Are Chronic Disease Indicators Associated with Living Close to Treatment, Waste, & Disposal Sites (Landfills) in Southeastern United States?

By

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DEDICATION

To my family, whose boundless love, encouragement, and sacrifices have fueled my journey every step of the way. Especially my mother Catherine Andrews and father James Kojo Antwi who continues to rest with the Lord. Your love has been the cornerstone of my achievements.

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ABSTRACT

This study investigated the associations between residential proximity to landfill sites and the prevalence of chronic diseases in the Southeastern United States. Utilizing a cross-sectional design, data from 624 landfills and 23,256 census tracts were analyzed. Chronic disease indicators included asthma, hypertension, diabetes, cancer, and mental health, sourced from the CDC's PLACES Project and adjusted for poverty, age, rurality, race, health insurance, and state. Spatial analysis techniques identified exposure proportions within 0.5, 1, 3, and 5-mile buffer zones of landfills. Results from the adjusted Generalized Linear Models revealed significant associations at 0.5 miles for diabetes (OR=6.72, p=.018), high blood pressure (OR=3.08), and asthma (OR=2.37, p=.003). Proximity to older landfills (pre-1990) and higher-volume landfills (>500 tons daily) demonstrated differential impacts on health outcomes. Findings suggest that closer residential proximity to landfills, particularly high-volume and older sites, is associated with increased prevalence of certain chronic diseases, emphasizing the need for mindful waste management and policy implications for health equity.

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CHAPTER I

INTRODUCTION

Treatment, Storage, and Disposal (TSD) facilities, including landfills, store by-products that have adverse health effects, posing a health threat to the people who live close to these facilities. Improper waste management has dire environmental and public health effects (*Waste and Human Health*, 2015). Municipal Solid Waste landfills are specifically designed to receive household waste and other types of nonhazardous wastes, according to the United States Environmental Protection Agency (US EPA, 2016). However, items that have the potential to cause adverse health effects on people, including electronic waste, always find their way into landfills, with an estimated 54 million tons of e-waste, such as TVs, computers, and phones generated annually (*Solid Waste*, 2021).

Municipal solid waste can be potentially hazardous, especially in many middle and low-income countries and communities where infectious and industrial waste are not segregated from domestic waste (Cointreau, 2006). Some major factors that pose a health risk to those living close to landfill sites include contamination of underground and surface water from leachate and surface runoff from landfill sites, volatile organic compounds, carbon dioxide, hydrogen sulfide, and methane emissions, particulate matter, chronic psychological stress and odor from living near such facilities (Mataloni et al., 2016a; Zhao et al., 2015, Cointreau, 2006)

There has been compounding evidence that shows that people who live closer to TSDs are at greater risk of poor environmental burden (De Feo et al., 2013). For nearly a century, discriminatory laws and policies have situated polluting industries near low-income communities and communities where racial minorities live, for instance, Black Americans are about 75% more likely to live near waste-producing facilities, or within fenced-lined communities, than an average American (Fleischman & Franklin, 2017). Poor environmental burden contributes greatly to chronic health outcomes such as asthma, high blood pressure, cancer, diabetes, and poor mental health (CDC, 2023), which will be the focus of the current study. A systematic review of the health risks associated with living close to landfills found evidence of severe health problems including increased mortality for lung cancer, births with congenital anomalies, congenital heart disease, an association between increased $PM_{2.5}$, reduced lung function in children aged 6 – 12 years, worsening mental and social health conditions such as negative mood states among several health conditions (Vinti et al., 2021; Nicoll, 2018).

A global spurt in population and economic development has resulted in a massive increase in the municipal solid waste generation of over 2.01 billion tons every year and that number is expected to rise to 3.4 billion tons by 2050 (Kaza et al., 2018). Globally, massive waste in urban areas is inundating local governments' capacity to effectively manage the high volumes of waste (Cointreau, 2006). The management of solid waste disproportionately affects the urban poor in a variety of ways including the impact on health, housing quality, service access, and livelihoods (*Solid Waste*, 2021; Ready, 2010). The knowledge of the extensive adverse health risks posed by living close to landfill sites is required to inform several factors such as choosing a location for the site, engineering quality, and operating practices to increase the safety of residents living close to those facilities and the workforce employed in the area (Walosik et al., 2021).

Purpose

The purpose of the study is to examine negative chronic health effects (chronic disease outcomes: Asthma, Hypertension, Diabetes, Cancer, and Mental Health) associated with residing close to treatment, waste, and disposal sites (landfills), or situating treatment waste and disposal sites close to residential areas.

Research Questions

This study aims to answer and provide insight into two questions:

1. Is there a difference in the prevalence of chronic diseases among residents living in census tracts near landfill sites compared to those living farther away, in the Southeastern United States?

2. Is there an association between the volume and duration of a landfill's operation and the prevalence of chronic diseases in nearby residential areas in the Southeastern United States?

Hypotheses

We hypothesize that the prevalence of chronic diseases in this study is higher among residents living near landfill sites compared to those residing in areas further away. We further hypothesize that high-volume and longer-operating landfill sites are associated with a higher prevalence of chronic diseases in neighboring residential areas.

Significance of Study

Hazardous sites are disproportionately situated in areas where marginalized and socially vulnerable populations live, resulting in a disproportionate distribution of disease outcomes, health inequities, and environmental injustices from toxic substances and the stress of living close to these sites. Findings from the study will guide public health measures in addressing the health risks and impacts on vulnerable populations as well as issues of environmental injustices. It will also serve as a resource for public health needs assessment when working with vulnerable populations.

CHAPTER II

LITERATURE REVIEW

Solid Waste

Any type of refuse, trash, garbage, or discarded material or any item consumers throw away after its use may be referred to as solid waste or municipal solid waste (MSW) based on where the waste is generated (Solid Waste, 2021; USEPA, 2017). Municipal solid waste is generally referred to as household waste and any type of nonhazardous waste (USEPA, 2016) and does not always take a physically solid form (It can include liquid, semi-liquid, or gaseous forms) (Walosik et al., 2021). The United States EPA bans certain household materials classified as hazardous from disposal in MSWLFs, including common household items like paints, cleaners/chemicals, motor oil, batteries, and pesticides (USEPA, 2016).

The characteristics of municipal solid waste components depend on the geography, culture, and income levels of the community (Chandrappa & Das, 2012). Globally, the components of municipal solid waste comprise an estimated 44% of food and other organic waste, and dry recyclables such as paper and cardboard, glass, metals, and plastics make up approximately 38% of the MSW (Kaza et al., 2018). The organic matter proportion in waste increases with decreasing income levels while dry recyclables increase with increasing income levels (Kaza et al., 2018). When MSW is not well managed, it can have mild to severe negative impacts on the environment. The breakdown of organic matter during decomposition releases harmful gases such as hydrogen sulfide (H2S), volatile organic compounds (VOCs), methane, and carbon dioxide (CO_2), that pose a threat to our health through the pollution of surface and groundwater, the soil, and the air (Liu et al., 2016, 2016; Mataloni et al., 2016b; Wilson, 2023; Zhao et al., 2015).

Waste Generation and Management

Urbanization, exponential population growth, and development are contributing to the waste generation problem, that has caused problems in our environment for centuries (Chandrappa & Das, 2012). Despite comprising only 16% of the world's population, high-income countries are believed to generate about a third of all global waste, some of which is sent to developing countries (Kaza et al.,). MSW management system involves waste generation, collection, transport, treatment, and disposal. Some effective approaches to MSW management include reduction in waste generation, reusing items, and recycling generated waste (*Solid Waste, 2021*). After exhausting these reduction measures or its unavailability, waste ends up being disposed of through other management methods such as incineration, or via landfill (*Solid Waste, 2021*).

Where does the trash go?

Despite recycling being the most positively perceived of all waste management methods (Yakah et al., 2023), an estimated 40% of all the waste collected worldwide ends up in some type of landfill (Kaza et al., 2018). Recycling, composting, and incineration are also some of how MSW is managed across the globe (Kaza et al., 2018). An estimated 2.01 billion tons of MSW is produced annually and that number is expected to rise to 3.4 billion tons by 2050 (Kaza et al., 2018). In 2018, MSW generated in the United States was estimated to be 292.4 million tons, approximately 4.9 pounds per person per day (USEPA, 2023). Out of the waste generated in the United States, an estimated 50% (146 million tons) were landfilled (USEPA, 2018).

Treatment, Storage and Disposal Facilities (TSDs).

Waste management goes through various steps and processes treat, store and finally dispose of onto land and into water depending on the type of waste. With MSW, the disposal facility is usually a sanitary landfill which is specifically designed to receive household waste, as well as other types of nonhazardous wastes (US EPA, 2016), therefore much of the literature will focus on sanitary landfills or modern landfills. According to Taylor et al. (2022), one in six Americans lives within three miles of a toxic waste site—often unknowingly (Taylor et al., 2022). Landfills have been regarded as an undesirable solution to the waste management problem (Jovanov et al., 2018), yet they remain popular in most countries including the United States due to their low cost and economic advantage and are projected to remain an integral part of MSW management systems worldwide (Vaverková, 2019).

Landfills in developing countries are usually of low quality and considered cheap methods of waste management (Yakah et al., 2023). Most landfills in these geographical areas are either open dumpsites (about 33% globally) or simply burying waste in the ground without proper engineering techniques to protect the environment (Kaza et al., 2018). Governments around the world are recognizing the cost and health risks posed by improper waste disposal (Kaza et al., 2018). The collection and sanitary disposal of waste have greatly improved from 50 years ago when most of the waste collected was disposed of in open dumps throughout the world (Vaverková, 2019).

Landfill Types

In the United States, the Environmental Protection Agency (EPA categorizes landfills into three types. These include Municipal Solid Waste Landfills (MSWLFs), Industrial Waste Landfills, and Hazardous Waste Landfills (USEPA, 2016). The names of the landfills usually come from the type of waste they receive. The EPA estimates that there are 1,908 MSWLFs in the continental United States all managed by the states where they are located (USEPA, 2016).

Siddiqua et al. (2022) defined a landfill as an engineered pit, particularly designed for receiving compacted solid waste and equipped with specific covering, so that the waste can be disposed of.

Modern Landfill Engineering

Modern Landfills

Modern landfills or Modern Sanitary Landfills relate to the regulated engineered landfills to reduce hazardous substances from landfills that will pollute the environment (Louis, 2004). The Resource Conservation and Recovery Act of 1976 (RCRA) is a legislation that defined Municipal Solid Waste Management practices in the United States and established standards for building sanitary landfills resulting in the banning of open dumpsites. The closure of dumpsites resulted in a waste crisis in the 80s and the widespread use of Sanitary or Modern landfills. According to (Louis, 2004), technology and performance-based standards for landfill management under RCRA have been very stringent since the 80s till the present day. The EPA in 1996 improved regulations to reduce non-methane organic compounds (NMOC) by 98% by requiring large landfills to collect and burn landfill gas (Louis, 2004).

Modern MSWLFs are discrete areas of land or excavation well-engineered and managed facilities designed for the disposal of household-generated wastes as well as other types of nonhazardous wastes such as commercial solid waste, nonhazardous sludge, conditionally exempt small quantity generator waste, and industrial nonhazardous solid waste (USEPA, 2016). Modern landfills are designed to protect the environment by isolating the waste, which is mostly stored in solid form, from the soil and underground water giving it its name Sanitary Landfills (Siddiqua et al., 2022; Tenodi et al., 2020).

Modern Landfill Engineering

The Code of Federal Regulations (CFR) part 258 addresses seven major aspects of MSWLFs which include: location restrictions, composite liners requirements, leachate collection and removal systems, operating practices, groundwater monitoring requirements, closure and post-closure care requirements, Corrective action provisions, and financial assurances (USEPA, 2016). Sanitary Landfill designs have a bottom comprised of liner systems on the sides made up of a compressed clay liner and plastic lining to prevent leaks and various layers of layering that ensure the landfill system provides a conducive environment for microorganisms to decompose the existing waste (Siddiqua et al., 2022; USEPA, 2016).

There is also a leachate system and an underground monitoring system, as well as a gas extraction system comprising installed pipes that collect leachate and potentially explosive gas such as methane from the bottom of the landfill which can be used for energy production (Siddiqua et al., 2022). Some Landfills have an anaerobic or aerobic bioreactor that facilitates the process of decomposition of organic waste within the landfill (Siddiqua et al., 2022; USEPA, 2016). Leachate collected in the system is pumped up to a storage tank for safe disposal and when the landfill is full, layers of soil and clay are used to seal the trash (USEPA, 2016).

Landfill Hazards and Risks

Despite the popularity and improvements made to landfills around the world, they still have the potential to pollute the environment and, therefore need to be monitored to determine the potential hazards posed to the environment (Vaverková, 2019) and those who live closer to landfills. The organic components in MSW undergo physical, chemical, and biological activity resulting in aerobic and anaerobic breakdown. The resulting changes become leachate, landfill gases, and odor (Walosik et al., 2021)

Some commonly identified landfill hazards include leachate that compromises underground water and surface water quality, and soil, air pollution and odor from landfill gas that threatens the health of humans and animals, carcinogenic polycyclic aromatic hydrocarbons (PAHs), heavy metals, methane and other greenhouse gas emissions accelerating climate change, and accumulation of toxins in animals, humans, and natural/environmental systems and occasional fires from certain landfills that contributes to PM10 concentration (Bihałowicz et al., 2021; Iravanian & Ravari, 2020; Jovanov et al., 2018; Kjeldsen et al., 2002; Tenodi et al., 2020; Vaverková, 2019). According to Gómez-Sanabria et al. (2022), $PM_{2.5}$ emissions from MSW contributed to 8% of the total global anthropogenic $PM_{2.5}$ emissions. $PM_{2.5}$ is related to lung cancers, chronic respiratory tract infections, Asthma, and cardiovascular diseases (Gumede & Savage, 2017; Hamra et al., 2014; Made et al., 2021)

Choosing Health Risks to Study

The World Health Organization (WHO) suggests that in choosing the health risk and disease outcome to study, the toxicological profile of the substances to which the population is exposed should be considered as well as the latency period, route, and timing of exposure (Dean, 2001). WHO in a report that assessed the hazards from landfills highlighted the following substances for special attention: metals, total petroleum hydrocarbons, polycyclic aromatic hydrocarbons, other aromatic hydrocarbons, chlorinated hydrocarbons, polychlorinated biphenyls, pesticides, methane, dioxins, asbestos, pharmaceuticals, pathogens, probably due to their harmful nature and potential carcinogenicity (Dean, 2001).

Diseases Associated with Living Close to Landfills.

Landfills pose a threat to public health as it has been linked to several health problems and diseases in populations that live close by these sites and landfill workers. Several studies in both the United States and other jurisdictions have explored the relationship between living close to landfill sites and the diseases associated with it, as well as landfill workers (Chatham-Stephens et al., 2013; Choi et al., 2006; Gumede & Savage, 2017; Kar & Basunia, 2020; Made et al., 2021; Nair, 2021; Tomita et al., 2020; Zhang et al., 2023)

US Southeast Landfill Study

Not many studies have been conducted in the US Southeast about proximity to landfills and health impacts. However, other parts of the country, especially New York and California have been heavily studied with the Love Canal in New York being heavily cited. Some of the health outcomes from studies across the US and Canada found adverse health outcomes including cancer, birth defects, low birth weight babies, spontaneous abortions, cognitive decline, and gastrointestinal issues, among others in a systematic review study of single and multisite landfill studies (Vrijheid, 2000). Landfills have been linked to less obvious non-respiratory illnesses, such as diabetes, through exposure to polychlorinated biphenyls (PCBs) originating from hazardous waste sites. A study in Aniston Alabama which has a history of PCB contamination, found a strong correlation between PCBs and the prevalence of diabetes in a clinical study after adjusting for diabetes risk factors. (Silverstone et al., 2012; Weinhold, 2013). This finding is very important as landfills are a source of PCB release into the environment (Gabryszewska & Gworek, 2021)

Acute and chronic diseases associated with landfills.

Health outcomes associated with landfills have been diverse in conditions similar around the world. A survey study in Kolkata, India, found a higher prevalence for both chronic health problems and acute health problems in people who lived within 1 km of a landfill site. Some of the reported chronic health problems included heart diseases, diabetes, hypertension, gastric problems, eye problems, asthma, and gall bladder problems. A study conducted in South Africa found acute health problems such as cough, breathing and respiratory symptoms, cold, fever, vomiting, allergy, and skin problems. Cold and cough were the commonly reported problems in that study with about 9 in 10 participants reporting having experienced them. About 6 in 10 participants reported breathing and respiratory symptoms (Kar & Basunia, 2020).

