are accepted, and whether any tire dealers haul scrap tires in the county directly to processing facilities. The total number of county collection sites was divided by the total county population as a measurement of site accessibility (more collection sites per 10,000 residents indicates a more "dense" collection system). The list of towns or cities served by curbside collection was used to calculate the percent of the county population who had curbside collection available to them. This data was used to analyze the effect of each collection method on special waste program effectiveness. Results of the regression analysis are provided in Table 7.

Table 7: Regression results for collection infrastructure

Parameter	White Goods Lbs/Person (n=20)		Scrap Tires Lbs/Person (n=16)		White Goods Cost/Ton (n=18)		Scrap Tires Cost/Ton (n=15)	
	β	p	β	p	β	p	β	p
Intercept	19.33	1.0000	28.20	1.0000	47.86	1.0000	86.62	1.0000
Number of drop off collection sites per 10,000 residents	8.88	0.0279*	4.80	0.0939	45.28	0.1219	0 †	0.9259
Percent of county residents served by curbside collection	-11.73	0.2362	0 †	0.5096	0 †	0.4905	0 †	0.3538
Annual number of special collection events	0 †	0.5566	0 †	0.5971	0 †	0.8336	0 †	0.9833
Dealers/retailers haul directly to processing facilities (0=No, 1=Yes)	NA	NA	4.48	0.0393*	NA	NA	0 †	0.2675
R^2	0.3603		0.3306		0.1429		0.0000	

* $p < 0.05$
† Regression coefficients are set to zero when dropped from the stepwise linear regression model
NA = Not applicable

These results show a significant positive association between the per-capita quantity of white goods collected in a county and the number of collection sites per 10,000 county residents. This supports the finding by Bach et al (2003) that higher densities of drop-off collection sites can increase the quantity of waste collected. It is also consistent with the recycling literature reviewed previously suggesting more convenient recycling systems improve recycling participation and behavior.

No significant relationship was observed between the number of collection sites and the effectiveness of scrap tire programs, but having tire dealers in the county haul directly to processing facilities was significantly associated with higher program effectiveness. In the previous analysis of education and outreach methods, a significant association was observed between counties that met with tire dealers and those that collected more scrap tires per person. Together, these observations could suggest tire dealers play an important role in the collection of scrap tires. As previously discussed, however, tire dealers normally have to produce large volumes of scrap tires to justify direct shipments to processing facilities. It is possible that these larger dealers are attracting customers from outside of the county, which would inflate the quantity of scrap tires collected in the county on a per-capita basis.

None of the other collection methods were significantly associated with the effectiveness of these county special waste programs. During the phone surveys, almost all counties mentioned that curbside collection or special events were insignificant sources of special wastes compared to the quantities dropped off at retailers, convenience sites, landfills, and transfer stations. Most counties, however, either did not track or could not quantify the exact percentages of waste collected through each method, so these claims could not be verified.

No significant association was observed between these collection methods and costs per ton for either white goods or scrap tire programs. The costs for collecting scrap tires and consolidating them at a county's central collection site may only be a small portion of total costs, and variations in these collection systems may not have a significant effect on overall costs per ton. It is also possible that higher costs for supporting more extensive white goods collection systems are offset by increased scrap metal revenue received for the wastes collected. If the extent of the collection system truly does not have a significant impact on total program costs per ton, it may suggest that counties could expand their collection infrastructure by adding more drop-off collection sites or encouraging more tire retailers to participate without significantly increasing their costs per ton.

To examine whether outsourcing special waste management to private companies had an influence on special waste program performance, survey participants were asked which steps of the special waste management process are performed by local government staff, and which ones are performed by employees of a private company under contract with the local government. Process steps included management of the county's central collection site, loading special wastes into trucks, and hauling special wastes to processing facilities. If a county's collection system included convenience sites (drop-off collection locations remote from the county landfill or transfer station), they were also asked if those sites were staffed by local government employees or contractors, and whether hauling of wastes from those sites was performed by local government employees or contractors. Their responses were analyzed and the results are provided in Tables 8 and 9.

Table 8: Regression results for outsourcing central collection site management

Parameter	White Goods Lbs/Person (n=20)		Scrap Tires Lbs/Person (n=16)		White Goods Cost/Ton (n=18)		Scrap Tires Cost/Ton (n=15)	
	β	p	β	p	β	p	β	p
Intercept	28.54	1.0000	30.35	1.0000	58.02	1.0000	86.62	1.0000
Central collection site managed by county/local government (0=No, 1=Yes)	0 †	0.5933	0 †	0.3562	0 †	0.8828	0 †	0.5623
Wastes loaded into trucks by county/local government staff (0=No, 1=Yes)	-9.56	0.0711	3.14	0.1512	-18.34	0.1133	0 †	0.9370
Wastes hauled to processing facilities by county/local government staff (0=No, 1=Yes)	-7.40	0.2402	0 †	0.2923	0 †	0.7186	‡	‡
R^2	0.1791		0.1413		0.1493		0.0000	

* $p < 0.05$
† Regression coefficients are set to zero when dropped from the stepwise linear regression model
‡ No variation observed in responses to these questions

Table 9: Regression results for outsourcing convenience site operations

Parameter	White Goods Lbs/Person (n=15)		Scrap Tires Lbs/Person (n=7)		White Goods Cost/Ton (n=13)		Scrap Tires Cost/Ton (n=6)	
	β	P	β	p	β	P	β	p
Intercept	26.84	1.0000	31.25	1.0000	78.13	1.0000	95.38	1.0000
Convenience sites operated by county/local government staff (0=No, 1=Yes)	0 †	0.6352	‡	‡	-40.31	0.0004*	‡	‡
Wastes hauled from convenience sites to central collection site by county/local government staff (0=No, 1=Yes)	0 †	0.6887	0 †	0.9449	0 †	0.8450	-12.73	0.1477
R^2	0.0000		0.0000		0.6972		0.4452	

* $p < 0.05$
† Regression coefficients are set to zero when dropped from the stepwise linear regression model
‡ No variation observed in responses to these questions

Outsourcing steps of the collection and management process for either special waste program was not significantly associated with measurements of program effectiveness. This was true for all steps in special waste management at central collection sites in addition to steps at remote convenience sites. This does not support findings of previous research related to household recyclables, which suggested outsourcing recyclable collection influenced recycling participation and other determinants of recycling program effectiveness. For special wastes, outsourcing collection and management may not necessarily increase quantities collected per resident.

Outsourcing collection may not guarantee reductions in costs per ton either. In fact, among counties that collected white goods at convenience sites, using county or local government employees to staff those sites was significantly associated with *lower* costs per ton. This contrasts with previous findings of Folz (1991), Hyde and Lovejoy (1995), and Carroll (1995) in the area of household recycling. Net costs per ton may be lower for these counties because labor rates for government employees do not include profit margins or overhead that would components of payments to contractors. Since county governments usually receive revenue for recycling the scrap metal in white goods, and this revenue often stays in the county solid waste department budgets, it is also possible that local government employees have a greater incentive to encourage county residents and businesses to drop off used appliances at the convenience sites. This would increase the amount of scrap metal revenue received by their department, which would lower net costs per ton. However, using local government staff to operate convenience sites was not significantly associated with the quantity of white goods collected per-capita. More research is needed to explore the possible reasons for this observation.

County survey participants were also asked about specific practices and infrastructure used to manage special wastes at the county's central collection site. For white goods, they were asked whether refrigerators, freezers, and air conditioners are separated from other types of white goods, whether refrigerant gases are removed on-site, whether white goods are stored on a paved area or under shelter, and whether dock or other platform is used when loading white goods into trucks. For scrap tires, they were asked whether tires are separated by type (e.g. passenger tires, truck tires, off-road tires, etc.), stored in a trailer, stored under shelter, moved with heavy equipment, loaded from a platform or dock, and whether they are laced when loading them into trucks. Theoretically, protecting white goods and scrap tires from dirt, mud, and precipitation by storing them on paved areas and under shelter should result in higher quality scrap that has greater value or is less costly to recycle. Removing refrigerant gases from refrigerators and freezers on-site would release scrap metal dealers or recyclers from this responsibility, and could increase the value of discarded white goods.

Using heavy equipment and loading platforms should also reduce the amount of labor required to move and load special wastes. Separating tires by type and lacing them when loading them into trailers should maximize the amount of tires that are included in each load, thereby reducing unit hauling costs. Results of the stepwise regression analysis for these management practices and infrastructure are shown in Table 10.

Table 10: Regression results for special waste management practices

Parameter	White Goods Lbs/Person (n=15)		Scrap Tires Lbs/Person (n=16)		White Goods Cost/Ton (n=18)		Scrap Tires Cost/Ton (n=15)	
	β	p	β	p	β	p	β	p
Intercept	31.38	1.0000	30.12	1.0000	31.83	1.0000	86.62	1.0000
Refrigeration devices separated from other white goods at central collection site (0=No, 1=Yes)	-10.74	0.0159*	NA	NA	0 †	0.6740	NA	NA
County removes Freon and other refrigerants from white goods at central collection site (0=No, 1=Yes)	0 †	0.9945	NA	NA	19.91	0.0993	NA	NA
White goods stored on a concrete pad or other paved area at central collection site (0=No, 1=Yes)	0 †	0.6883	NA	NA	0 †	0.5503	NA	NA
Special wastes stored under shelter at central collection site (0=No, 1=Yes)	0 †	0.7627	0 †	0.8614	-30.38	0.0940	0 †	0.3627
County uses a dock or other platform for loading special wastes into trucks (0=No, 1=Yes)	0 †	0.4316	-2.69	0.2445	0 †	0.9717	0 †	0.3689
County uses heavy equipment (grapplers, loaders, skid steers, etc) for moving and loading special wastes (0=No, 1=Yes)	0 †	0.2556	0 †	0.7103	‡	‡	0 †	0.8063
Tires separated by type at central collection site, e.g. passenger tires, truck tires, off-road tires, etc., (0=No, 1=Yes)	NA	NA	0 †	0.6020	NA	NA	0 †	0.6991
Tires stored in a trailer at central collection site (0=No, 1=Yes)	NA	NA	0 †	0.9990	NA	NA	0 †	0.6350
Tires "laced" when loaded into trucks (0=No, 1=Yes)	NA	NA	0 †	0.6309	NA	NA	0 †	0.2720
R^2	0.2826		0.0954		0.2510		0.0000	

* $p < 0.05$
† Regression coefficients are set to zero when dropped from the stepwise linear regression model
‡ No variation observed in responses to these questions
NA = Not applicable

The only significant observation related to county special waste program effectiveness was that counties who separated refrigeration devices from other white goods at their landfill or transfer station collected fewer pounds per person. The reason for this finding is unclear, since white goods have already been collected by the time they are separated. Some counties indicated that they tested refrigerators and freezers brought to their collection sites and reused or donated those that were still functional. However, the number of reused appliances was relatively small and not likely to have a significant impact on the total amount of white goods collected. More research is needed to explain possible causes of this finding.

Among county white goods programs, storing white goods under shelter was associated with lower costs per ton, and removal of refrigerant gases on-site was associated with higher costs per ton, but these relationships did not attain conventional levels of significance ($p=0.09$ and 0.10, respectively). Storing white goods under shelter protects them from exposure to precipitation, which helps to keep them clean and reduces rust. It is possible that this enhances the value of the scrap metal and increases the revenue received for it, reducing net costs per ton. Removal of Freon and other refrigerant gases from refrigerators, freezers, and air conditioning units must be done by staff that are trained and certified in this practice, and also requires special equipment. Counties use either in-house staff or contractors to perform this service. Higher costs per ton among these counties could suggest that the additional expense of removing refrigerants on-site may exceed any additional revenue received from higher value scrap. However, this practice may also be common among counties with programs that are more extensive and costly for other reasons, possibly because these counties also tend to use more equipment, labor, or infrastructure to maximize the value of collected white goods. More investigation is required to explore possibilities for this finding.

None of the other infrastructure or management practices examined by this study were significantly associated with the two measurements of special waste program performance examined here. While these practices may indeed influence quantities collected per-capita or net costs per ton for some county special waste programs, the survey results suggest that these factors are not likely among the most significant factors related to measurements of North Carolina special waste program performance.

Survey participants were also asked about county efforts to minimize costs and maximize revenue associated with their special waste programs. Specifically, they were asked whether the county used a competitive bidding process to obtain recycling or disposal services, whether they receive scrap metal revenue for white goods, and if so whether that revenue remains in the solid waste budget (usually called an "enterprise fund" when this practice is allowed). These efforts could help counties to reduce the net costs associated with their special waste programs, which might enable investment in more convenient collection infrastructure. Obtaining revenue from the sale of recyclables, particularly if this revenue remains in the solid waste department budget, provides a strong incentive for counties to maximize revenue by collecting greater quantities of white goods. The effects of these efforts were analyzed with results presented in Table 11.

Table 11: Regression results for efforts to minimize cost and maximize revenue

Parameter	White Goods Lbs/Person (n=15)		Scrap Tires Lbs/Person (n=16)		White Goods Cost/Ton (n=15)		Scrap Tires Cost/Ton (n=15)	
	β	p	β	p	β	p	β	p
Intercept	26.01	1.0000	31.13	1.0000	51.11	1.0000	86.62	1.0000
Competitive bid process used for waste processing contract (0=No, 1=Yes)	0 †	0.2897	0 †	0.5884	23.64	0.0389*	0 †	0.4108
County receives revenue for scrap material (0=No, 1=Yes)	0 †	0.8392	NA	NA	19.78	0.1364	NA	NA
Revenue from scrap material remains in county solid waste departments budget (0=No, 1=Yes)	0 †	0.2984	NA	NA	0 †	0.9491	NA	NA
Disposal cost per ton	NA	NA	0 †	0.8798	NA	NA	0 †	0.8471
R^2	0.0000		0.0000		0.2901		0.0000	

* $p < 0.05$
† Regression coefficients are set to zero when dropped from the stepwise linear regression model
NA = Not applicable

These results show that none of counties' efforts to minimize cost or maximize revenue were associated with the quantity of special wastes collected per-capita. Interestingly, there was a significant association between counties that competitively bid their white goods disposal contracts and those that reported *higher* costs per ton. This is opposite of the expected relationship, since a competitive bid process is designed to maximize the amount of revenue received for the scrap metal in white goods, which should help reduce net costs. The additional revenue received by establishing scrap metal rates through a competitive bidding process may not be large enough to significantly reduce net costs for white goods programs. Competitive bidding may also be associated with counties that generally have more extensive programs and higher costs for other reasons (e.g. use of more equipment, labor, infrastructure, etc.), which offset the increased revenue earned from scrap metal recycling.