In a study that examined bioaerosols in the landfill environment, Nair (2021) concluded that landfill sites loaded with pathogenic microbes could become an epicenter of an outbreak with landfill workers and people residing close to the sites standing at the greatest risk of infection. Bioaerosol exposure has been linked to eye irritation, musculoskeletal problems, gastrointestinal issues, and respiratory symptoms (Nair, 2021). A 10-year risk study of waste pickers in South Africa found pronounced cardiovascular disease risk and metabolic diseases including high blood pressure, diabetes, and obesity. The study also found an unusually higher prevalence of blood pressure, diabetes, and obesity among normal-weight populations and in women as compared to men (Made et al., 2021, p. 10).

Diseases and air pollution from landfills

Air pollution from landfills has been a major contributor to health problems among residents living close to landfills as well as a source of psychological burden due to the odor from landfills. A comprehensive review of literature that accessed the air pollutants around landfill sites, Salami & Popoola (2023) found particulate matter PM2.5 and PM10, to be particularly higher around landfill sites. Also, polycyclic aromatic hydrocarbon (PAH), CO2, CH4, H2S, SO2, NO2, CO, and several ranges of air pollutants are relatively higher near landfill sites.

These gases are known to have deleterious effects on the health of the people who live in proximity to these sites, including lung cancer other types of cancers, and respiratory infections (Mazzucco et al., 2020). Particulate matter has been heavily linked to cancers of the trachea, bronchus, and lungs (Hamra et al., 2014). There was a reported increase in male cancers of the skin and pancreas even after adjusting for age and sex among residents in proximity to landfills (Porta et al., 2009). According to the US EPA, landfills contributed to 14% of the total methane gas emissions in the United States in 2021 (US EPA, 2023). Methane gas is a potent greenhouse gas and a potential driver of climate change (Balcombe et al., 2018). Landfill gases, however, are not all bad news. If well managed, they can be collected and processed to generate energy (US EPA, 2023).

Proximity Associations with Disease

Evidence has shown that proximity to landfill sites poses health risks to reproduction and the reproductive system. In the case of pregnant women and newborns, congenital anomalies, teratogenicity, low birth weight, and mortality have also been associated with proximity to a landfill site (Kihal-Talantikite et al., 2017; Mazzucco et al., 2020). Evidence of risk of birth defects associated with proximity to landfills by Elliott (2001) found that, despite being small, the was an excess risk of neural tube defect, abdominal wall defect, surgical correction of gastroschisis, exomphalos, low and very low birth weight. Evidence of low and very low birth rates commonly runs through several studies. Birth defects and congenital anomalies including chromosomal defects were also reported by Porta et al. (2009) among residents living within a distance of 3 km. It is worth noting that stillbirth, small-for-gestation age, spontaneous abortion, and neonatal death were not associated with proximity to landfill sites (Kihal-Talantikite et al., 2017)

The health impacts of living in proximity to landfills have persisted even after controlling for socioeconomic status, showing the strength of the association. Tomita et al. (2020) found a significantly increased likelihood of depression, tuberculosis, asthma, and diabetes in a population living within 5 km of a landfill in South Africa.

Proximity to landfill sites and waste workers has been associated with severe psychological stress and mental health issues. Other mental health issues such as anxiety and depression have also been reported in previous studies (Nguyen et al., 2021).

Definition of Residential Proximity

No universally recognized proximity buffer ranges exist for assessing the health effects of landfills. Different researchers have made use of different buffer distances without justification for their mainly arbitrary choice (Kihal-Talantikite et al., 2017). A WHO report in 2000 opined that exposure from landfill sites is likely to be limited beyond 1 km from the site by the air pathway, and 2 km by the water pathway. Kihal-Talantikite et al. (2017) have argued that this WHO report is what has guided most researchers who stated in their papers that exposure from landfill sites is likely to be limited beyond 1 km from the site by the air pathway, and 2 km by the water pathway. They added that researcher expertise in chemical exposure has also been a determining factor since chemical exposures from landfills have been detected up to 3 km from landfills.

Other factors influencing the choice of distance have also been whether the residential area is urban or rural with previous studies choosing a buffer of 2-3 km for urban areas and 4-5 km for rural areas respectively (Boyle et al., 2004). Varying distances have been used for various reasons ranging from 100 – 500 meters (*Assessing planning proposals within the buffer of a landfill*, 2017; Fazzo et al., 2020; Njoku et al., 2019), 1 – 2 km (Dean, 2001; Elliott, 2001; Gouveia & Prado, 2010; Gumede & Savage, 2017; Kihal-Talantikite et al., 2017; Vrijheid, 2000; Aggarwal et al., 2018), 3 km (Fielder, 2000; Kihal-Talantikite et al., 2017) and 4 – 5 km (Boyle et al., 2004; Tomita et al., 2020). Several different distances have equally been studied including 1 mile (Choi et al., 2006; Goodman et al., 2010; Tansel & Inanloo, 2019).

Distance selection in the US.

In the United States, a one-mile buffer has been the most commonly used in proximity to waste sites study when studying issues of environmental burden and environmental injustices (CDC&ATSDR, 2022). Some such studies include a study in Massachusetts (Goodman et al., 2010), a California study (Huang & London, 2012) , and a Florida study that accessed odor impact from landfills(Tansel & Inanloo, 2019). In conclusion, distance selection has been arbitrary with researchers choosing their distances for various reasons including their expertise level and expected outcomes.

Social Determinants of Health and Environmental Justice.

The social determinants of health (SDH) are the non-medical factors that influence health outcomes. They are the conditions in which people are born, grow, work, live, and age, and the wider set of forces and systems shaping the conditions of daily life. Research shows that social determinants can be more important than health care or lifestyle choices in influencing health. For example, numerous studies suggest that SDH accounts for between 30-55% of health outcomes (*Social Determinants of Health, n.d). The world has seen considerable health gains over the last century, but their distribution is vastly unequal. This has led to inequities in health – avoidable and unfair differences in health status between groups of people or communities* (*Action on Social Determinants of Health Equity, n.d*). The threat associated with the health and geographic distribution of hazardous pollutant sites remains a controversial issue. Research has shown that hazardous waste sites are differentially located in predominately socially vulnerable (minority and low-income) communities, raising issues of environmental justice.

Environmental justice *"…is the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income, with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies." -EPA*

Health equity *"…is the state in which everyone has a fair and just opportunity to attain their highest level of health. Achieving this requires focused and ongoing societal efforts to address historical and contemporary injustices, overcoming economic, social, and other obstacles to health and healthcare, and eliminating preventable health disparities." -CDC*

This goal will be achieved when everyone enjoys:

- The same degree of protection from environmental and health hazards, and
- Equal access to the decision-making process to have a healthy environment in" which to live, learn, and work.

Promoting Environmental Justice (EJ) is key to advancing health equity. The Environmental Justice Index (EJI) can help to inform and focus public health interventions aimed at alleviating health disparities by identifying communities facing the worst cumulative impacts of environmental burdens on health, and to track the success of programs and interventions across time by providing iterative updates for comparison.

The EJI can help public health officials, policymakers, and communities identify and respond to the varied environmental and social factors that affect a community's health and well-being. EJI databases and maps can be used to:

- Identify areas that may require special attention or additional resources to improve health and health equity.
- Characterize the unique, local factors driving cumulative impacts on health to inform policy and decision-making.
- Establish meaningful goals and measure progress towards EJ and health equity.

CHAPTER III

METHODOLOGY

Study Area

In this study, we defined the United States Southeast Region to include ten states: Georgia, Arkansas, Kentucky, Mississippi, Louisiana, South Carolina, North Carolina, Tennessee, Alabama, and Florida. Census tract-level health estimates in these states were used to calculate health outcomes for residential proximity to landfills. Census tracts are small relatively permanent statistical subdivisions of a county, uniquely numbered in each county with a numeric code, averaging about 4000 inhabitants (ranges between 1200 minimum and 8000 maximum). A county, however, is a political and administrative division of a state, that provides certain local governmental services and is much bigger than a census tract. In partnership with the Robert Woods Johnson Foundation, the Centers for Disease Control and Prevention (CDC) expanded in 2020 to include small area and census tract health outcome estimates, whereas before, only county-level estimates existed. In considering smaller area estimates, findings from this study add more power and significance to the actual happenings in the population.

Methods and Materials

Operational Definitions:

Buffer Distances: What constitutes "near" and "farther away" from landfill sites? Based on the reviewed literature, living near a landfill site, for this study, was considered all distances 5 miles and below, and any distance beyond 5 miles were considered farther away from a landfill site. Buffer distances were created from landfill sites to approximate the proportion of census tracts exposed at 0.5, 1, 3, and 5 miles.

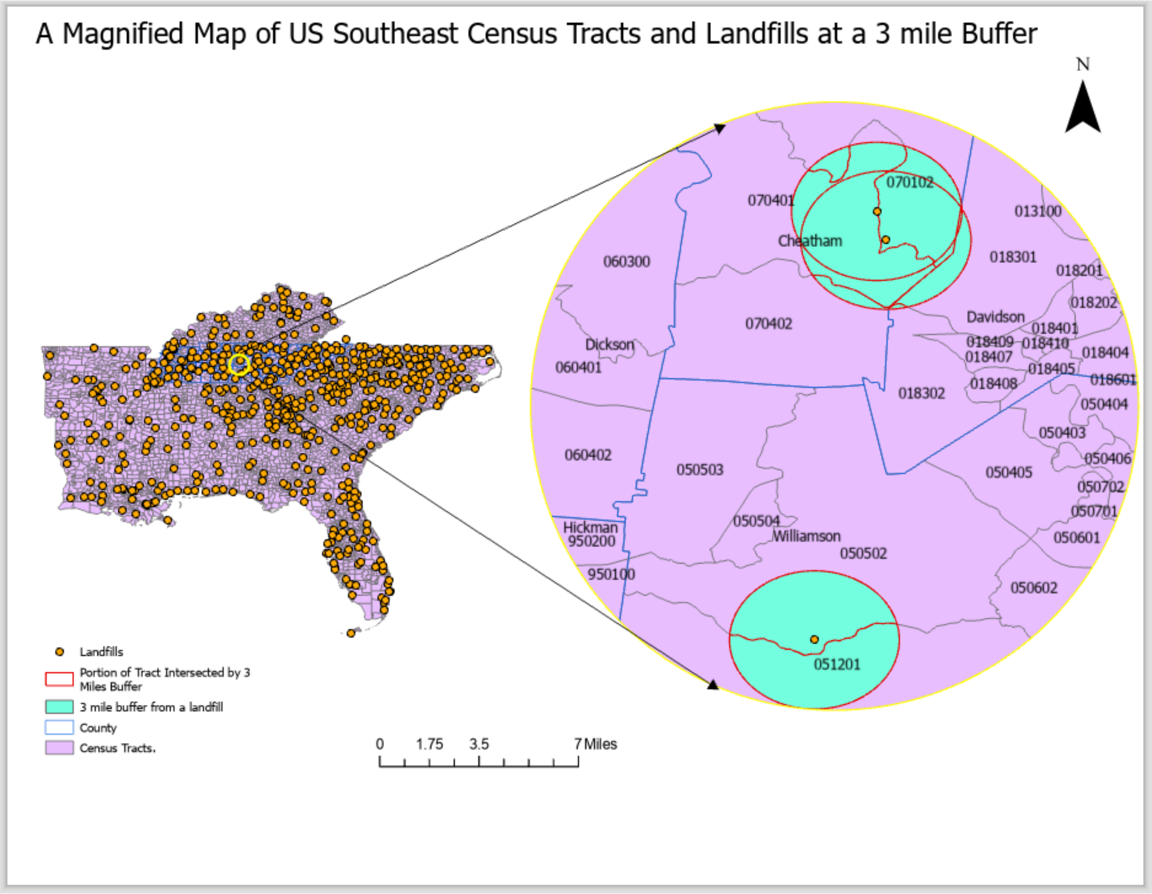


Figure 1

Magnified Map of US Southeast Census Tracts and Landfills at 3 Mile Buffer.

Landfill volume and operational duration*:* The study classified landfills based on volume and operational duration. Age and volume classifications were based on literature and regulatory agency definitions. Based on the literature, landfills that accept 500 tons or more waste per day are considered a high-volume landfill and those accepting below that figure a low-volume landfills. Also, a landfill that had been operating before 1990 was considered an old landfill, and those established after 1990 were considered new landfills for this study.

Data source**:** Data was downloaded from the 2022 CDC/ATSDR Environmental Justice Index Social and Environmental Ranking. The Environmental Justice Index (EJI) is the inaugural nationwide index designed to address the cumulative impacts of environmental justice (EJ) and health equity on a localized basis. It expands upon prior initiatives aimed at developing EJ screening and mapping tools at both state and federal levels. The EJI framework incorporates localized assessments of factors about distributive and procedural justice, as well as the combined effects of injustices on health and overall well-being. Operating at the level of census tracts, the EJI utilizes data from various sources including the U.S. Census Bureau, the U.S. Environmental Protection Agency, the U.S. Mine Safety and Health Administration, and the U.S. Centers for Disease Control and Prevention. These data sources are employed to evaluate the cumulative impacts of environmental injustice across more than 71,000 census tracts in the United States. Each tract is evaluated based on 36 environmental, social, and health indicators, which are grouped into three primary modules and ten distinct domains. The composite EJI score is derived by aggregating the ranked scores from three modules: the Environmental Burden Module, the Social Vulnerability Module, and the Health Vulnerability Module (CDC&ATSDR, 2022)

The landfill data was from the Environmental Protection Agency with geolocation for landfill sites. Rural/Urban Continuum codes from the United States Department of Agriculture datasets. The landfill type was limited to MSWLF. MSWLF characteristics such as operating and closed landfills, landfill volume, landfill age, and landfill type were considered for analysis. The rural-to-urban continuum codes will be incorporated as a decent measure for the rural function of a community.

Chronic Diseases of Concern**:** The chronic disease prevalence data for this study were derived from the CDC's PLACES Project, which utilizes data from the Behavioral Risk Factor Surveillance System (BRFSS) (CDC, 2023). The BRFSS is a comprehensive telephone survey that collects data from U.S. residents regarding their health-related risk behaviors, chronic health conditions, and use of preventive services. Historically, BRFSS has provided data at the state and county levels. However, the CDC's PLACES project extends this further by modeling these data to offer estimates at the census tract level, thereby enabling more granular public health assessments and interventions. This modeling approach allows for the extrapolation of BRFSS-collected data to finer geographic resolutions, capturing the health status of populations at the neighborhood level and thereby enriching the understanding of local health disparities and needs.

For this study, the following health outcomes, as defined and derived from BRFSS questions, are considered:

- Asthma: Represented by the percentage of individuals in a census tract who answered "Yes" to the question, "Have you ever been told by a doctor, nurse, or other health professional that you have asthma?"
- High Blood Pressure: The proportion of the census tract's population reporting a diagnosis of hypertension, based on the affirmative response to the question, "Have you ever been told by a doctor, nurse, or other health professional that you have high blood pressure?"
- Cancer (except skin): This metric is derived from the question, "Have you ever been told by a doctor, nurse, or other health professional that you have cancer?" Responses indicating skin cancer are excluded from this measure.

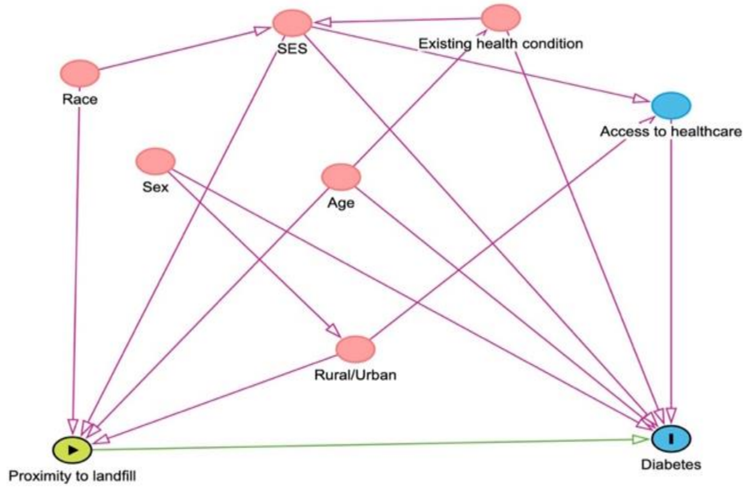
- Diabetes: The percentage of respondents within a census tract indicating "Yes" to the question, "Have you ever been told by a doctor that you have diabetes?" Cases of gestational diabetes are typically excluded from this measure.
- Poor Mental Health: This outcome is quantified by responses to the question, "Now thinking about your mental health, which includes stress, depression, and problems with emotions, for how many days during the past 30 days was your mental health not good?" For this study, the metric reflects the percentage of individuals reporting 14 or more days of poor mental health within the past month.

By leveraging BRFSS data through the innovative methodologies of the PLACES project, this study utilizes detailed, localized health outcome data to investigate the associations between living in proximity to landfill sites and the prevalence of chronic diseases within census tracts in the Southeastern United States.