There was no significant association between counties that competitively bid their scrap tire contracts and total costs per ton. Only two companies recycle scrap tires in North Carolina, so it is possible that a lack of options and reduced competition limits the impact that competitive bidding can have on total scrap tire program costs.

Counties that haul scrap tires or white goods long distances might be expected to pay more for hauling to processing facilities. This could contribute to higher unit costs for management and disposal, and could also reduce incentives to increase collection of special wastes. To assess whether hauling distance influences special program performance, counties were asked to provide the location of their central collection site, and the location of the facility where their white goods and scrap tires are sent for disposal. An internet mapping service (Google Maps©, http://maps.google.com) was used to calculate the distance between these two locations. The relationships between this distance and program performance measurements were analyzed, with results presented in Table 12.

Table 12: Regression results for hauling distance

Parameter	White Goods Lbs/Person (n=15)		Scrap Tires Lbs/Person (n=16)		White Goods Cost/Ton (n=18)		Scrap Tires Cost/Ton (n=15)	
	β	p	β	p	β	p	β	p
Intercept	26.01	1.0000	31.13	1.0000	62.10	1.0000	86.62	1.0000
Miles to processing facility	0 †	0.8492	0 †	0.7096	0 †	0.6829	0 †	0.8196
R^2	0.0000		0.0000		0.0000		0.0000	

† Regression coefficients are set to zero when dropped from the stepwise linear regression model

These results show that the distance from processing facilities does not have a significant influence on these special waste program performance measurements. While hauling distances probably have an effect, particularly on unit costs, they do not appear to be a major factor distinguishing counties that reported high performance measurements from those that reported low measurements.

The previously described analyses examined aspects of NC county white goods and scrap tire programs in several categories (program design participants, education and outreach methods, collection infrastructure, etc.). They attempted to identify the program characteristics within each category that are most significantly associated with each performance measurement. When establishing priorities for further investigation or future research, however, it is often helpful to identify those factors among all categories that are most significantly associated with program performance. This requires a single model that incorporates all potentially significant predictor variables. To construct such a model, all of the factors that reached significance at the level $p < 0.10$ in the previous analyses were identified, and are shown in Table 13.

Table 13: Significant factors identified in previous stepwise regression analyses

Parameter	White Goods Lbs/Person (n=20)		Scrap Tires Lbs/Person (n=16)		White Goods Cost/Ton (n=18)		Scrap Tires Cost/Ton (n=15)	
	β	p	β	p	β	p	β	p
County government staff provided program design input (0=No, 1=Yes)	19.26	0.0285*					-18.74	0.0376*
State agency staff provided program design input (0=No, 1=Yes)							8.99	0.0588
Private industry provided program design input (0=No, 1=Yes)	12.18	0.0044*	-5.65	0.0159*				
Published reports or studies provided program design input (0=No, 1=Yes)	-7.50	0.0654						
Meeting with product dealers / retailers used to educate (0=No, 1=Yes)			6.44	0.0029*	30.55	0.0869	-7.63	0.0053*
Letters to product dealers / retailers used to educate (0=No, 1=Yes)							-11.02	0.0022*
Pamphlets, brochures, or bumper stickers used to educate (0=No, 1=Yes)							10.21	0.0027*
Presentations at community meetings used to educate (0=No, 1=Yes)	-10.11	0.0708					-12.56	0.0037*
Speeches by local/state officials used to educate (0=No, 1=Yes)					-34.54	0.0823	18.95	0.0025*
Radio or television advertisements used to educate (0=No, 1=Yes)							7.10	0.0678
Billboards used to educate (0=No, 1=Yes)			-7.07	0.0564				
Number of drop off collection sites per 10,000 residents	8.88	0.0279*	4.80	0.0939				
Dealers/retailers haul directly to processing facilities (0=No, 1=Yes)			4.48	0.0393*				
Wastes loaded into trucks by county/local government staff (0=No, 1=Yes)	-9.56	0.0711						
Refrigeration devices separated from other white goods at central collection site (0=No, 1=Yes)	-10.74	0.0159*						

County removes Freon and other refrigerants from white goods at central collection site (0=No, 1=Yes)					19.91	0.0993		
Special wastes stored under shelter at central collection site (0=No, 1=Yes)					-30.38	0.0940		
Competitive bid process used for waste processing contract (0=No, 1=Yes)					23.64	0.0389*		
Convenience sites operated by county/local government staff (0=No, 1=Yes)					-40.31	0.0004*		

* $p < 0.05$

A final forward stepwise regression model was constructed for each performance measurement using all of the significant variables identified in Table 13. These final models were run to assess the relative impact of characteristics from all categories and identify those features of county special waste programs most significantly associated with program performance. Results of these final models are presented in Table 14.

Table 14: Final stepwise regression results for all significant factors

Parameter	White Goods Lbs/Person (n=20)		Scrap Tires Lbs/Person (n=16)		White Goods Cost/Ton (n=18)		Scrap Tires Cost/Ton (n=15)	
	β	p	β	p	β	p	β	p
Intercept			28.81	1.0000	56.91	1.0000	97.65	1.0000
County government staff provided program design input (0=No, 1=Yes)	0 †	0.7766					0 †	0.6858
State agency staff provided program design input (0=No, 1=Yes)							0 †	0.7877
Private industry provided program design input (0=No, 1=Yes)	6.00	0.0865	-3.76	0.0821				
Published reports or studies provided program design input (0=No, 1=Yes)	0 †	0.4288						
Meeting with product dealers / retailers used to educate (0=No, 1=Yes)			3.59	0.0595	24.26	0.1396	-6.89	0.0121*
Letters to product dealers / retailers used to educate (0=No, 1=Yes)							-8.86	0.0052*
Pamphlets, brochures, or bumper stickers used to educate (0=No, 1=Yes)							10.65	0.0031*
Presentations at community meetings used to educate (0=No, 1=Yes)	-9.77	0.0391*					-12.21	0.0066*
Speeches by local/state officials used to educate (0=No, 1=Yes)					0 †	0.5770	18.58	0.0043*
Radio or television advertisements used to educate (0=No, 1=Yes)							9.19	0.0312*
Billboards used to educate (0=No, 1=Yes)			0 †	0.4208				
Number of drop off collection sites per 10,000 residents	4.23	0.2400	0 †	0.8167				
Dealers/retailers haul directly to processing facilities (0=No, 1=Yes)			0 †	0.5295				
Wastes loaded into trucks by county/local government staff (0=No, 1=Yes)	-4.11	0.1904						

Refrigeration devices separated from other white goods at central collection site (0=No, 1=Yes)	-5.02	0.2079						
County removes Freon and other refrigerants from white goods at central collection site (0=No, 1=Yes)					23.95	0.0333*		
Special wastes stored under shelter at central collection site (0=No, 1=Yes)					-20.66	0.2099		
Competitive bid process used for waste processing contract (0=No, 1=Yes)					14.59	0.1828		
R^2	0.6416		0.4855		0.5026		0.8907	

* $p < 0.05$

† Regression coefficients are set to zero when dropped from the stepwise linear regression model

Among county white goods programs, presenting information about white goods recycling at community meetings is the most significant factor associated with program effectiveness. This method of educating residents and businesses was associated with counties that collected fewer pounds per person. As discussed previously, these presentations may be an effective way to educate the public about the importance of white goods recycling, but the public may be responding by using appliance collection options offered by retailers or other private sector firms (such as private junkyards or scrap metal dealers). Discarded white goods have a relatively high market value due to their scrap metal content, and these businesses have an incentive to collect white goods as a source of revenue. It is also possible that community meeting presentations are conducted in counties that already have lower per-capita collection rates (possibly due to illegal dumping) as a way to increase awareness and boost participation in white goods collection. More research is needed to explore how educating the public and local businesses through community meetings is related to resulting performance measurements of white goods programs.

The relationship between counties that solicited program design input from private industries and higher per-capita collection rates also approached significance (p=0.09).

Knowledge of major residential, commercial, or industrial sources of white goods shared by appliance retailers and scrap metal dealers might help counties design more effective collection systems.

Removal of Freon and other refrigerant gases from refrigerators, freezers, and air conditioners at central collection sites was significantly associated with higher white goods costs per ton. When this is done by counties on-site, it must be performed either by trained and certified local government staff or by contractors, who usually charge a fee for each appliance serviced. The observed association could indicate that removal of refrigerants on-site is an expensive service that is more cost-effectively performed by scrap metal dealers, metal recyclers, or other "final holders" of discarded refrigeration devices. It could also indicate, however, that counties with white goods programs that are already expensive on a per-ton basis for other reasons (due to more extensive collection or management of white goods, perhaps) also choose to remove refrigerant gases themselves as a way to improve the value of their scrap metal and maximize the revenue received for it. More research is needed to explore how costs for refrigerant removal services relate to overall white goods program costs of counties that provide on-site refrigerant removal services.

Among scrap tire programs in this final stepwise regression analysis, meeting with tire retailers came closest to achieving conventional levels of significance in its association with counties that collected more tires per-capita ($p=0.06$). Possible reasons for this observation were discussed previously. Engaging retailers in the scrap tire collection process could result in a collection system that is more convenient for county residents and collects more scrap tires per resident. However, it is also possible that meetings with tire retailers occur more often in counties with greater numbers of retailers or larger retail facilities. These businesses could attract customers from other counties, which would increase the quantity of tires collected per-capita in the host county.

Scrap tire programs that received design input from private industry representatives also approached significance in their association with lower effectiveness ($p=0.08$). This could indicate that tire businesses encouraged county governments to provide more collection sites so that fewer tire dealers needed to collect, store, and haul scrap tires themselves. If dropping-off tires at these county sites is less convenient for residents than leaving scrap tires with tire retailers, it could account for lower per-capita collection. In many cases, however, retailers choose to accept used tires for disposal regardless of government-sponsored collection options as a service for their customers. More data is required on the extent of retailer scrap tire collection, and more research will be needed to explore the relationships between tire dealer education, collection, and resulting county per-capita collection quantities.

Several education methods continued to be significantly associated with lower costs per ton among scrap tire programs in this final stepwise regression analysis, including meeting with tire retailers, letters to tire retailers, and presenting at community meetings. Two of these methods involved reaching out to tire dealers, one of which (meeting with tire dealers) was simultaneously associated with counties that collected more scrap tires per-capita ($p=0.06$) and those that reported lower costs per ton ($p=0.01$). This suggests that engaging retailers in the scrap tire collection process may be a good strategy for maximizing the performance of county scrap tire programs. Educating the public about scrap tire recycling through community meetings may also help to improve public awareness of existing collection options so that these counties do not need to fund more extensive collection systems.

Several education methods were also associated with higher scrap tire costs per ton, including pamphlets, brochures, or bumper stickers, speeches by local or state officials, and radio or television advertisements. Outreach and advertising campaigns using these media can be expensive, but direct costs for advertising would not normally be included in scrap tire program costs reported to the state. These media usually cover all recyclable materials accepted by the county, and are not focused on scrap tires. Counties using these media for education and advertising may also support more extensive recycling programs that use more collection methods, infrastructure, equipment, and labor, which could also increase costs per ton for managing scrap tires. The observed association between higher costs per ton and speeches by local or state officials is consistent with this possibility, since support from local leaders would likely be required to sustain the budgets required to operate these more extensive recycling programs.

Table 15 shows the results of the final stepwise regression analysis restricted to those counties that reported using convenience sites to collect white goods.

Table 15: Final stepwise regression results for all significant factors among counties with convenience sites

Parameter	White Goods Lbs/Person (n=15)		Scrap Tires Lbs/Person (n=7)		White Goods Cost/Ton (n=13)		Scrap Tires Cost/Ton (n=6)	
	β	p	β	p	β	p	β	p
Intercept					69.54	1.0000		
Meeting with product dealers / retailers used to educate (0=No, 1=Yes)					0 †	0.6327		
Speeches by local/state officials used to educate (0=No, 1=Yes)					0 †	0.4944		
County removes Freon and other refrigerants from white goods at central collection site (0=No, 1=Yes)					22.53	0.0025*		
Special wastes stored under shelter at central collection site (0=No, 1=Yes)								
Competitive bid process used for waste processing contract (0=No, 1=Yes)					0 †	0.6855		
Convenience sites operated by county/local government staff (0=No, 1=Yes)					-41.39	<0.0001*		
R^2					0.8833			

* $p < 0.05$

† Regression coefficients are set to zero when dropped from the stepwise linear regression model

These results continue to find a significant association between counties that reported higher costs per ton and those that removed refrigerant gases on-site. They also show a highly significant relationship between counties that use county or local government staff to operate convenience sites and those that reported lower costs per ton. These results suggest that a relationship may exist between outsourcing steps of the white goods management process and resulting unit costs for these programs.

As described earlier, higher unit costs among counties that outsourced operation of convenience sites contrasts with the previous findings of several researchers in the area of household recyclables. It is possible that these net costs are lower because the local government labor rates do not include profit margins or overhead that are components of payments to contractors, although this is unlikely to account for all of the reduced cost. Local government employees may have an incentive to encourage citizens and businesses to increase the quantities of white goods dropped off at county convenience sites, since this would increase the amount of revenue received by the county government and, in many cases, the county solid waste department. However, higher quantities of white goods per-capita were not observed among counties using local government staff to operate convenience sites. More information and research is needed to understand the reasons for this observation, possibly through a systematic comparison of counties using government employee with those that use contractors to staff convenience centers.

CONCLUSIONS

This empirical study explored factors associated with performance measurements of North Carolina county white goods and scrap tire programs. While prior research on these wastes is limited, studies of conventional household recycling programs suggest both exogenous and endogenous factors can influence measurements of program performance. This study examined associations between these factors and two measurements for special waste programs operated by North Carolina counties: pounds of white goods and scrap tires collected per county resident (referred to as program "effectiveness") and total program costs per ton of waste managed (referred to as program "efficiency").