Control Variables: In the construction of our model, careful consideration was given to a range of environmental and socio-demographic variables that have the potential to influence chronic disease outcomes. These variables were selected based on data available from the CDC's Environmental Justice Index (EJI), a comprehensive dataset that integrates a variety of health determinants. The EJI provides granular, census tract-level data, enabling the identification and control of key factors in our analysis. The specific variables included as controls in our study are as follows:

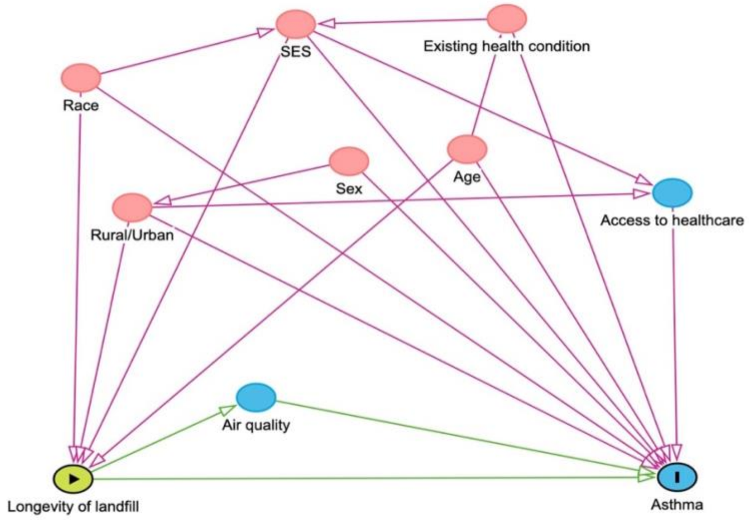
- **Poverty**: Measured by the percentage of individuals in a census tract living below 200% of the federal poverty line. This threshold was chosen to capture a broader spectrum of economic disadvantages that may not be evident when only considering the traditional poverty line.
- **Age**: Age data were aggregated to reflect the proportion of the population 65 and older.
- **Race/Ethnicity**: Instead of categorizing by specific racial and ethnic groups, our study utilized a composite minority metric, representing the percentage of the population within a census tract identified as belonging to any minority group.
- **Insurance Status**: This variable captures the proportion of the uninsured population within a census tract, serving as a proxy for access to healthcare services.
- **Rural/Urban Residency**: Utilizing the Rural-Urban Continuum code, residential areas were classified into three categories: metropolitan (urban areas with a population of 50,000 or more), micropolitan (urban clusters with a population of at least 10,000 but less than 50,000), and rural (areas outside the boundaries of metropolitan and micropolitan areas). This classification allows for the assessment of the impact of urbanization on health outcomes.

To systematically analyze the influence of these control variables on the relationship between proximity to landfill sites and chronic disease prevalence, we employed an epidemiologic tool, Dagitty. Dagitty was utilized to graphically represent the assumed causal relationships among variables, facilitating the identification of potential confounding factors and ensuring the robustness of our model. Through this approach, we aimed to elucidate the direct and indirect pathways through which living near landfill sites might affect health, while accounting for the socio-demographic and environmental context captured by the EJI dataset.



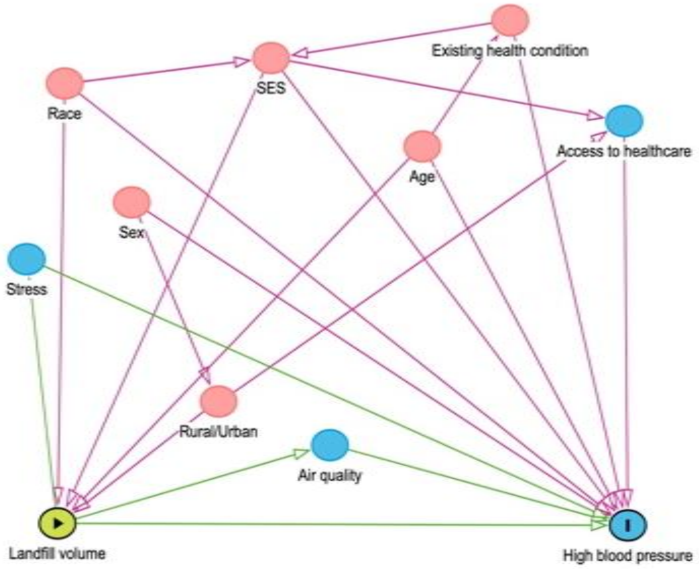
DAG 1.

Directed Acyclic Graph for Proximity to Landfill and Diabetes



DAG 2

Directed Acyclic Graph for Longevity of Landfill and Asthma.



DAG 3.

Directed Acyclic Graph for Landfill volume and High Blood Pressure.

Analysis

Geoprocessing: In the geoprocessing phase of our study, we employed ArcGIS Pro 3.0 to conduct spatial analyses that integrate landfill site characteristics with the geographic context of the Southeastern United States. Initially, we plotted each landfill site location onto the map, incorporating detailed attributes such as the daily volume of waste received and the operational age of the landfill. Subsequently, to assess the spatial relationship between landfill proximity and population health, we constructed four concentric buffer zones—spanning 0.5-mile, 1 mile, 3 miles, and 5 miles—around each landfill site.

For each buffer zone, we performed an intersection analysis with the census tracts in the Southeastern US to determine the extent of overlap (Figure 3). This intersection allowed us to calculate an exposure proportion for each census tract based on the area within the buffer relative to the total area of the tract. For instance, if a census tract had an intersected area of 50,000 square meters within a 0.5-mile buffer, and the total area of the census tract was 1,000,000 square meters, the exposure proportion at the 0.5-mile distance would be calculated as 5%. This methodological step was replicated for each buffer distance, yielding distinct exposure proportions that reflect varying degrees of landfill proximity.

Following the spatial analysis, we merged the geoprocessed data with relevant adjustment and outcome variables obtained from the previously mentioned data sources, including the CDC's Environmental Justice Index and CDC PLACES. This comprehensive dataset, now enriched with both spatial exposure measures and sociodemographic characteristics, was then exported into STATA 18 for advanced statistical analysis.

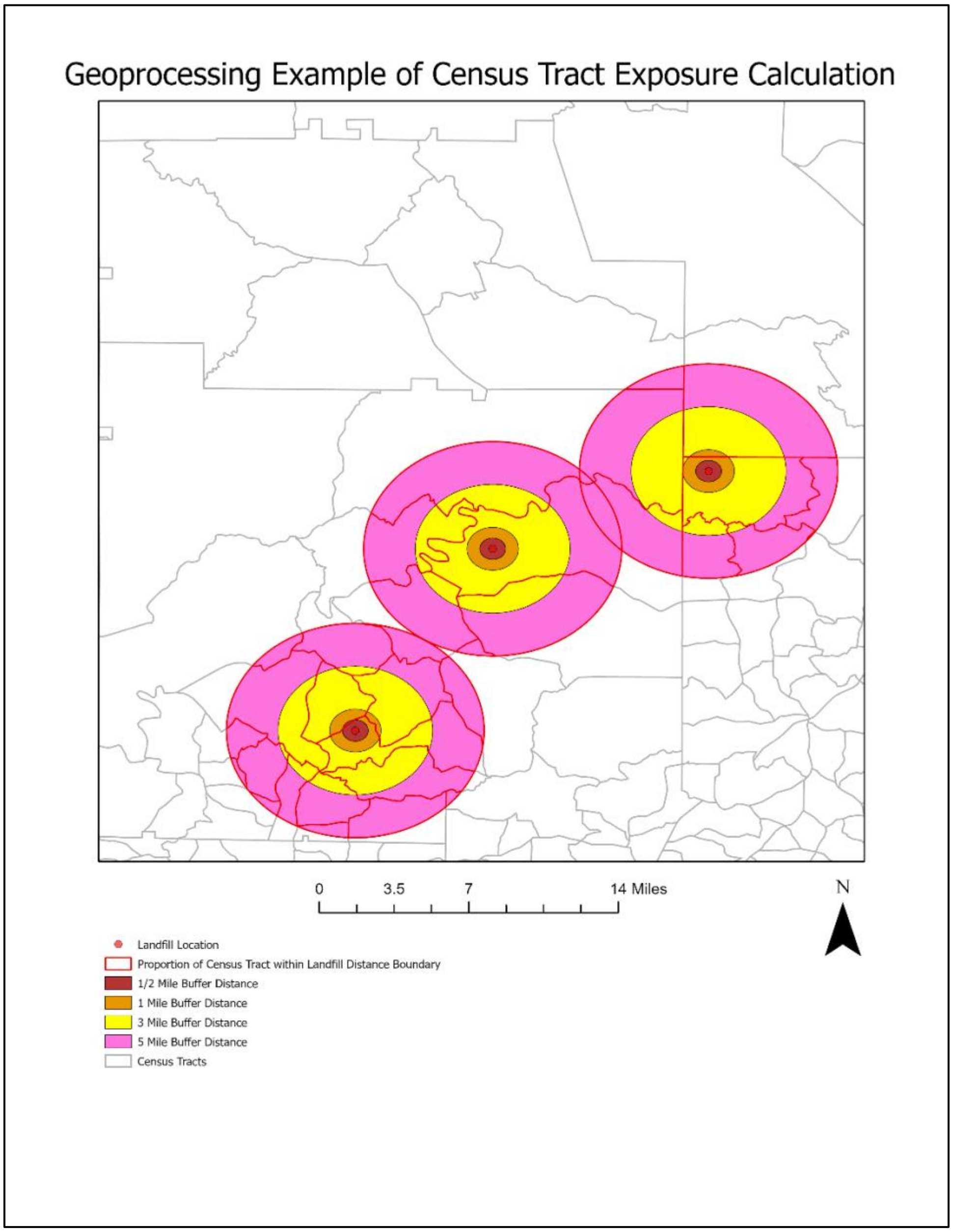


Figure 2

Example of intersection geoprocessing of landfill buffer and census tracts.

Data Analysis: Statistical analyses were performed in STATA/SE 18.0 (College Station, TX) and spatial analyses in ArcGIS Pro (ArcGIS Pro, 3.0). After data cleaning in the preparatory stage of the analysis, we conducted checks for normality and distributions of our data to ensure the appropriateness of our statistical models including normality tests for skewness and histograms. Both Multiple Linear Regression (MLR) and Generalized Linear Models (GLM) were considered for the analysis, with a particular focus on their ability to accurately model the relationship between the prevalence of various health outcomes and a set of predictor variables, including both continuous and categorical factors. After an evaluation based on the Akaike Information Criterion (AIC) and the standard errors of model estimates, the GLM was selected as the superior model due to its lower AIC values and reduced standard errors, indicating a better fit for our data. We opted for a GLM with a Gaussian family after comparing it against models with a Poisson distribution, as the Gaussian model presented even lower AIC values (Appendix). Additionally, to account for potential heteroscedasticity and to ensure robustness in our variance estimation, we employed the robust option in STATA. All coefficients derived from the GLM were exponentiated to obtain the odds ratios, providing a more interpretable measure of the effect sizes associated with our predictor variables. The proportions of a census tract within a 0.5, 1, 3, and 5-mile buffer of a landfill were used to determine the level of exposure. Prevalence estimates for tract-level asthma, diabetes, high blood pressure, mental health, and cancer were used as a continuous outcome variable.

CHAPTER IV

RESULTS

In the Southeastern United States comprising Alabama, Arkansas, Georgia, Florida, Kentucky, Louisiana, Mississippi, North Carolina, South Carolina, and Tennessee, 624 Landfill facilities and 23,256 Census Tracts with health data were used for the analysis. Out of that number, 13,770 census tracts had landfills in them, while 9,486 did not have any landfills in them (Table 1).

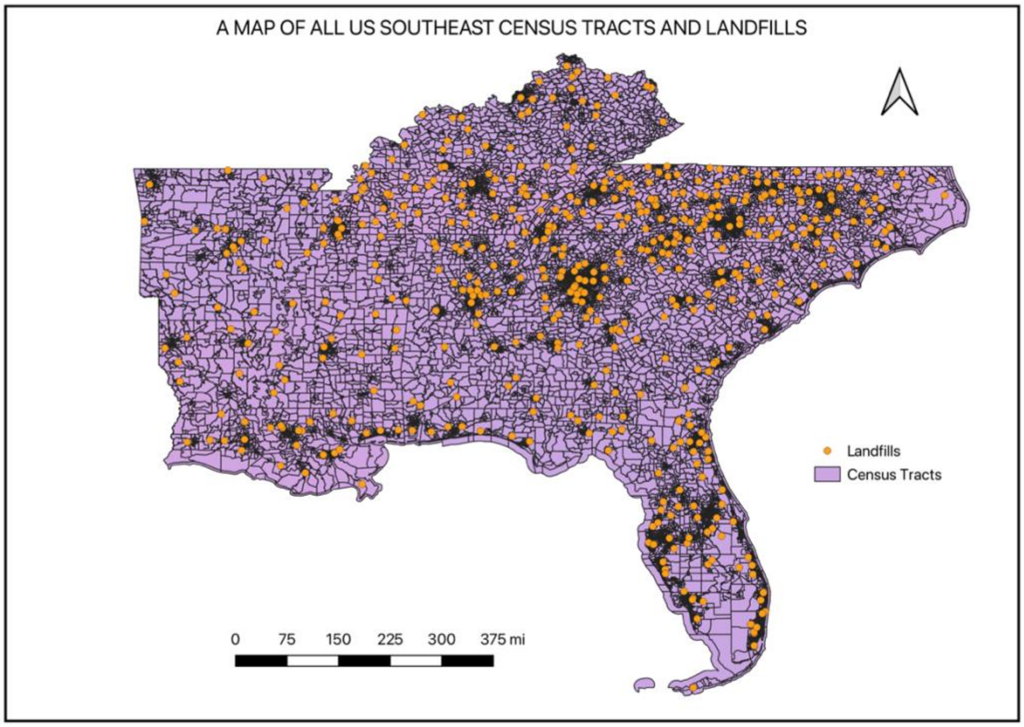


Figure 3

A map showing how landfills are distributed across the Southeast.

Table 1

Southeastern Census Tract Characteristics by Landfill Status (N=23,256).

Control Variables		Southeast Census Tracts % (95% CI)	Tracts without a landfill % (95% CI)	Tracts with a landfill % (95% CI)	
		n = 23,256	*n* = 9,486	*n* = 13,770	*p*
Below 200% Poverty Line		36.64 (24.11-49.45)	36.83 (24.07-49.57)	36.46 (24.13-49.36)	0.55
% 65 Years or Older		.16 (.119-.202)	.167 (.128-.211)	.155 (.114-.197)	< 0.001
% Minority		34 (15.6-63)	30.6 (13.9-55.5)	36.3 (17-69.9)	< 0.001
Rural/Urban Status	*Metro*	19,188 (82.5%)	7,365 (77.6%)	11,823 (85.9%)	< 0.001
	Micro	2,406 (10.3%)	1,133 (11.9%)	1,273 (9.2%)	
	Rural	1,662 (7.1%)	988 (10.4%)	674 (4.9%)	
% of Uninsured		10.3 (6.6-14.9)	10 (6.3-14.5)	10.5 (6.8-15.2)	< 0.001
State	*AL*	1,536 (6.6%)	745 (7.9%)	791 (5.7%)	< 0.001
	AR	800 (3.4%)	454 (4.8%)	346 (2.5%)	
	FL	5,742 (24.7%)	2,882 (30.4%)	2,860 (20.8%)	
	GA	3,846 (16.5%)	1,073 (11.3%)	2,773 (20.1%)	
	KY	1,317 (5.7%)	773 (8.1%)	544 (4.0%)	
	LA	1,828 (7.9%)	776 (8.2%)	1,052 (7.6%)	
	MS	749 (3.2%)	487 (5.1%)	262 (1.9%)	
	NC	3,537 (15.2%)	1,023 (10.8%)	2,514 (18.3%)	
	SC	1,379 (5.9%)	637 (6.7%)	742 (5.4%)	
	TN	2,522 (10.8%)	636 (6.7%)	1,886 (13.7%)	

Notes: Data are presented as median (IQR) for continuous measures, and n (%) for categorical measures. Landfill status is defined as a census tract intersecting with a 5-mile buffer of a landfill centroid. P-values from t-tests in continuous variables and chi-squares in categorical.

The unadjusted generalized linear models presented in Tables 2 and 3 explore the correlations between landfill proximity, age, intake volume, and select health outcomes across census tracts. In Table 2, the relationship between distance from landfills and health outcomes reveals a significant decrease in the prevalence of reported high blood pressure cases as distance increases, particularly notable at a five-mile radius. Asthma shows a markedly different pattern; the likelihood of reported asthma cases significantly rose with proximity to landfills, most prominently within a half-mile. Cancer prevalence, intriguingly, decreases significantly nearer to landfills. Mental health outcomes, when controlling for the effect of other variables, had no impact with landfill distance at any measured buffer zone. Diabetes prevalence exhibits a trend of increasing odds near landfills, although this association does not reach statistical significance.