The first phase of the analysis examined relationships between exogenous factors and performance measurements using multiple linear regression. More densely populated counties reported collecting lower quantities of white goods but greater quantities of scrap tires per-capita, although this latter finding narrowly missed achieving conventional levels of significance ($p=0.08$). This could be due to a greater presence of appliance retailers and tire dealers in more densely populated counties, who often take back used products from their customers when selling new products. If appliance retailers sell used appliances independently to receive revenue for the scrap metal (bypassing county collection programs) while tire dealers take their scrap tires to free county collection sites, the observed association could result. Counties with high population densities may also provide more opportunities to reuse functional appliances, which may also help explain lower per-capita collection in these counties. Counties with higher total population also reported lower scrap tire costs per ton. These counties generate greater quantities of tires, and may be using their higher volumes to negotiate lower rates for scrap tire hauling and processing.

The second phase of this analysis focused on factors endogenous to county white goods and scrap tire programs, including program design participants, education and outreach initiatives, collection methods and infrastructure, management practices, degree of outsourcing or privatization, and others. Phone surveys were used to collect this information from counties whose reported performance measurements were among the highest and lowest reported across the state, excluding extreme values and controlling for the effects of significant exogenous factors identified in the first phase of the analysis. Forward stepwise linear regression was used to analyze these data, first by analyzing all endogenous variables within each category independently, and then by analyzing all significant and nearly-significant endogenous variables from all categories together in a final stepwise regression model.

In the separate category analyses of white goods program effectiveness, counties that received program design input from in-house county government staff and private industry sources, and those with a greater density of collection sites (more collection sites per 10,000 county residents) reported collecting more white goods per-capita. In-house knowledge of citizen preferences and behaviors combined with private sector awareness of major white goods sources might help counties design better collection systems that collect more wastes. The association between greater collection site density and program effectiveness is consistent with prior research linking higher collection system convenience with improved recycling behavior. Interestingly, counties that reported separating refrigerators and freezers from other types of white goods (to extract refrigerants or prevent accidental releases) reported collecting lower quantities of white goods per-capita. There are no obvious reasons for this finding, since white goods have already been collected at the time they are separated. In the final analysis, which included all significant variables from all categories, the only significant association was between counties that used community meetings to educate citizens and businesses about white goods disposal (which only approached significance at $p=0.07$ in the category analysis) and those that reported collecting lower quantities of white goods per resident. While presenting recycling information at schools, civic organizations, county commissioner meetings, and other community gatherings may be an effective way to educate the public about recycling, residents may respond by using more convenient appliance take-back services offered by retailers, which could divert white goods from county collection programs and result in lower per-capita collection rates. Community meetings may also be used as a way to increase awareness and boost participation in white goods collection in counties that already have lower per-capita collection rates.

Analysis of the relationships between scrap tire program effectiveness and each category of endogenous variables found that meeting with tire dealers to educate them about scrap tire disposal and having some dealers haul scrap tires directly to processing facilities were both associated with counties that collected more scrap tires per-capita. Together, these findings could suggest retailers play an important role in the collection of scrap tires, and engaging them in the process could be a way to increase or sustain high per-capita collection rates. However, since retailers typically need to generate large quantities of scrap tires to justify direct shipments, it could also mean large retailers operating in these counties attract customers (and scrap tires) from outside of the county, which would increase quantities collected per resident. Counties that solicited input from private industry sources in the design of their scrap tire programs reported collecting fewer pounds per resident. If private sector consultants encourage counties to provide more collection sites to minimize their storage and hauling costs, and if these collection sites are less convenient or less accessible, residents may store more of their used tires in garages or possibly discard them illegally. This could reduce the quantity of scrap tires collected by these counties, and may explain this observation. However, retailers may also lose business by not accepting scrap tires from customers who value the convenience of this service, so more investigation is needed to understand this observation. None of these endogenous factors reached conventional levels of significance in the final analysis, although the relationship between counties that met with tire retailers and those that collected more tires came closest ($p=0.06$).

The category analyses of white goods program efficiency found counties that competitively bid their white goods disposal contracts reported *higher* costs per ton, which is opposite of the expected relationship. It is possible that the additional revenue obtained by competitively bidding scrap metal rates may not be large enough to significantly reduce net costs, or that competitive bidding may be associated with counties that already provide more extensive white goods programs, whose higher costs offset increased scrap metal revenue. The final analysis found counties that removed refrigerant gases from white goods at their central collection sites reported higher costs per ton. This suggests it may be more cost-effective for counties to have scrap metal processors extract refrigerants at their facilities rather to self-perform this service at county collection sites. Again, however, counties that perform this service may also provide more extensive white goods program that cost more for other reasons. Among counties operating convenience sites (drop-off collection locations remote from the county landfill or transfer station), the final analysis found a highly significant association ($p<0.0001$) with lower costs per ton when these sites were staffed with county or local government employees, and not contractors. This suggests outsourcing operation of convenience sites may not always be a cost-effective strategy for county white goods programs.

In the separate category analyses of scrap tire program efficiency, lower county program costs per ton were found among counties that solicited program design input from in-house county government staff, suggesting local knowledge of resident preferences and county characteristics may help counties to design cost-effective scrap tire programs. Both category and final analyses found that several education methods were significantly associated with scrap tire costs per ton. Counties that met with and mailed information to local tire dealers reported lower costs per ton. This suggests that it may be cost-effective for counties to solicit participation from tire retailers in the collection of scrap tires, although it could also indicate counties meet with retailers because they already collect large quantities of tires. Counties that educated residents and businesses at community meetings about scrap tire disposal also experienced lower costs per ton, possibly because this form of outreach effectively informs citizens about existing tire disposal options and reduces the need for more extensive collection systems. Higher costs per ton were reported by counties that used pamphlets, brochures, or bumper stickers, radio or television ads, and speeches by local or state officials to advertise their recycling program. Use of these advertising methods could be associated with counties that generally support more extensive recycling programs, including scrap tire programs that are more costly on a per ton basis.

The results of this analysis suggest three primary conclusions. First, the performance of North Carolina special waste programs is related to specific characteristics and features of these programs, particularly methods used to educate citizens and businesses about special waste recycling and decisions to outsource portions of the collection and management process. Counties that used community meetings to educate the public about special waste recycling collected more scrap tires but fewer white goods per capita. Reported costs per ton were related to how counties educated citizens and businesses about special waste disposal, with methods targeting tire retailers associated with lower costs per ton and those focusing on general recycling information for a wider public audience linked to higher costs per ton. Higher costs per ton for white goods were found among counties that outsourced operation of remote collection facilities and removed refrigerants on-site. While causal relationships can only be proven through further study, the relationships observed in this analysis suggest that at least some program features may influence special waste program performance in North Carolina. Counties may be able to change their programs in specific ways (e.g. by engaging the public and businesses in special waste collection, or by adding or removing specific services) to help improve performance.

Second, the results suggest product retailers may play an important role in collection of white goods and scrap tires, which can influence county program performance. While retailers were not the primary focus of this study, several findings suggest that retailers are collecting significant portions of white goods and scrap tires. The quantity of white goods collected per capita by county programs was lower in counties with higher population densities, which also tend to have more appliance retail facilities that have independent appliance take-back programs. Counties where tire retailers were more engaged in the collection process, by meeting regularly with county solid waste officials and hauling scrap tires directly to processing facilities, also collected more scrap tires per capita. Again, while these relationships do not prove that retailer collection is a direct cause of the performance outcome, contributions by retailers to the collection process provide plausible explanations for the observed relationships. Lower costs per ton were also found among counties that educated tire retailers directly, which suggests engaging retailers in the collection process may also play a role in reducing unit costs for scrap tire collection and management.

Third, it is interesting to note that among the most significant endogenous program factors found in this study, only one was associated with the same performance measurement for both white goods and scrap tires. Even this factor (private industry input into program design) had opposite effects on program effectiveness between the two program types. This suggests that specific factors influencing the performance of special waste programs depend on particular characteristics of the special waste. The locations where special wastes are generated, the frequency of disposal, the quantities produced, and the value of processed materials are all factors that could influence performance measurements for these programs. These details are also likely to be very important for program managers to understand before deciding who to involve in the design and operation of the program, which education methods to use, what kind of collection infrastructure to support, and how waste should be managed and processed. Proposed policies for managing new types of special wastes should also account for these details, and use lessons from existing special waste programs cautiously only after careful consideration of the similarities and differences between the wastes.

This study was an exploratory analysis only. Several associations were identified between special waste program factors and performance measurements, but causal relationships could not be confirmed. Special waste collection and management is a complex process, with many factors that can influence operating costs and quantities collected. Education and outreach methods, collection infrastructure, management practices, outsourcing of process steps, and market prices for processed material could all have an impact on performance outcomes, both independently and through interactions with one another. For each statistically significant relationship found in this study, plausible explanations were proposed but must be verified through further research before they can be used as a basis for action or change.

Performance measurements for county white goods and scrap tire programs were calculated using data recently reported by North Carolina counties on waste quantities and program operating costs. The accuracy of this data was not independently verified in this study, although counties with extreme performance measurements were excluded from the analyses to control for potential reporting errors. Errors resulting in non-extreme performance measurements, however, could not be readily identified or controlled. The Solid Waste Section of the NC Division of Waste Management does provide counties with guidelines on how quantities and costs should be reported for these programs, but reported data are not typically audited for compliance with these guidelines. Auditing this data for compliance with the guidelines or using full cost accounting techniques to establish program costs would help improve the accuracy and consistency of performance measurements. This would help make future empirical performance analyses more meaningful and ensure findings represent true relationships between program factors and performance improvements.

Sample sizes were small in the second phase of this analysis, which limited the ability to obtain high levels of statistical significance in the results. Most findings that achieved significance only did so at the level $p < 0.05$. Samples of counties used in each analysis, however, represented at least 15% of all North Carolina counties in most cases. In future analyses, collecting data using shorter, more targeted surveys with a larger sample of counties would improve the potential significance of findings.

Existing research on special waste program performance is very limited, which presents many opportunities for future study. The endogenous program factors examined here represent a very rough and incomplete framework of variables describing how special waste programs are structured and operated. Additional insight into the determinants of performance could be gained by collecting more details about the factors examined here, such as the types of suggestions offered by program design participants, the content of outreach and education methods, or the locations and collection practices of retailers. Many other factors could also influence performance but were not readily available to include in this analysis, such as geographic variations in labor rates, fuel costs, or market values of processed materials across the state. Each endogenous program characteristic was analyzed for independent effects on program performance in this study, but some may interact with others in ways that influence performance outcomes. It is possible, for example, that some education and outreach initiatives are more effective at encouraging residents to use certain types of collection services over others. A number of these possible interactions were discussed previously. This research focused on relationships between aspects of special waste programs and performance outcomes, but did not address any intermediate factors such as citizen awareness or participation in special waste recycling. Measuring and analyzing these intermediate factors could also improve understanding of how special waste programs can be designed and improved to optimize performance.

Special waste collection and management involves many participants and a variety of logistical arrangements. Given this complexity of these processes, there are likely to be many exogenous and endogenous factors that influence performance outcomes. This study identified significant associations between several of these factors and performance measurements for North Carolina county white goods and scrap tire programs. These findings provide a few early steps toward understanding how community characteristics, program designs, stakeholders, education and outreach initiatives, collection infrastructure, management practices, and other aspects of special waste programs relate to measurements of their performance. Future findings on exogenous determinants of program performance will help to improve understanding of factors that facilitate or constrain performance, which will help establish realistic expectations for the performance of these programs. Findings on endogenous determinants will help confirm how program characteristics can be designed or changed in ways that help optimize performance. Future research in this area can also help to inform policies targeting other types of special wastes, such as used electronic products.

Policies regulating special wastes are becoming increasingly prevalent due to growing awareness of the potential hazards associated with traditional solid waste disposal. Many of these policies require local governments, as traditional providers of solid waste services, to operate programs for collecting and managing these wastes. Analyzing the performance of these programs will continue to be important for demonstrating that special waste policies are successfully reducing landfill disposal, discouraging illegal dumping, promoting recycling, and improving management of hazardous substances.

APPENDIX A: SOURCES OF COUNTY DEMOGRAPHIC DATA

Demographic Variable	Indicator / Approximation	Sources
County population	North Carolina State Demographics Population Estimates	2003 Revised County Population Estimates http://demog.state.nc.us/demog/rev03p.html 2004 Certified County Population Estimates http://demog.state.nc.us/demog/cert04pa.html
Geographic area	County land area	US Census http://factfinder.census.gov/servlet/GCTTable?_bm=y&-geo_id=04000US37&-_box_head_nbr=GCT-PH1&-ds_name=DEC_2000_SF1_U&-redoLog=false&-format=ST-2&-mt_name=DEC_2000_SF3_U_GCTP11_ST2
County population density	County population density	Calculated from county population and county geographic land area (see above)
Gender	Males per 100 females	US Census http://factfinder.census.gov/servlet/GCTTable?_bm=y&-geo_id=04000US37&-ds_name=DEC_2000_SF1_U&-_lang=en&-redoLog=false&-format=ST-2&-mt_name=DEC_2000_SF1_U_GCTP5_ST2&-CONTEXT=gct
Age	Median Age	US Census http://factfinder.census.gov/servlet/GCTTable?_bm=y&-geo_id=04000US37&-ds_name=DEC_2000_SF1_U&-_lang=en&-redoLog=false&-format=ST-2&-mt_name=DEC_2000_SF1_U_GCTP5_ST2&-CONTEXT=gct
Race	Percent White	US Census http://factfinder.census.gov/servlet/GCTTable?_bm=y&-geo_id=04000US37&-ds_name=DEC_2000_SF1_U&-_lang=en&-redoLog=false&-format=ST-2&-

		mt_name=DEC_2000_SF1_U_GCTP6_ST2&-CONTEXT=gct
Education	Percent of population 25 years and over with bachelor's degree or higher	US Census http://factfinder.census.gov/servlet/GCTTable?-geo_id=04000US37&-mt_name=DEC_2000_SF3_U_GCTP11_ST2&-ds_name=DEC_2000_SF3_U
Income	Median household income estimates for North Carolina counties, 2002	US Census Small Area Income & Poverty Estimates http://quickfacts.census.gov/qfd/states/37000lk.html
Home ownership	Percent of occupied housing units owned	US Census http://factfinder.census.gov/servlet/GCTTable?_bm=y&-geo_id=04000US37&-ds_name=DEC_2000_SF1_U&-_lang=en&-redoLog=false&-format=ST-2&-mt_name=DEC_2000_SF1_U_GCTH6_ST2&-CONTEXT=gct
Household size	Average household size of occupied housing units	US Census http://factfinder.census.gov/servlet/GCTTable?_bm=y&-geo_id=04000US37&-ds_name=DEC_2000_SF1_U&-_lang=en&-redoLog=false&-format=ST-2&-mt_name=DEC_2000_SF1_U_GCTH6_ST2&-CONTEXT=gct
Political affiliation	Percent of registered voters registered as Democrats	NC State Board of Elections Voter Statistics for 2004/01/01 http://www.sboe.state.nc.us/stats/vr_stats_results.asp?EC=2004%2F01%2F01&B2=Submit