Table 3 shifts focus to the landfill characteristics of age and daily volume. Here, the age of the landfill does not manifest a significant correlation with high blood pressure. However, older landfills correlate with a significant uptick in asthma cases, while high-volume landfills show the opposite—significantly fewer cases. In terms of cancer, proximity to older landfills is significantly associated with reduced odds, unlike high-intake landfills, which do not show a significant difference. Mental health patterns reveal a significant association with older landfills indicating more reported poor mental health, whereas larger-volume landfills correlate with fewer such reports. Lastly, neither the age of the landfill nor the daily volume it processes displays a significant connection with diabetes prevalence.

Table 2

Unadjusted Generalized Linear Model of Landfill Distance with Select Health Outcomes by Census Tract (N=23,256)

Disease Outcome	*OR*	*SE*	*z*	*p > z*	95% CI	
High Blood Pressure						
1/2 mile	0.068	0.139	-1.32	0.187	0.001	3.687
1 mile	0.079	0.059	-3.37	0.001	0.018	0.345
3 miles	0.189	0.040	-7.97	< 0.001	0.126	0.285
5 miles	0.192	0.027	-11.78	< 0.001	0.146	0.253
Asthma						
1/2 mile	8.025	4.080	4.1	< 0.001	2.962	21.738
1 mile	2.138	0.376	4.32	< 0.001	1.514	3.016
3 miles	1.199	0.054	4.02	< 0.001	1.097	1.309
5 miles	1.042	0.031	1.39	0.163	0.983	1.104
Cancer						
1/2 mile	0.015	0.007	-9.13	< 0.001	0.006	0.038
1 mile	0.165	0.028	-10.43	< 0.001	0.117	0.231
3 miles	0.486	0.026	-13.51	< 0.001	0.438	0.540
5 miles	0.544	0.019	-17.53	< 0.001	0.509	0.583
Mental Health						
1/2 mile	2.950	2.692	1.18	0.236	0.493	17.655
1 mile	1.502	0.542	1.13	0.26	0.740	3.048
3 miles	1.150	0.104	1.54	0.123	0.963	1.374
5 miles	0.981	0.060	-0.31	0.757	0.870	1.107
Diabetes						
1/2 mile	8.541	9.906	1.85	0.064	0.879	82.942
1 mile	1.093	0.458	0.21	0.832	0.481	2.484
3 miles	0.925	0.106	-0.68	0.497	0.740	1.157
5 miles	0.921	0.072	-1.06	0.287	0.791	1.072

Notes: Each health outcome is the estimated % of population in census tract reporting illness.

Table 3

Unadjusted Generalized Linear Model of Landfill Age and Intake Volume with Select Health Outcomes by Census Tract (N=13,770)

Disease Outcome	*OR*	*SE*	*z*	*p > z*	95% CI	
High Blood Pressure						
Older than 1990	0.791	0.128	-1.44	0.149	0.576	1.087
500 Tons or greater	0.822	0.108	-1.49	0.137	0.636	1.064
Asthma						
Older than 1990	1.148	0.038	4.21	< 0.001	1.076	1.224
500 Tons or greater	0.701	0.019	-12.97	< 0.001	0.664	0.739
Cancer						
Older than 1990	0.843	0.033	-4.34	< 0.001	0.780	0.910
500 Tons or greater	1.055	0.035	1.62	0.104	0.989	1.126
Mental Health						
Older than 1990	1.356	0.097	4.26	< 0.001	1.179	1.560
500 Tons or greater	0.797	0.047	-3.87	< 0.001	0.711	0.894
Diabetes						
Older than 1990	1.117	0.099	1.24	0.214	0.938	1.330
500 Tons or greater	0.910	0.066	-1.3	0.192	0.789	1.049

In an adjusted generalized linear model, examining the association between proximity to landfill sites and health outcomes, the results indicated varying relationships by health condition and distance (Table 4). Living within a half-mile of a landfill saw an odds ratio (OR) of 3.08 for high blood pressure, but this was not statistically significant, 95% CI [0.14, 68.21]. However, the odds of high blood pressure decrease significantly with increasing distance from landfills, with an OR of 0.57 at 3 miles, $p < .001$, 95% CI [0.43, 0.76], and an OR of 0.50 at 5 miles, $p < .001$, 95% CI [0.41, 0.60]. Asthma prevalence was significantly higher within a half-mile radius of landfills (OR = 2.37, $p = .003$, 95% CI [1.33, 4.24]), and the relationship remained significant at 1 mile (OR = 1.66, $p < .001$, 95% CI [1.34, 2.06]). At distances of three and five miles, the associations were not significant. Cancer showed a significant negative association with proximity to landfills. At a half-mile, the OR was 0.42, $p = .001$, 95% CI [0.25, 0.69], and at one mile, the OR was 0.72, $p < .001$, 95% CI [0.61, 0.85], suggesting that the reported prevalence of cancer was lower closer to landfills. Mental health also presented a significant negative association with proximity; at a half-mile, the OR was 0.11, $p < .001$, 95% CI [0.04, 0.29]. This association lessened but remained significant up to five miles (OR = 0.72, $p < .001$, 95% CI [0.68, 0.77]). Diabetes showed a significant positive association at a half-mile (OR = 6.72, $p = .018$, 95% CI [1.39, 32.51]) and at one mile (OR = 2.24, $p = .003$, 95% CI [1.32, 3.80]). However, at distances of three and five miles, the associations were not statistically significant.

Table 4

Adjusted Generalized Linear Model of Landfill Distance with Select Health Outcomes by Census Tract (N=23,256)

Disease Outcome	*OR*	*SE*	*z*	*p > z*	95% CI	
High Blood Pressure						
1/2 mile	3.083	4.871	0.71	0.476	0.139	68.208
1 mile	1.510	0.769	0.81	0.418	0.557	4.097
3 miles	0.573	0.082	-3.88	< 0.001	0.432	0.759
5 miles	0.499	0.048	-7.25	< 0.001	0.414	0.602
Asthma						
1/2 mile	2.375	0.702	2.93	0.003	1.330	4.239
1 mile	1.662	0.182	4.63	< 0.001	1.341	2.060
3 miles	1.024	0.030	0.81	0.421	0.967	1.085
5 miles	0.953	0.017	-2.64	0.008	0.919	0.988
Cancer						
1/2 mile	0.417	0.107	-3.42	0.001	0.253	0.689
1 mile	0.724	0.060	-3.86	< 0.001	0.615	0.853
3 miles	0.950	0.024	-2.07	0.038	0.905	0.997
5 miles	0.914	0.014	-5.88	< 0.001	0.887	0.942
Mental Health						
1/2 mile	0.108	0.054	-4.41	< 0.001	0.040	0.290
1 mile	0.652	0.138	-2.03	0.042	0.431	0.986
3 miles	0.711	0.036	-6.66	< 0.001	0.643	0.786
5 miles	0.721	0.023	-10.2	< 0.001	0.677	0.768
Diabetes						
1/2 mile	6.724	5.406	2.37	0.018	1.391	32.507
1 mile	2.241	0.605	2.99	0.003	1.321	3.803
3 miles	1.065	0.078	0.87	0.386	0.923	1.229
5 miles	1.060	0.051	1.2	0.23	0.964	1.166

Notes: Each health outcome is the estimated % of population in census tract reporting illness. Adjusted for poverty, age, rurality, race, health insurance, and state.

In an adjusted generalized linear model analyzing health outcomes in relation to the age of landfills and their daily waste intake volume, the following relationships were observed among census tracts (Table 5). High blood pressure was significantly associated with landfills older than 1990, with an odds ratio (OR) of 0.73 (95% CI [0.592, 0.897], p = .003), indicating a lower odds of reported high blood pressure in areas near older landfills. Conversely, living near landfills with a daily intake greater than 500 tons was associated with higher odds of high blood pressure (OR = 1.56, 95% CI [1.305, 1.866], p < .001). For asthma, no significant association was found with older landfills (OR = 1.01, 95% CI [0.976, 1.052], p = .476). However, proximity to landfills with a daily intake greater than 500 tons was associated with a lower odds of reported asthma cases (OR = 0.89, 95% CI [0.855, 0.917], p < .001). Cancer prevalence showed no significant relationship with either the age of the landfill (OR = 0.996, 95% CI [0.964, 1.029], p = .802) or the daily intake volume (OR = 0.98, 95% CI [0.953, 1.010], p = .201). Mental health outcomes were not significantly associated with older landfills (OR = 1.01, 95% CI [0.939, 1.090], p = .764). In contrast, living near landfills with a higher daily intake was significantly associated with a higher odds of reported mental health issues (OR = 1.39, 95% CI [1.304, 1.479], p < .001). Finally, diabetes prevalence was not significantly associated with older landfills (OR = 0.92, 95% CI [0.826, 1.017], p = .100), while landfills with a daily intake greater than 500 tons were associated with higher odds of diabetes (OR = 1.31, 95% CI [1.196, 1.425], p < .001) (Figure 4).

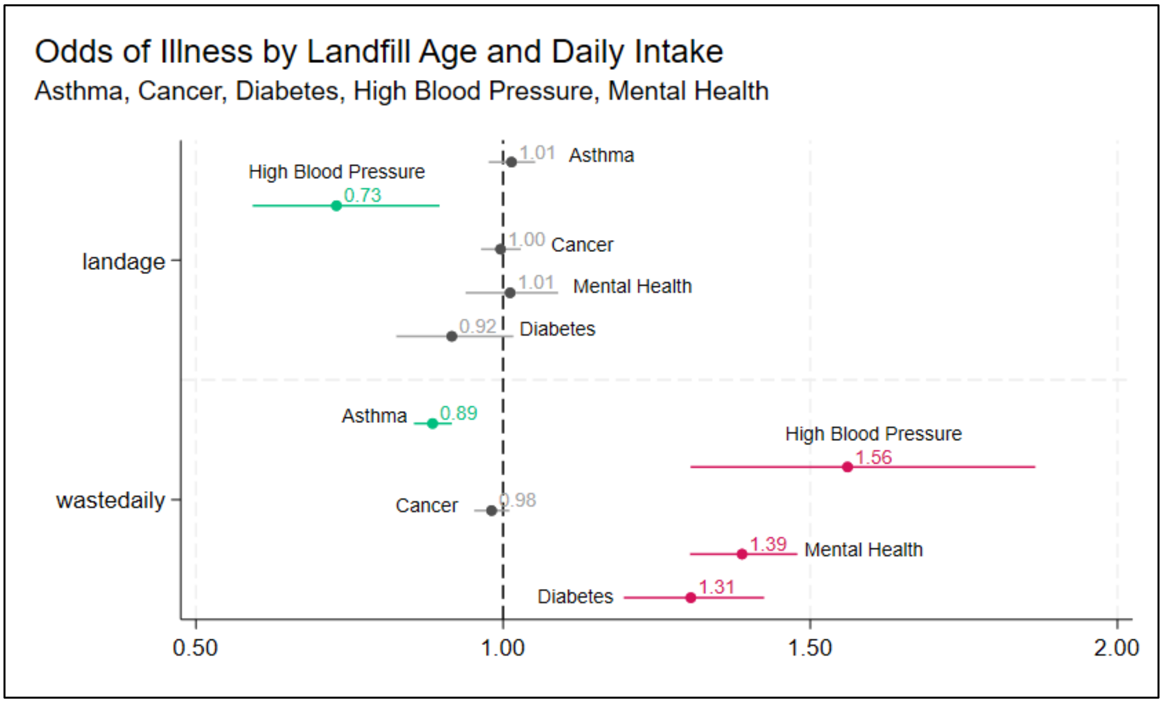


Figure 4

Odds of illness by landfill age and daily intake (N=13,770)

Table 5

Adjusted Generalized Linear Model of Landfill Age and Intake Volume with Select Health Outcomes by Census Tract (N=13,770)

Disease Outcome	*OR*	*SE*	*z*	*p > z*	95% CI	
High Blood Pressure						
Older than 1990	0.729	0.077	- 2.99	0.003	0.592	0.897
500 Tons or greater	1.561	0.142	4.88	< 0.001	1.305	1.866
Asthma						
Older than 1990	1.014	0.019	0.71	0.476	0.976	1.052
500 Tons or greater	0.885	0.016	- 6.84	< 0.001	0.855	0.917
Cancer						
Older than 1990	0.996	0.016	- 0.25	0.802	0.964	1.029
500 Tons or greater	0.981	0.015	- 1.28	0.201	0.953	1.010
Mental Health						
Older than 1990	1.011	0.038	0.3	0.764	0.939	1.090
500 Tons or greater	1.389	0.045	10.24	< 0.001	1.304	1.479
Diabetes						
Older than 1990	0.917	0.049	- 1.65	0.1	0.826	1.017
500 Tons or greater	1.306	0.058	5.98	< 0.001	1.19632	1.425

Notes: Each health outcome is the estimated % of population in census tract reporting illness. Landfills built in 1990 or later are the referent. Landfills that receive <500 tons daily are the referent. Adjusted for poverty, age, rurality, race, health insurance, and state.

In an adjusted generalized linear model assessing the impact of landfill proximity and the age of the landfill on health outcomes, several associations were observed (Table 5). The model took into account the year the landfill was built, with a particular focus on those constructed prior to 1990, often referred to as old landfills. For high blood pressure, the odds ratio (OR) for living within a half-mile of an old landfill was 2.99, yet this relationship was not statistically significant (p = .490), with a very wide 95% confidence interval (CI) ranging from 0.133 to 67.349. The OR significantly decreased with distance, indicating an inverse relationship at 3 miles (OR = 0.50, p < .001, 95% CI [0.372, 0.680]) and even more so at 5 miles (OR = 0.30, p < .001, 95% CI [0.236, 0.370]). For asthma, proximity to old landfills within a half-mile showed a significant positive association with an OR of 1.78 (p = .045, 95% CI [1.013, 3.141]), suggesting an increased likelihood of reporting asthma cases. This association was maintained at one mile with an OR of 1.45 (p = .001, 95% CI [1.173, 1.805]), but it was not significant at distances beyond 3 miles. The prevalence of reported cancer cases near old landfills within a half-mile showed a significant negative association with an OR of 0.52 (p = .010, 95% CI [0.313, 0.852]). This negative association was also seen at one mile but became non-significant at greater distances. Regarding mental health, the findings revealed a significantly negative association within a half-mile of old landfills, with an OR of 0.17 (p < .001, 95% CI [0.064, 0.461]), which indicated a lower prevalence of poor mental health reports in proximity to the landfill. This trend of negative associations continued up to five miles, though less pronounced (OR = 0.73, p < .001, 95% CI [0.672, 0.790]). For diabetes, the analysis presented a non-significant trend toward an increased likelihood of reporting diabetes within a half-mile of old landfills (OR = 3.89, p =

.086, 95% CI [0.826, 18.355]), becoming significant at one mile (OR = 1.72, p = .043, 95% CI [1.018, 2.918]). Beyond 3 miles, the association was not significant.

Table 6

Adjusted Generalized Linear Model of Landfill Distance and Age of Landfill with Select Health Outcomes by Census Tract (N=23,256)

Disease	*Landfill Built prior to 1990 (Old Landfills)*					
Outcome	*OR*	*SE*	*z*	*p > z*	95% CI	
High Blood Pressure						
1/2 mile	2.993	4.756	0.690	0.490	0.133	67.349
1 mile	1.499	0.771	0.790	0.431	0.547	4.110
3 miles	0.503	0.077	-4.470	< 0.001	0.372	0.680
5 miles	0.296	0.034	-10.610	< 0.001	0.236	0.370
Asthma						
1/2 mile	1.784	0.515	2.000	0.045	1.013	3.141
1 mile	1.455	0.160	3.410	0.001	1.173	1.805
3 miles	0.927	0.029	-2.390	0.017	0.872	0.986
5 miles	0.789	0.017	-10.740	< 0.001	0.756	0.824
Cancer						
1/2 mile	0.517	0.132	-2.590	0.010	0.3130	0.852
1 mile	0.800	0.067	-2.650	0.008	0.6789	0.944
3 miles	1.004	0.026	0.140	0.889	0.953	1.057
5 miles	0.941	0.017	-3.290	0.001	0.907	0.976
Mental Health						
1/2 mile	0.171	0.086	-3.490	< 0.001	0.064	0.460
1 mile	0.812	0.174	-0.970	0.33	0.533	1.235
3 miles	0.780	0.043	-4.470	< 0.001	0.670	0.870
5 miles	0.729	0.030	-7.660	< 0.001	0.672	0.790
Diabetes						
1/2 mile	3.893	3.080	1.720	0.086	0.826	18.355
1 mile	1.724	0.463	2.030	0.043	1.018	2.918
3 miles	0.868	0.068	-1.820	0.069	0.744	1.011
5 miles	0.767	0.044	-4.580	< 0.001	0.684	0.859

Notes: Each health outcome is the estimated % of population in census tract reporting illness. Adjusted for poverty, age, rurality, race, health insurance, and state.