APPENDIX B: COUNTY SELECTION PROCESS FOR SECOND PHASE OF ANALYSIS

Counties were excluded from this analysis if they failed to report quantity and cost data, or if they reported scrap tire disposal using the number of tires or number of loads instead of tons. Of those counties that did report the required information, the top and bottom 10% of counties were also excluded to minimize the chance of selecting counties whose performance measurements were excessively high or low because of reporting errors or other data anomalies, as described previously. Counties not excluded were selected to participate in phone surveys in the following four groups (one group for each performance measurement within each program):

1. White goods program effectiveness (lbs/person)
2. Scrap tire program effectiveness (lbs/person)
3. Scrap tire program efficiency (cost/ton)
4. White goods program efficiency (cost/ton)

Within each of these groups, counties were stratified and selected as described below. Stratification was intended to minimize variations in performance associated with exogenous factors already identified in the first phase of this analysis. It helped to control for known exogenous predictors of county special waste program performance (population and population density), increasing the likelihood that that significant variations in program performance would be explained by endogenous program features (i.e. characteristics of the special waste collection and management program itself). In other words, selecting counties from each strata of population density and population improved chances that findings in the second phase of this analysis are would be due to differences in the design and operation of the special waste program itself, rather than exogenous demographic characteristics already known to have an effect. Additional selection information about each of these groups is provided in the following sections.

1. White goods program effectiveness (lbs/person)

The first phase of this analysis found that county population density had a highly significant negative effect on the white goods program effectiveness (pounds collected per-capita). When selecting counties to survey based on the effectiveness of their white goods programs, counties were organized into the following 6 strata:

1. < 50 persons/square mile (n = 8)
2. 50-100 persons/square mile (n = 19)
3. 100-150 persons/square mile (n = 12)
4. 150-200 persons/square mile (n = 9)
5. 200-250 persons/square mile (n = 7)
6. > 250 persons/square mile (n = 11)

Within each of these strata, counties were ranked based on their white goods program effectiveness (lbs/person) and the top and bottom ranked counties were selected to participate in the survey.

2. Scrap tire program effectiveness (lbs/person)

Population density had a nearly-significant ($p=0.08$) positive effect on scrap tire program effectiveness. Because the influence of this exogenous factor approached significance, counties were organized into the following strata based on population density:

1. < 200 persons/square mile (n = 44)
2. > 200 persons/square mile (n = 20)

Within each of these strata, counties were ranked based on their scrap tire program effectiveness (lbs/person). In the larger stratum (< 200 persons/square mile), the top 3 and bottom 3 counties were selected to participate in the survey and in the smaller stratum (> 200 persons/square mile) and the top 2 and bottom 2 counties were selected to participate.

3. Scrap tire program efficiency (cost/ton)

Total population had a significant negative effect on the efficiency of scrap tire programs. When selecting counties based on the efficiency of their scrap tire programs, counties were organized into the following 4 strata:

1. < 50,000 people (n = 29)
2. 50,000 – 100,000 people (n = 17)
3. 100,000 – 150,000 people (n = 7)
4. 150,000 people (n = 12)

Within each of these strata, counties were ranked based on their scrap tire program efficiency (cost/ton) and the top and bottom ranked counties were selected to participate in the survey. Since only 4 strata were used, the top 2 and bottom 2 counties were selected in the largest stratum (< 50,000 people).

4. White goods program efficiency (cost/ton)

County population had no significant effect on the efficiency of white goods programs. However, with the significant number of rural counties in North Carolina (77 of NC's 100 counties) a selection process based only on program efficiency could prevent all larger counties from being included in the white goods efficiency analysis. To help ensure any findings of this analysis would be usable for counties of different sizes, it was desirable to survey at least some larger counties. As a result, counties were organized into the following 4 strata based on county population:

1.	< 50,000 people	(n = 26)
2.	50,000 – 100,000 people	(n = 23)
3.	100,000 – 150,000 people	(n = 7)
4.	150,000 people	(n = 6)

Within each of these strata, counties were ranked based on their white goods program efficiency (cost/ton) and the top and bottom ranked counties were selected to participate in the survey. Since only 4 strata were used, the top 2 and bottom 2 counties were selected in the largest stratum (< 50,000 people).

Other county selection comments

The phone surveys conducted with selected counties were long and detailed, so it was desirable to avoid surveying the same county for both its white goods and scrap tire programs. Using this selection process, 4 counties were originally selected for both program surveys. In these 4 cases, the county was randomly selected for one program survey and the next higher or lower-ranked county was selected for the other program survey.

When conducting the second phase of this analysis, counties with extreme performance measurements were still excluded. For example, if a county was selected based its program effectiveness, but its program efficiency measurement fell within the top 10% or bottom 10% of all counties in the state, that county was still excluded from all analyses of efficiency. Among the counties surveyed for their white goods programs, one county (Wake) was excluded from the effectiveness analysis and three counties (Anson, Guilford, and Lincoln) were excluded from the efficiency analysis. Among the counties surveyed for their scrap tires programs, one county (Mitchell) was excluded from the effectiveness analyses and two counties (Ashe and Granville) were excluded from the efficiency analysis. Again, these counties were excluded to avoid considering measurements that may be artificially high or low due to poor record keeping or reporting practices.

SOURCES

American Metals Market. (April 2006). *March Price Averages*. Retrieved from http://www.findarticles.com/p/articles/mi_m3MKT/is_48-4_113/ai_n15934883

Apperson, Charles S., Szurnlas, Daniel E., and Powell, Eugene E. (1994). *Survey of Mosquito-Transmitted Viruses Associated with Tire Disposal Sites in North Carolina*. A final report submitted to the Solid Waste Section of the North Carolina Dept. of Environment, Health, and Natural Resources.

Appliance Recycling Centers of America, Inc. (ARCA). *Appliance Recycling Facts*. Retrieved from http://www.arcainc.com/html/appliance_recycling_facts.html.