In an adjusted model analyzing the impact of proximity to landfills with a daily waste intake of over 500 tons on community health outcomes, the following associations were observed (Table 6). For high blood pressure, the odds ratio (OR) at a half-mile distance from the landfill was 4.44, but this was not statistically significant (p = .351), with a very wide 95% confidence interval (CI) [0.193, 102.25], indicating considerable variability in the estimate. At greater distances, the OR for high blood pressure was significantly less than one at three miles (OR = 0.51, p < .001, 95% CI [0.374, 0.685]) and at five miles (OR = 0.28, p < .001, 95% CI [0.225, 0.352]), suggesting a lower reported prevalence with increasing distance from the landfill. For asthma, living within a half-mile radius of a high-intake landfill was indicated by an OR of 1.63, although this was not statistically significant (p = .089, 95% CI [0.929, 2.863]). The relationship becomes significant at one mile (OR = 1.41, p = .002, 95% CI [1.138, 1.746]) but is not significant at three miles and beyond. Cancer prevalence indicated a significant negative association at a half-mile distance (OR = 0.51, p = .009, 95% CI [0.308, 0.842]) and at one mile (OR = 0.80, p = .007, 95% CI [0.675, 0.939]), with no significant association at greater distances. For mental health, there was a significant negative association close to high-intake landfills at a half-mile (OR = 0.22, p = .002, 95% CI [0.080, 0.578]). This pattern continued significantly up to five miles (OR = 0.72, p < .001, 95% CI [0.661, 0.776]). Diabetes was significantly associated with proximity to a high-intake landfill at a half-mile (OR = 4.83, p = .049, 95% CI [1.008, 23.095]) and at one mile (OR = 1.86, p = .021, 95% CI [1.097, 3.162]), with no significant associations observed at distances of three miles or greater.

Table 7

Adjusted Generalized Linear Model of Landfill Distance and Daily Waste Intake with Select Health Outcomes by Census Tract (N=23,256)

Disease Outcome	*Daily Intake >500 Tons*					
	OR	*SE*	*z*	*p > z*	95% CI	
High Blood Pressure						
1/2 mile	4.447	7.114	0.930	0.351	0.193	102.251
1 mile	1.732	0.896	1.060	0.288	0.628	4.775
3 miles	0.506	0.078	-4.410	< 0.001	0.374	0.685
5 miles	0.282	0.032	-11.090	< 0.001	0.225	0.352
Asthma						
1/2 mile	1.631	0.468	1.700	0.089	0.929	2.863
1 mile	1.410	0.154	3.140	0.002	1.138	1.746
3 miles	0.924	0.029	-2.510	0.012	0.869	0.983
5 miles	0.796	0.018	-10.360	< 0.001	0.763	0.831
Cancer						
1/2 mile	0.510	0.131	-2.630	0.009	0.308	0.842
1 mile	0.796	0.067	-2.700	0.007	0.675	0.939
3 miles	1.003	0.026	0.120	0.907	0.953	1.056
5 miles	0.942	0.017	-3.250	0.001	0.908	0.977
Mental Health						
1/2 mile	0.215	0.108	-3.050	0.002	0.080	0.578
1 mile	0.881	0.189	-0.590	0.555	0.579	1.341
3 miles	0.787	0.044	-4.290	< 0.001	0.706	0.878
5 miles	0.716	0.029	-8.150	< 0.001	0.661	0.776
Diabetes						
1/2 mile	4.825	3.855	1.970	0.049	1.008	23.095
1 mile	1.862	0.503	2.300	0.021	1.097	3.162
3 miles	0.873	0.068	-1.740	0.082	0.749	1.018
5 miles	0.750	0.043	-5.020	< 0.001	0.670	0.839

Notes: Each health outcome is the estimated % of population in census tract reporting illness. Adjusted for poverty, age, rurality, race, health insurance, and state.

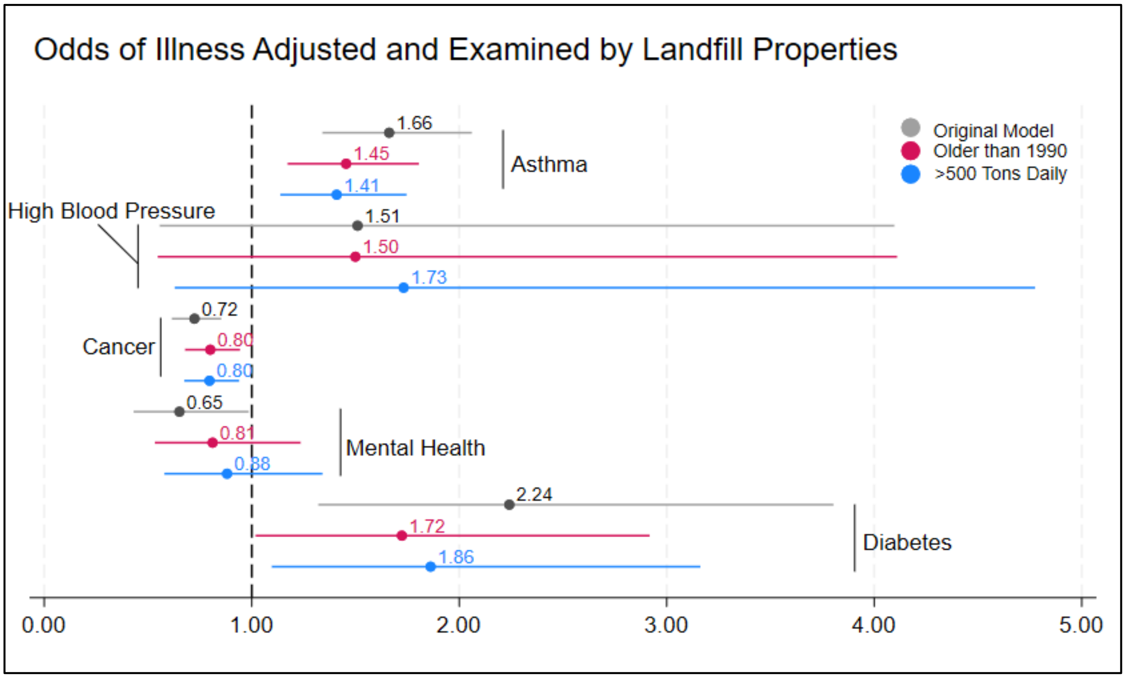


Figure 5

Odds of chronic disease examined by landfill properties at 1-mile distance (N=23,256)

Within a one-mile buffer zone, we compared ORs from the original model, which did not account for landfill age or daily waste intake volume, with models that adjusted for these properties (Figure 5). For high blood pressure, the original model shows an OR of 1.66, indicating a 66% increased odds of reporting high blood pressure within one mile of a landfill. When adjusting for older landfills (built prior to 1990), the OR decreases slightly to 1.45, and further decreases to 1.41 when considering landfills with a daily intake greater than 500 tons, suggesting that both the age and volume of the landfill may mitigate the increased odds of high blood pressure.

In the case of asthma, the OR in the original model is 1.51, suggesting a 51% increased odds of reporting asthma. Adjustments for older landfills result in a similar OR of 1.50, and adjusting for higher intake landfills yields a slightly higher OR of 1.73, indicating that higher daily intake may be associated with an increased likelihood of asthma. For cancer, the original model's OR of 0.72 suggests a decreased odds of reporting cancer within the one-mile buffer. This protective effect appears slightly more pronounced when considering older landfills (OR = 0.65) and is maintained with high intake landfills (OR = 0.81), although all models indicate a reduced likelihood of cancer reports. Mental health outcomes show an OR of 0.98 in the original model, suggesting no significant difference in odds. However, when adjusted for older landfills, the odds decrease (OR = 0.81), suggesting a lower likelihood of mental health issues. This potential protective effect is more substantial for landfills with greater than 500 tons daily intake (OR = 0.65). For diabetes, the original model indicates a substantially increased likelihood of reporting diabetes (OR = 2.24), which remains higher when adjusting for older landfills (OR = 1.72) and is slightly less for high-intake landfills (OR = 1.86), although all indicate increased odds.

CHAPTER V

DISCUSSION

This study examined the prevalence of chronic health disease outcomes using census tract health estimates, environmental burden model, and social vulnerability model of census tracts within 0.5, 1, 3, and 5-mile proximity to Treatment, Storage, and Disposal Sites (TSDs) sites (landfills) in the Southeastern United States. This study adds to the existing body of literature by exploring how the volume of a landfill and their operational duration impact the health of the people living close to them. Several studies have ascertained compounding evidence that people living close to TSDs have a greater risk of poor environmental burden. Despite stricter management and standards, TSDs still pose a health risk. For instance, certain household products classified as hazardous still find their way into Municipal Solid Waste Landfills (MSWLFs) despite their banning (USEPA, 2016). Hence, a study of this kind was warranted to ascertain the potential health risks posed to individuals living in proximity to TSDs. The GLM analysis conducted on the relationship between proximity to landfills and various health outcomes at the census tract level using different buffer distances reveals compelling associations that warrant attention and further local-level investigation. The focus of this chapter is to discuss the implications of these findings in the context of public health and environmental justice.

High Blood Pressure

Proximity to TSDs showed a strong association with increased odds of high blood pressure especially at closer Euclidean buffer distances within a half-mile and one-mile radius of landfill receiving more than 500 tons of waste a day. These findings align with previous studies linking exposure to environmental pollutants emitted from landfills to cardiovascular health issues. Our results showed that residents living within a half mile of a landfill have a three times excess risk of experiencing high blood pressure and are 50% more likely to have a blood pressure if they reside within a one-mile radius compared to those who do not, even after adjusting for poverty, age, rurality, and health insurance. The higher prevalence rates at closer distances highlight the potential chronic health risks faced by communities residing closest to TSDs. The lack of statistical significance of the findings in the other adjusted models can be attributed to several confounders. In a survey study accessing the prevalence of the disease among those residing within one kilometer of a landfill in Kolkata, India, Kar & Basunia (2020) found that participants suffered from high blood pressure at an excess risk of 4.3%. Our results show a negative correlation risk at three miles and beyond in the adjusted model.

Diabetes:

While the mechanisms underlying TSDs and Diabetes associations are complex and multifaceted including environmental stressors, genetics, and lifestyle behaviors, the statistically significant correlation between proximity to TSDs and Diabetes at a half mile and one mile buffer distances cannot be ignored. Our results showed that people within a half mile and one mile were 6.7 times and 2.2 times more likely to have a diagnosis of diabetes respectively. These higher odds of diabetes prevalence within a half mile and one mile after controlling for poverty, age, rurality, and health insurance indicate a higher disease risk among the vulnerable population living close to landfills. In comparison to other studies, a survey study in India found an excess risk of diabetes prevalence (6.3%) among participants living within one kilometer (0.62 miles) of a landfill in Kolkata (Kar & Basunia, 2020). Tomita et al. (2020) in a South African Study found a significantly greater likelihood of diabetes in individuals residing within five kilometers of waste sites after controlling for poverty. These findings underscore the importance of considering the broader social determinants of health when investigating the impact of environmental exposures on metabolic health. The association between PCB, a landfill hazard, and Diabetes has been well studied including a mice study in Massachusetts that sought to explain the mechanism involved (Weinhold, 2013)

Cancer

When it comes to cancer, interestingly, the analysis did not find a significant association between landfill proximity and cancer at all distances. This outcome is not very surprising as the literature has shown contrasting outcomes when it comes to cancers that have been heavily studied. In a systematic review study, Vrijheid (2000) examined several North American studies, including studies from Love Canal, New York, that looked at single and multisite found conflicting results for different multisite studies even within New York alone. Some of the studies found an excess increase in cancer prevalence and mortality while others did not find any associations. In another study in Staten Island, NY, there was an excess increase in thyroid cancer incidence in a community near a landfill compared to the control communities (Van Gerwen et al., 2021). Jarup et al. 2002 in an ecological study analyzed cancer risks among populations living within 2 km of 9565 operational landfills in Great Britain between 1982 and

1997. The results showed no excess risks for the cancers of concern in the study. In this study, the lack of association can be attributed to several factors, including sample size, methodology, and the specific types of cancer examined. For instance, the cancer prevalence in the census tract health estimates exclude skin cancers. Further research with larger and more diverse datasets is necessary to explore this relationship comprehensively, as well as narrowing down to specific cancers.

Mental Health

This study demonstrates a noteworthy finding concerning mental health outcomes. Mental Health outcomes were statistically insignificant in the unadjusted model, incredibly protective in the adjusted model. The driver of this finding could be attributed to the poverty variable. The rural poor in the US South have been underdiagnosed when it comes to mental health due to inadequate access to mental health facilities among several barriers that can likely mask the effect of proximity to landfill exposure and the prevalence of poor mental health using these kinds of healthcare data (Fox et al., 1995). The findings emphasize the importance of considering the broader social determinants of health when investigating the impact of environmental exposures on mental well-being. The stress of living with the stench of landfills and the mere sight of a mountain of trash can cause poor mood states and anxiety. Underreporting of poor mental health among poor populations is common. A cross-sectional study in Hanoi, Vietnam where MSW collectors self-reported their stress symptoms found low psychological stress symptoms report (Nguyen et al., 2021).

Asthma

Proximity to landfills and association with respiratory diseases and Asthma has been heavily studied in North America, Europe, and around the world (Tomita et al., 2020; Vrijheid, 2000). The results of this study showed a significant correlation between the half miles and one-mile Euclidean buffer distances after controlling for poverty, age, rurality, and health insurance, which are common confounders. Air quality was not adjusted due to the direct influence landfill gases have on air quality. An epidemiological tool called Dagitty was used to analyze causal relationships between landfills and air quality. It highlighted air quality has a direct causal relation with landfills and therefore is a nonadjustable variable. There was no data for personal-level confounders such as pet ownership and household allergens. Landfills are known to emit gases that are potentially irritable to the respiratory tract hence a significant association up to a three-mile distance was not very surprising.

Implication for Environmental Justice

The disproportionate burden of landfill proximity on marginalized and socioeconomically disadvantaged communities is a critical environmental justice issue. These communities often lack the political power and resources to oppose the siting of landfills near their neighborhoods, leading to environmental inequities and health disparities. Policymakers and urban planners must prioritize the involvement of these communities in decision-making and ensure equitable distribution of waste management facilities. In addition, there should be implementation of measures to mitigate the health risks faced by vulnerable populations including those living close to landfill facilities.

Policy and Community Intervention

Despite the lack of direct exposure identification for the health risks involved in this study, landfills still pose direct risks to communities near them. Addressing the health impacts of landfill proximity requires a multi-faceted approach involving policy interventions, community engagement, and environmental remediation efforts. Strategies such as stricter zoning regulations, community-driven participatory research, and investments in alternative and more environmentally friendly infrastructure can help reduce exposure to landfill-related pollutants and promote health equity. Additionally, promoting waste reduction, recycling, and sustainable waste management practices can lessen the environmental burden on communities while addressing broader environmental sustainability goals.

Limitations and Future Directions

Despite the robustness of the GLM analysis, this study has several limitations. This is an ecological study and therefore open to generalization bias. The lack of direct exposure measurement prevents generalizing mitigation measures and drawing conclusions on the disease risk associated with proximity to landfills. The data used is population-level data and prone to bias hence communities and local governments should invest in local-level research to identify the direct risks their landfills pose to their communities. Other sources of bias include potential confounding variables that are not accounted for in the analysis, such as individual lifestyle factors and specific characteristics of the landfill sites. All the landfills are represented by point data and not the true land size it operates on. Moreover, the cross-sectional nature of the study design precludes causal inference, highlighting the need for longitudinal studies to establish temporality and causal relationships. Future research should also explore the differential impacts of landfill proximity on vulnerable subpopulations and consider the interactive effects of multiple environmental stressors.

Conclusion

The findings highlight the environmental exposures and health risks the socially vulnerable populations are subjected to even after controlling for poverty, age, rurality, and health insurance. Addressing the health disparities associated with landfill proximity requires a holistic and collaborative approach that integrates public health, environmental justice, and community empowerment efforts. By prioritizing the well-being of impacted communities and advancing equitable environmental policies, we can work towards creating healthier and more resilient communities for all. By exploring landfill volume and age, this study explores an aspect that has been given minimum attention.

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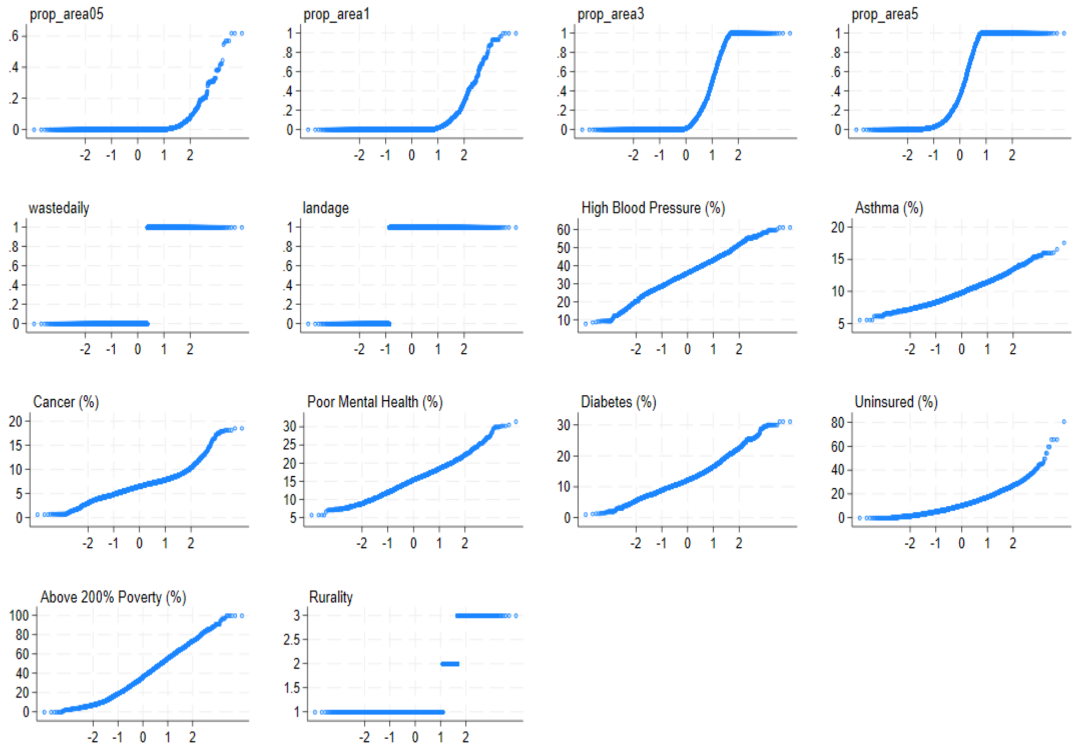
APPENDICIES

Appendix A

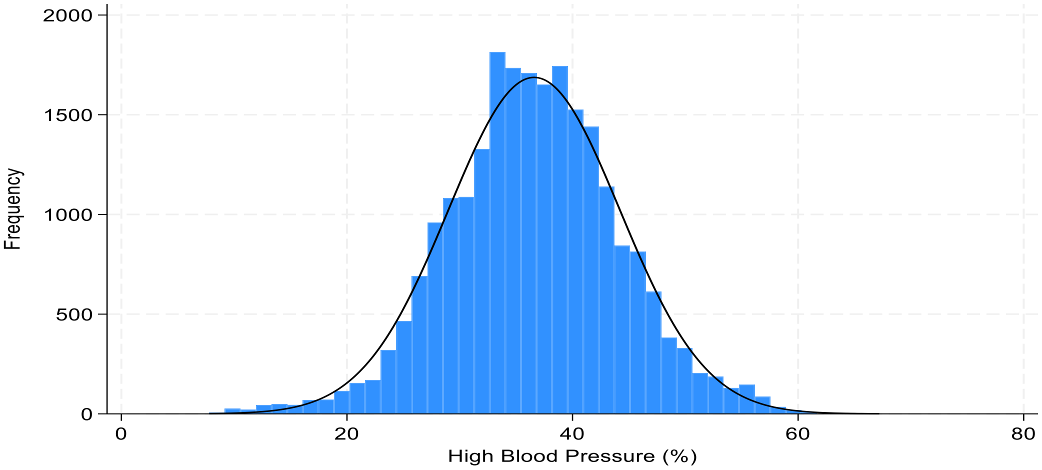
Variable characteristics, distributions, and model diagnostics.

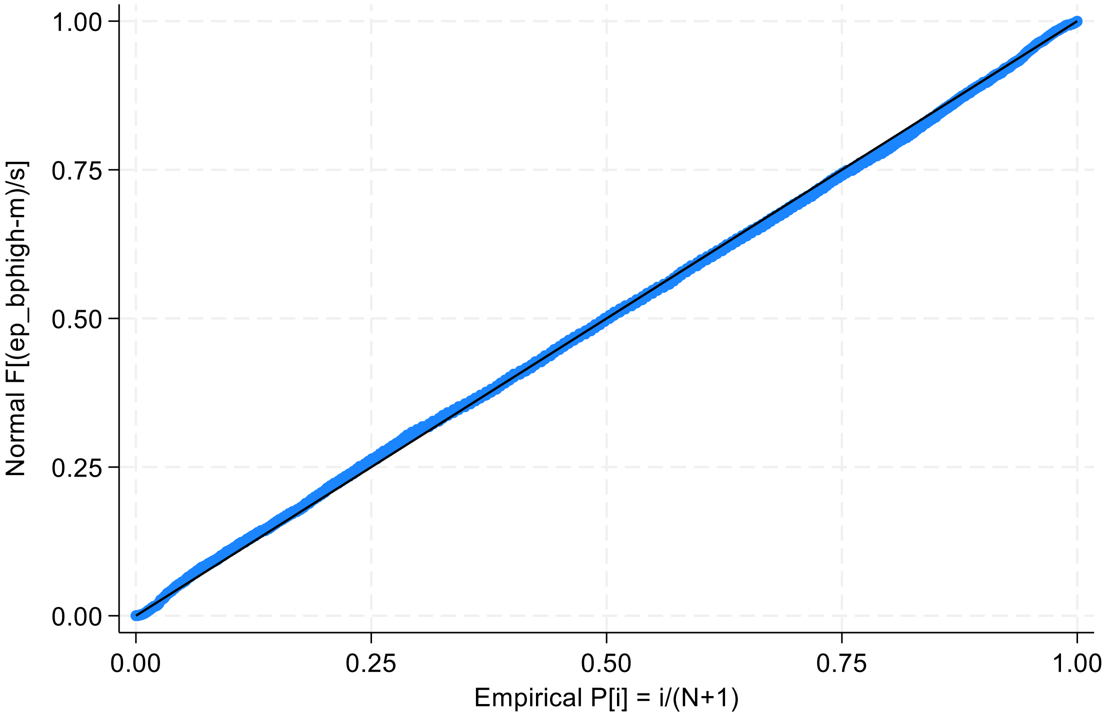
Quantile Plots for Variables:

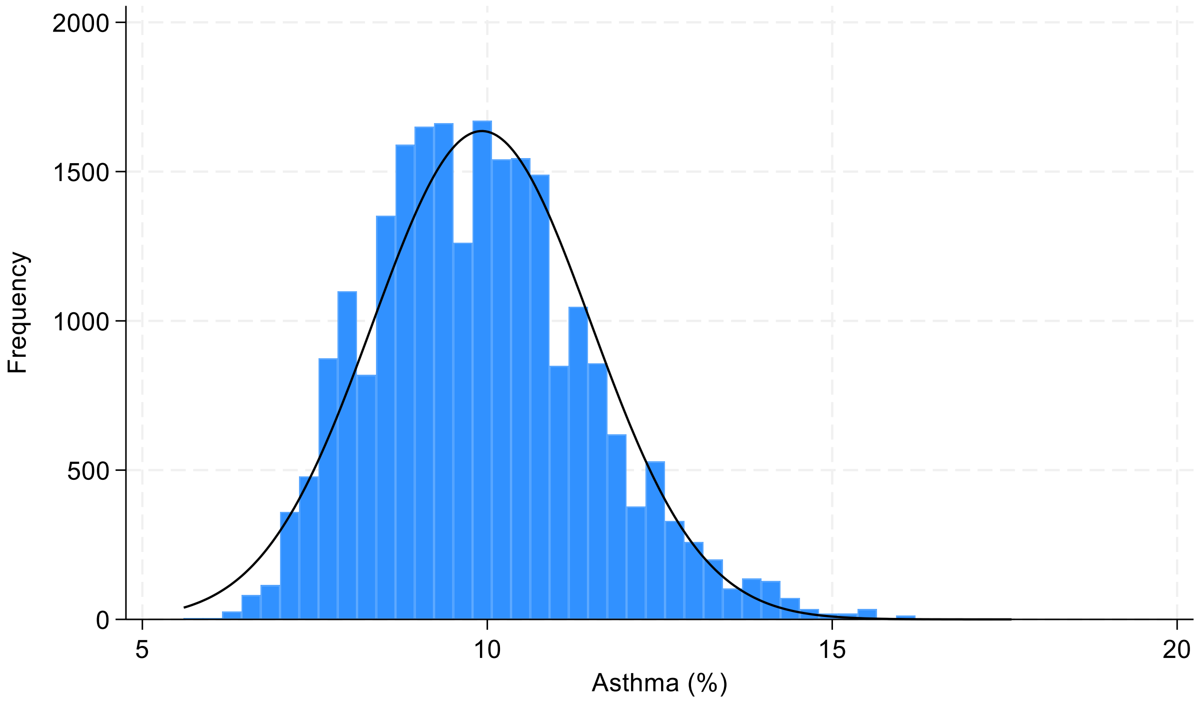


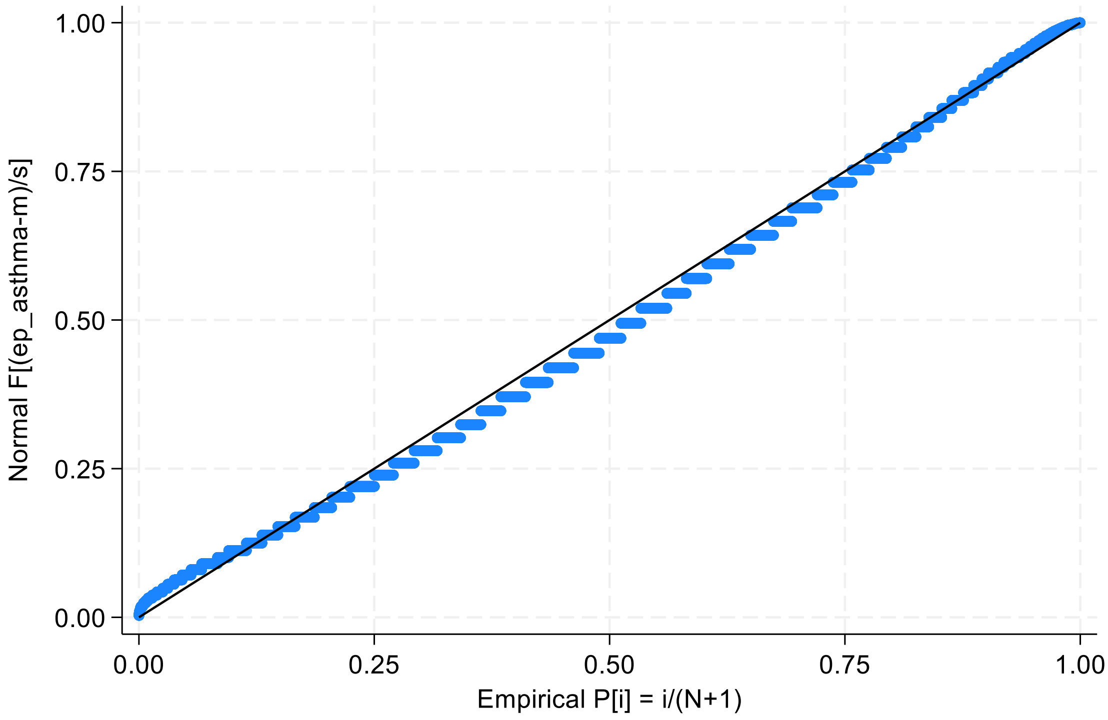
Appendix B

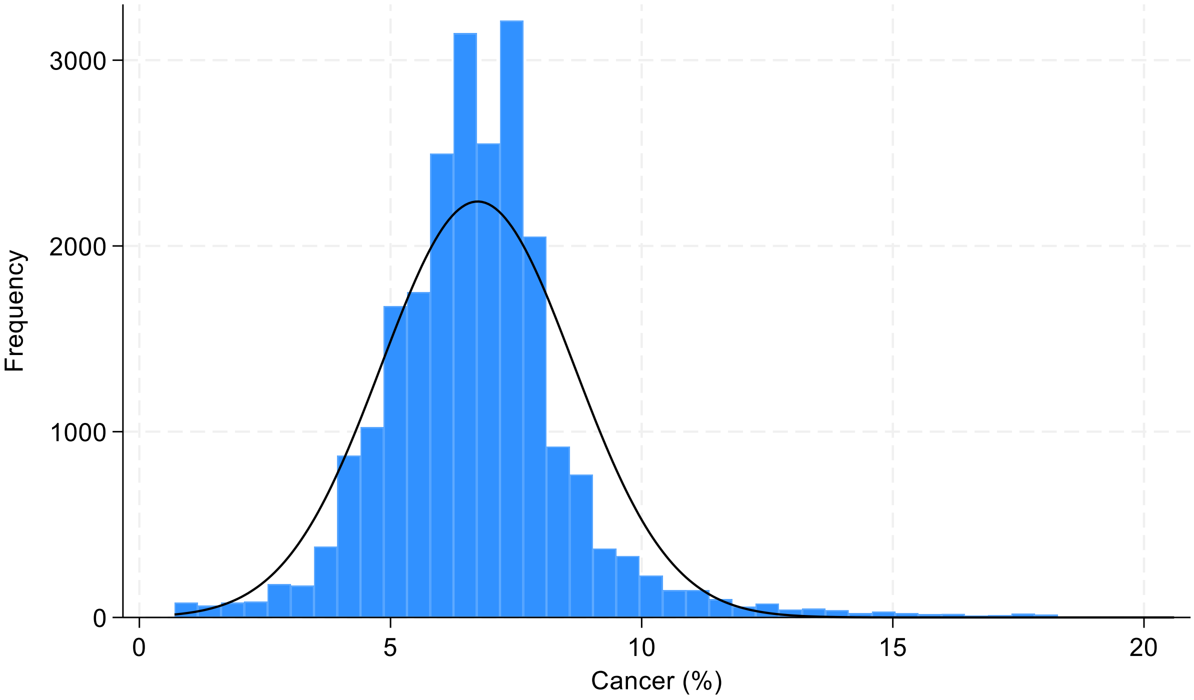
Outcome variables.