Appliance Recycling Information Center (ARIC). *INFOBulletin #1 - Recycling Major Home Appliances*. Retrieved from http://www.aham.org/industry/ht/action/GetDocumentAction/id/5363

Appliance Recycling Information Center (ARIC). *INFOBulletin #2 – Average Ferrous Content of Major Home Appliances*. Retrieved from http://www.aham.org/industry/ht/action/GetDocumentAction/id/5364

Appliance Recycling Information Center (ARIC). (June 2001). *INFOBulletin #3 - State White Goods Disposal Laws*. Retrieved from http://www.aham.org/industry/ht/action/GetDocumentAction/id/5365.

Appliance Recycling Information Center (ARIC). *INFOBulletin #5 - Major Appliances and PCB Small Capacitors*. Retrieved from http://www.aham.org/industry/ht/action/GetDocumentAction/id/5367

Appliance Recycling Information Center (ARIC). (March 2005). *INFOBulletin #8 - Mercury in Home Appliances*. Retrieved from http://www.aham.org/industry/ht/action/GetDocumentAction/id/5370.

Bach, Heinz, Mild, Andreas, Natter, Martin, and Weber, Andreas. (August 2003). "Combining Socio-Demographic and Logistic Factors to Explain the Generation and Collection of Waste Paper". *Resources Conservation and Recycling*. 41(2004). 65-73.

Bacot, Hunter, McCabe, Amy S., Fitzgerald, Michael R., Bowen, Terry, and Folz, David. (March 1993) "Practicing the Politics of Inclusion: Citizen Surveys and the Design of Solid Waste Recycling Programs". *American Review of Public Administration*. 23(1): 29-41.

Berger, Ida E. (July 1997). "The demographics of recycling and the structure of environmental behavior". *Environment and Behavior*. 29(4): 515-531.

Blackman, Allen and Palma, Alejandra. (September 2002). *Scrap Tires in Ciudad Juárez and El Paso: Ranking the Risks*. Resources for the Future. Discussion Paper 02-046.

Carroll, Wayne. (Spring 1995). "The Organization and Efficiency of Residential Recycling Services". *Eastern Economic Journal*. 21(2). 215-225.

Derksen, Linda and Gartrell, John. (1993). "The Social Context of Recycling." *American Sociological Review*. 58(3). 434-442.

Feiock, Richard C. and Kalan, Lesley Graham. (March 2001). "Assessing the Performance of Solid Waste Recycling Programs Over Time". *American Review of Public Administration*. 31(1): 22-32.

Folz, David H. (1991). "Recycling Program Design, Management, and Participation: A National Survey of Municipal Experience." *Public Administration Review*. 51(3): 222-231.

Folz, David H. and Hazlett, Joseph M. (1991). "Public Participation and Recycling Peformance: Explaining Program Success." *Public Administration Review*. 51(6): 526-532.

Folz, David H. (1995). "The Economics of Municipal Recycling: A Preliminary Analysis." *Public Administration Quarterly*. 19(3). 299-320.

Folz, David H. (1999). "Municipal Recycling Performance: A Public Sector Environmental Success Story." *Public Administration Review*. 59(4). 336-345.

Folz, David H. (2004). "Service Quality and Benchmarking the Performance of Municipal Services." *Public Administration Review*. 19(3). 209-220.

Gamba, Raymond J. and Oskamp, Stuart. (1994). "Factors Influencing Community Residents' Participation in Commingled Curbside Recycling Programs." *Environment and Behavior*. 26(5). 587-612.

Hornik, Jacob and Cherian, Joseph. (1995). "Determinants of Recycling Behavior: A Synthesis of Research Results." *Journal of Socio-Economics*. 24(1). 105-127.

Hughes, Jeff. "Paying Up Front for Disposal of Special Wastes". (Winter 2003). *Popular Government.*

Hyde, Jeffrey and Lovejoy, Stephen. (1995). "Recycling: The High Cost of Being Environmentally Correct." *Staff Paper, Department of Agricultural Economics, Purdue University*. 11 pp.

Kinnaman, Thomas C. and Fullerton, Don. (2000). "Garbage and Recycling with Endogenous Local Policy." *Journal of Urban Economics*. 48(3): 419-442.

Major Appliance Resource Management Alliance (MARMA). (February 1997). *Appliance Recycling in North America: Infrastructure and Challenges.*

Midwest Assistance Program, Inc. (June 2003). *The Study of White Goods Recycling and Disposal in Missouri.*

North Carolina Department of Environment and Natural Resources, Division of Waste Management (NC DENR). (2004). *North Carolina Solid Waste Management Annual Report: July 1, 2003 – June 30, 2004.*

North Carolina Department of Environment and Natural Resources, Division of Waste Management (NC DENR). (2000). *North Carolina Scrap Tire Management Report.* October

North Carolina Division of Pollution Prevention and Environmental Assistance (NC DPPEA). *Emissions from Open Tire Fires*. Retrieved from http://www.p2pays.org/ref/11/10504/html/intro/openfire.htm.

Oskamp, Stuart, Burkhardt, Rachel L., Schultz, P. Wesley, Hurin, Sharrily, and Zelezny, Lynnette. (Winter 1998). "Predicting Three Dimensions of Residential Curbside Recycling: An Observational Study". *Journal of Environmental Education*. 29(2): 37-42.

Owens, Julie, Dickerson, Sharyn, and Macintosh, David. (2000). "Demographic Covariates of Residential Recycling Efficiency". *Environment and Behavior*. 32(5): 637-650.

Peretz, Jean H., Tonn, Bruce E., and Folz, David H. (2005). "Explaining the Performance of Mature Municipal Solid Waste Recycling Programs." *Journal of Environmental Planning and Management*. 48(5). 627-650.

Rubber Manufacturers Association (RMA). (July 2004). *U.S. Scrap Tire Markets: 2003 Edition.* Retrieved from http://www.rma.org/scrap_tires/.

Saphores, Jean-Daniel M., Nixon, Hilary, Ogunseitan, Oladele A., and Shapiro, Andrew A. (October 2005). *Household Willingness to Recycle Electronic Waste.*

US Environmental Protection Agency (US EPA). (March 1996). *Characterization of Municipal Solid Waste in the United States: 1995 Update*. EPA530-R-96-001.

US Environmental Protection Agency (US EPA). (June 1997). *Characterization of Municipal Solid Waste in the United States: 1996 Update*. EPA530-R-97-015.

US Environmental Protection Agency (US EPA). (May 1998). *Characterization of Municipal Solid Waste in the United States: 1997 Update*. EPA530-R-98-007.

US Environmental Protection Agency (US EPA). (July 1999). *Characterization of Municipal Solid Waste in the United States: 1998 Update*. EPA530-R-99-021.

US Environmental Protection Agency (US EPA). (July 2001). *Municipal Solid Waste in the United States: 1999 Facts and Figures*. EPA530-R-01-014.

US Environmental Protection Agency (US EPA). (June 2002). *Municipal Solid Waste in the United States: 2000 Facts and Figures*. EPA530-R-02-001.

US Environmental Protection Agency (US EPA). (October 2003). *Municipal Solid Waste in the United States: 2001 Facts and Figures*. EPA530-R-03-011.

US Environmental Protection Agency (US EPA). (April 2005). *Municipal Solid Waste in the United States: Facts and Figures for 2003*. EPA530-F-05-003.

US Environmental Protection Agency (US EPA). *Tire Fires*. Retrieved from http://www.epa.gov/epaoswer/non-hw/muncpl/tires/fires.htm.