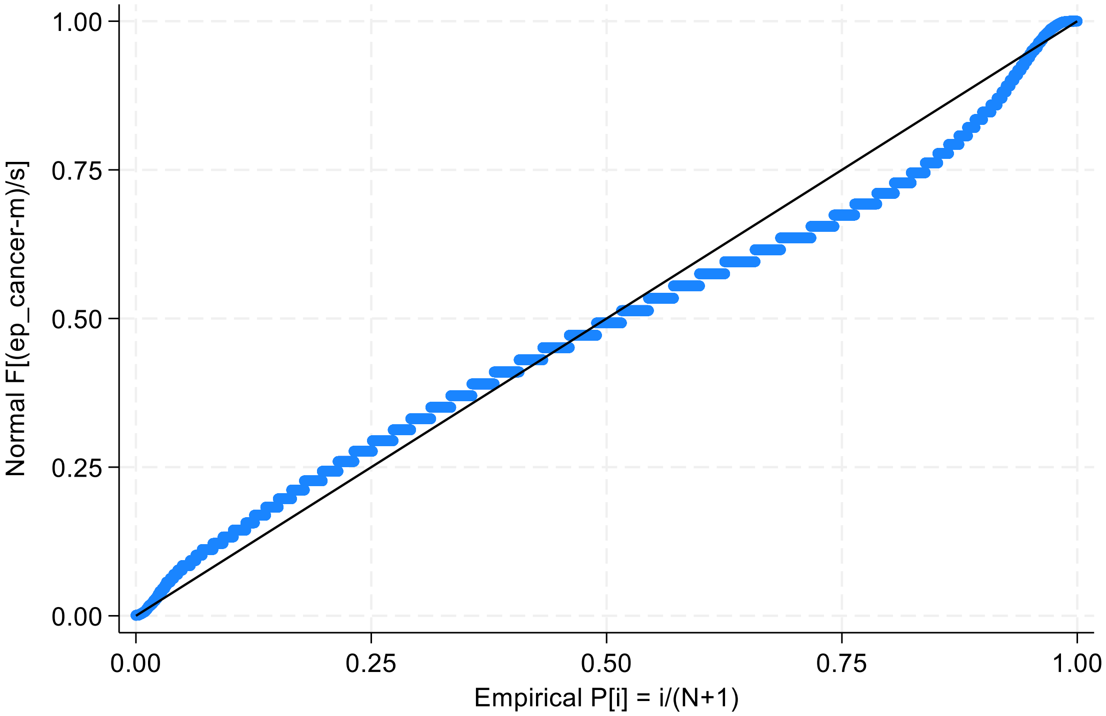


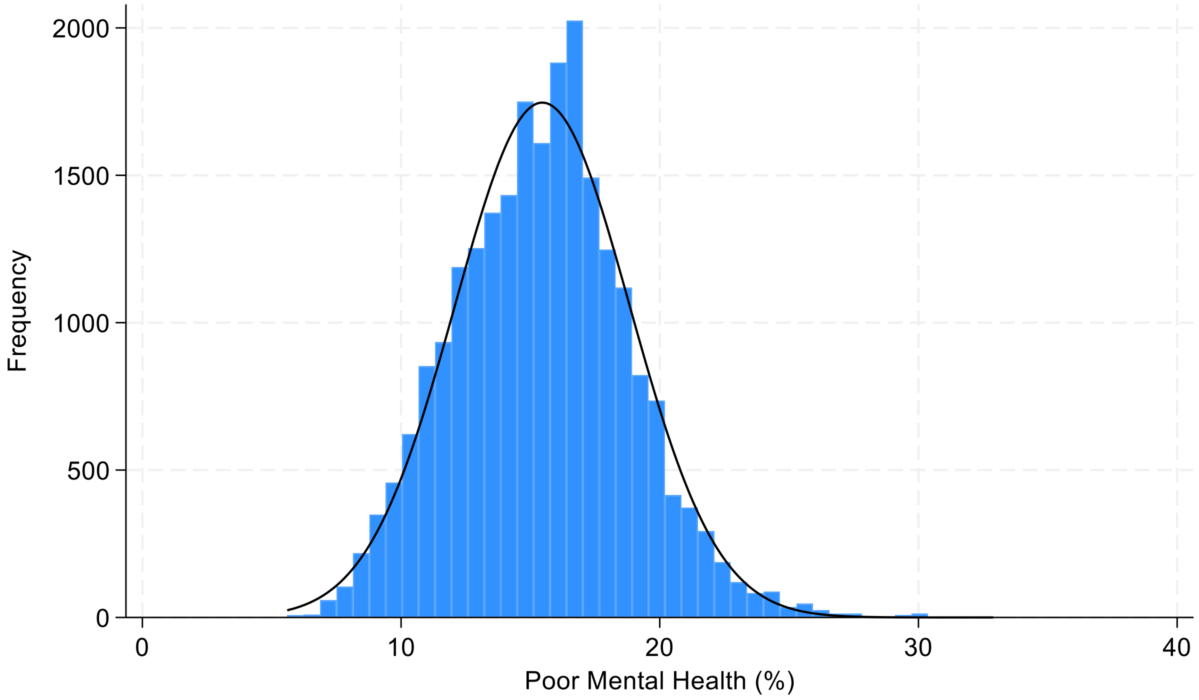


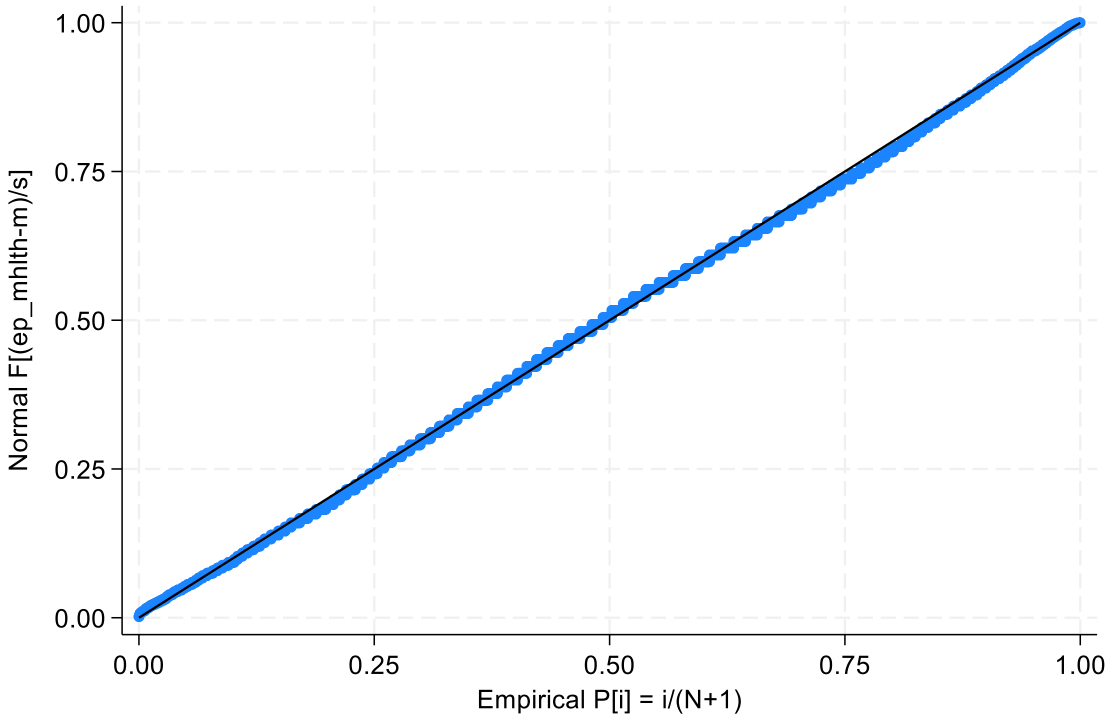

Frequency
2000
1500
1000
500
0
5
10
15
20
Asthma (%)

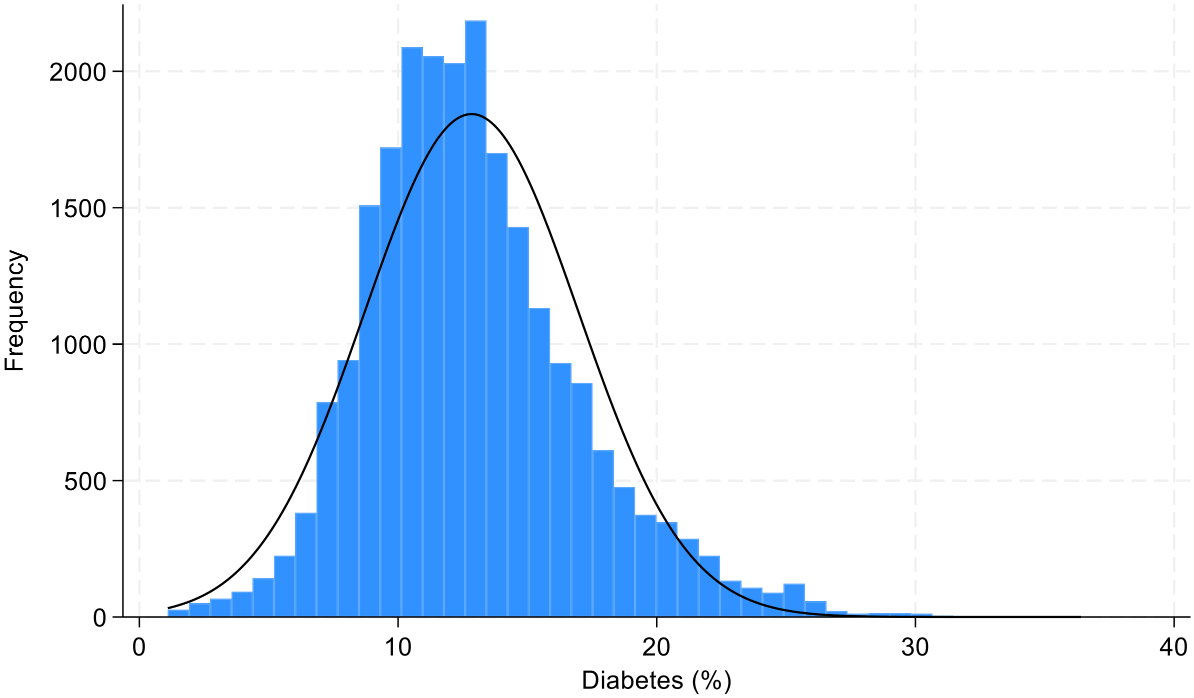

Normal F[(ep_asthma-m)/s]
1.00
0.75
0.50
0.25
0.00
0.00
0.25
0.50
0.75
1.00
Empirical P[i] = i/(N+1)

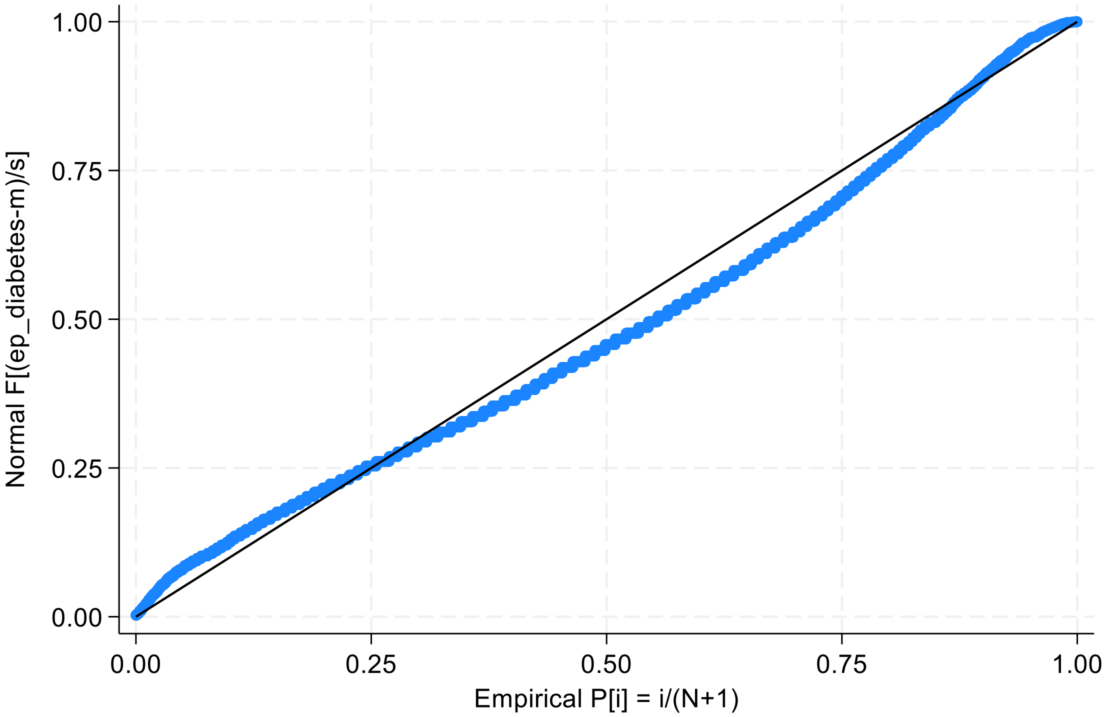

3000
2000
1000
0
Frequency
0
5
10
15
20
Cancer (%)


1.00
0.75
0.50
0.25
0.00
Normal F[(ep_cancer-m)/s]
0.00
0.25
0.50
0.75
1.00
Empirical P[i] = i/(N+1)


Frequency
2000
1500
1000
500
0
0
10
20
30
40
Poor Mental Health (%)


Normal F[(ep_mhlth-m)/s]
1.00
0.75
0.50
0.25
0.00
0.00
0.25
0.50
0.75
1.00
Empirical P[i] = i/(N+1)

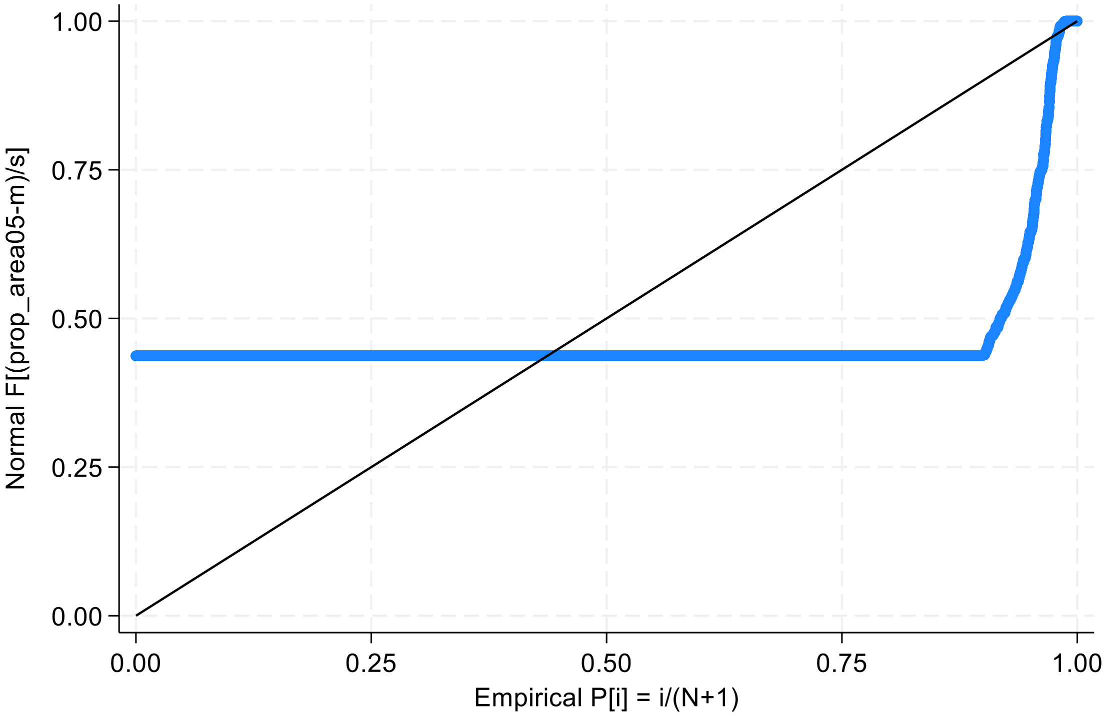

Frequency
0
500
1000
1500
2000
0
10
20
30
40
Diabetes (%)

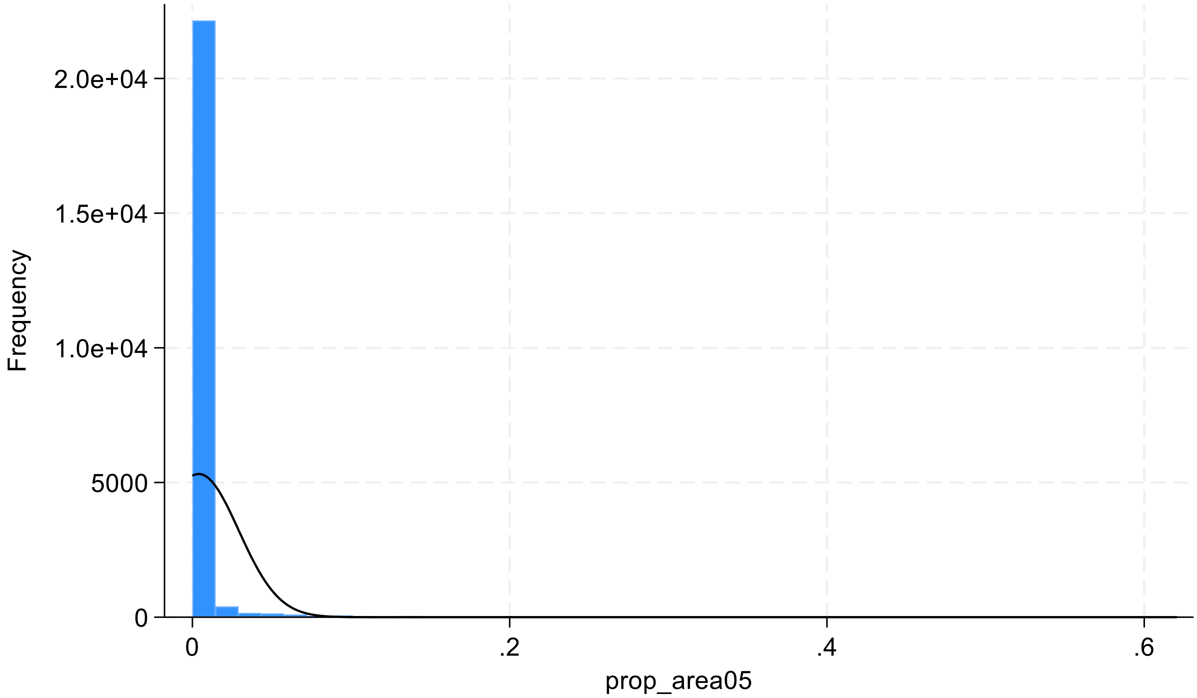

Normal F[(ep_diabetes-m)/s]
0.00
0.25
0.50
0.75
1.00
0.00
0.25
0.50
0.75
1.00
Empirical P[i] = i/(N+1)

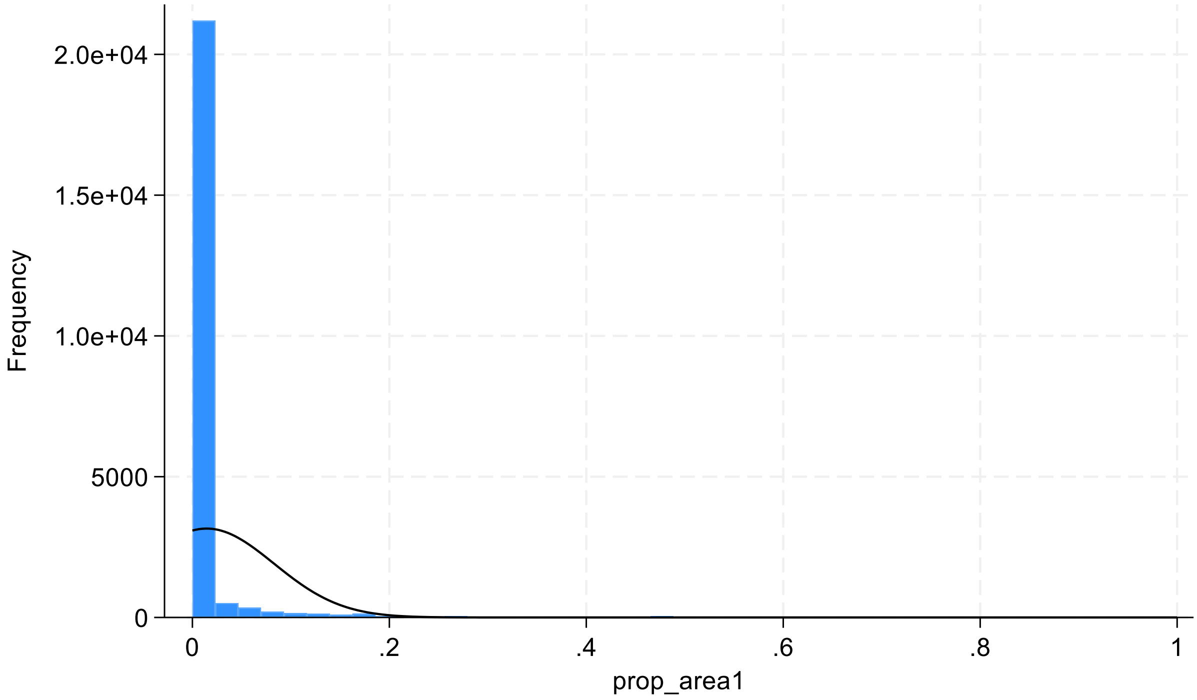
```
. tab landage

    landage |      Freq.     Percent        Cum.
------------+-----------------------------------
          0 |      2,665       19.35       19.35
          1 |     11,105       80.65      100.00
------------+-----------------------------------
      Total |     13,770      100.00

.
. tab wastedaily

 wastedaily |      Freq.     Percent        Cum.
------------+-----------------------------------
          0 |      8,821       64.06       64.06
          1 |      4,949       35.94      100.00
------------+-----------------------------------
      Total |     13,770      100.00
```

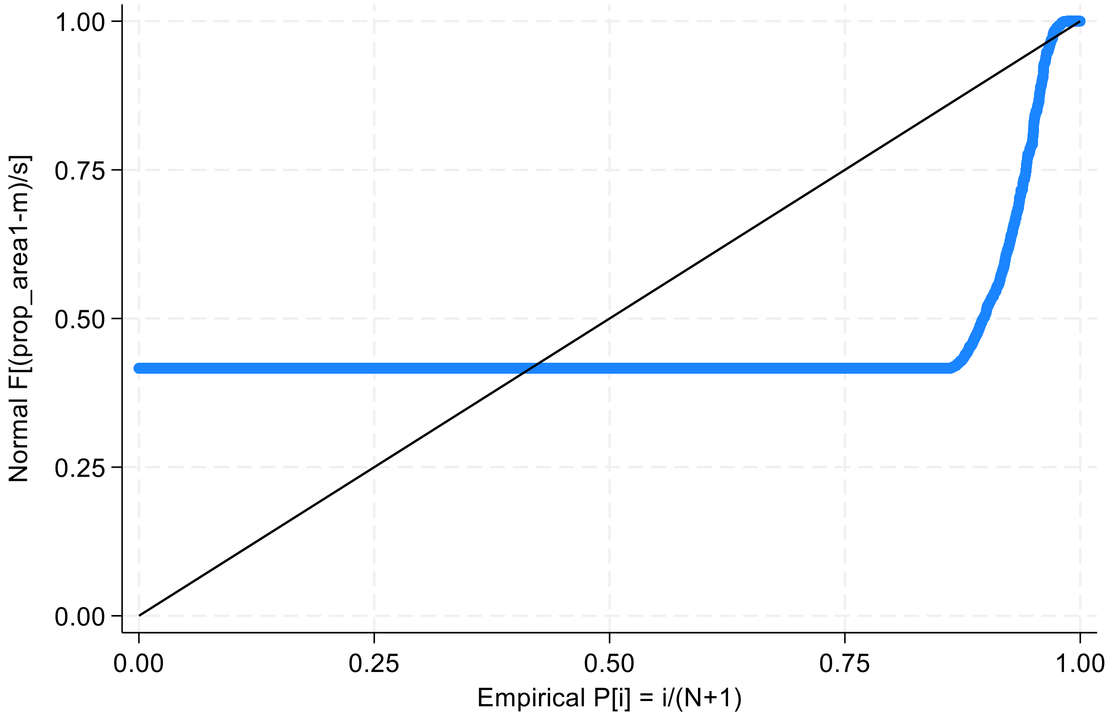
Appendix C

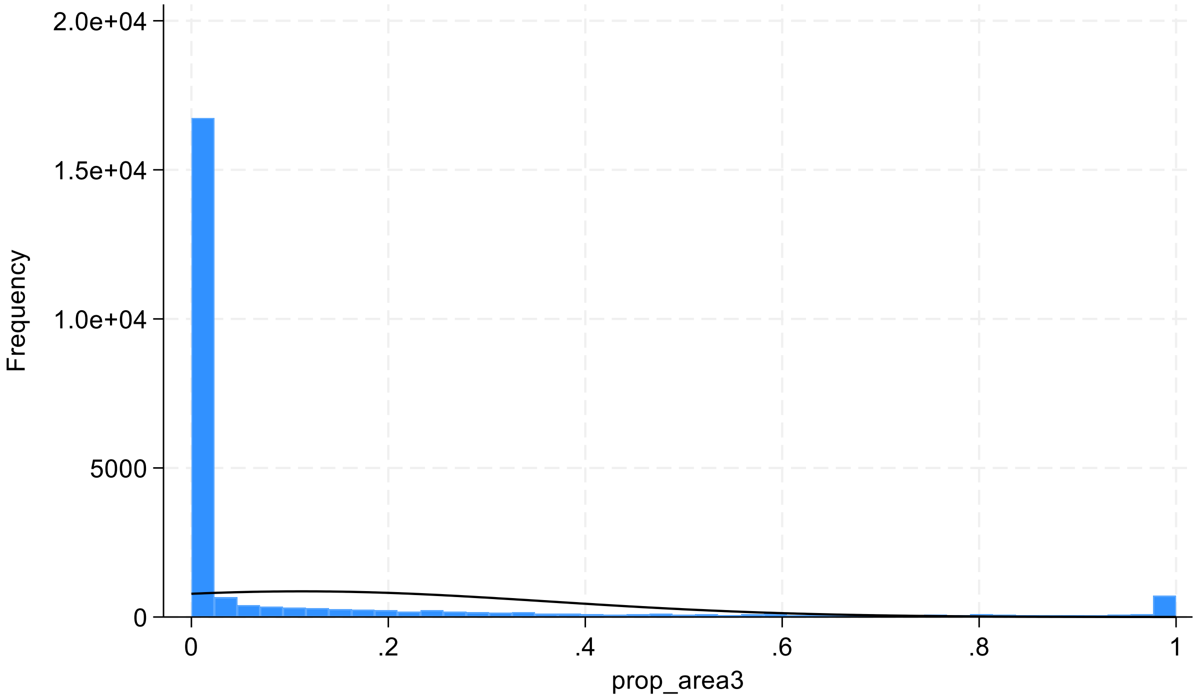
% of tract exposed at various distances

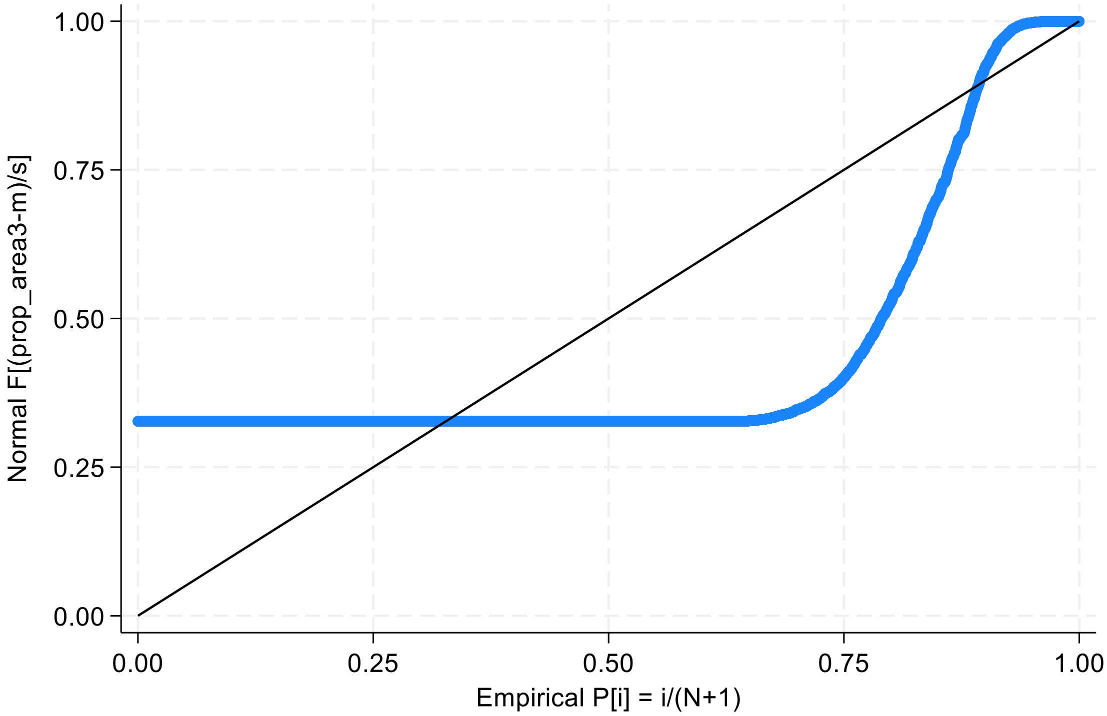


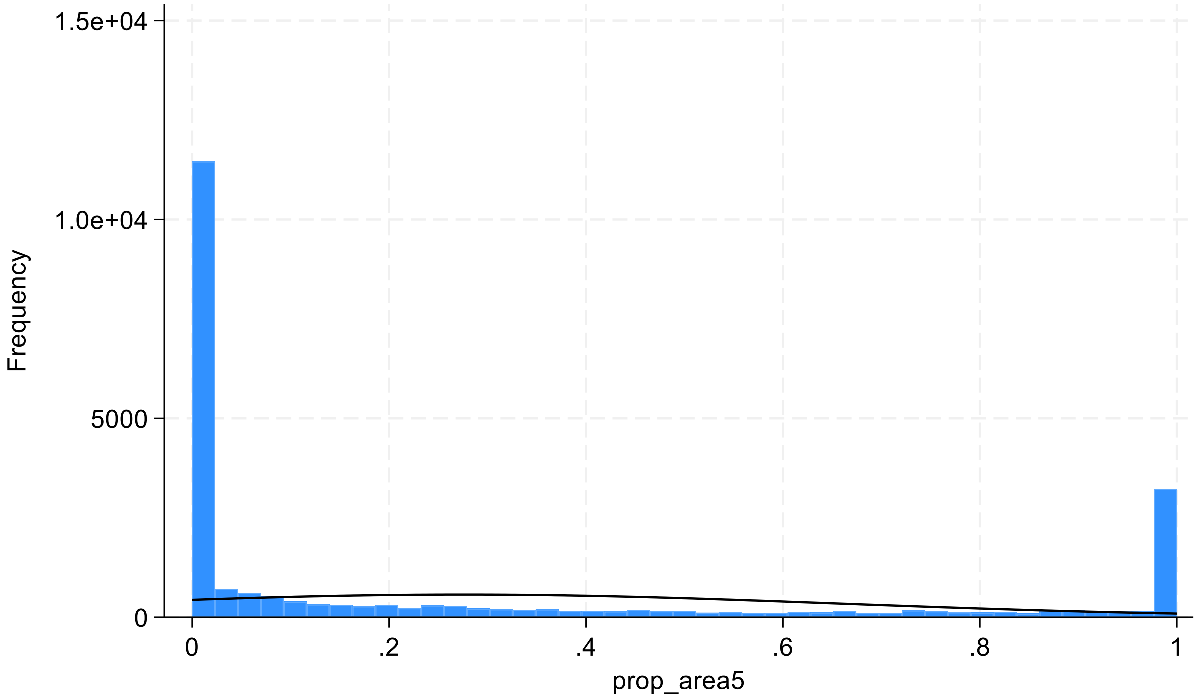


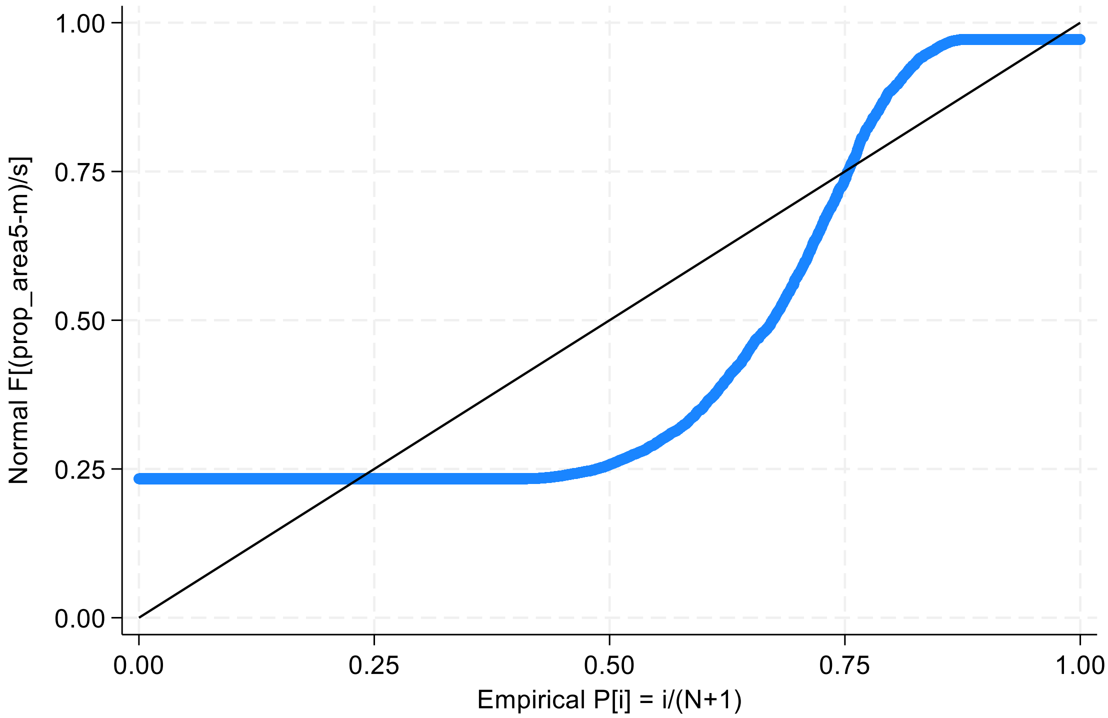

Frequency
2.0e+04
1.5e+04
1.0e+04
5000
0
0
.2
.4
.6
.8
1
prop_area1


Normal F[(prop_area1-m)/s]
1.00
0.75
0.50
0.25
0.00
0.00
0.25
0.50
0.75
1.00
Empirical P[i] = i/(N+1)


2.0e+04
1.5e+04
1.0e+04
5000
0
Frequency
0
.2
.4
.6
.8
1
prop_area3

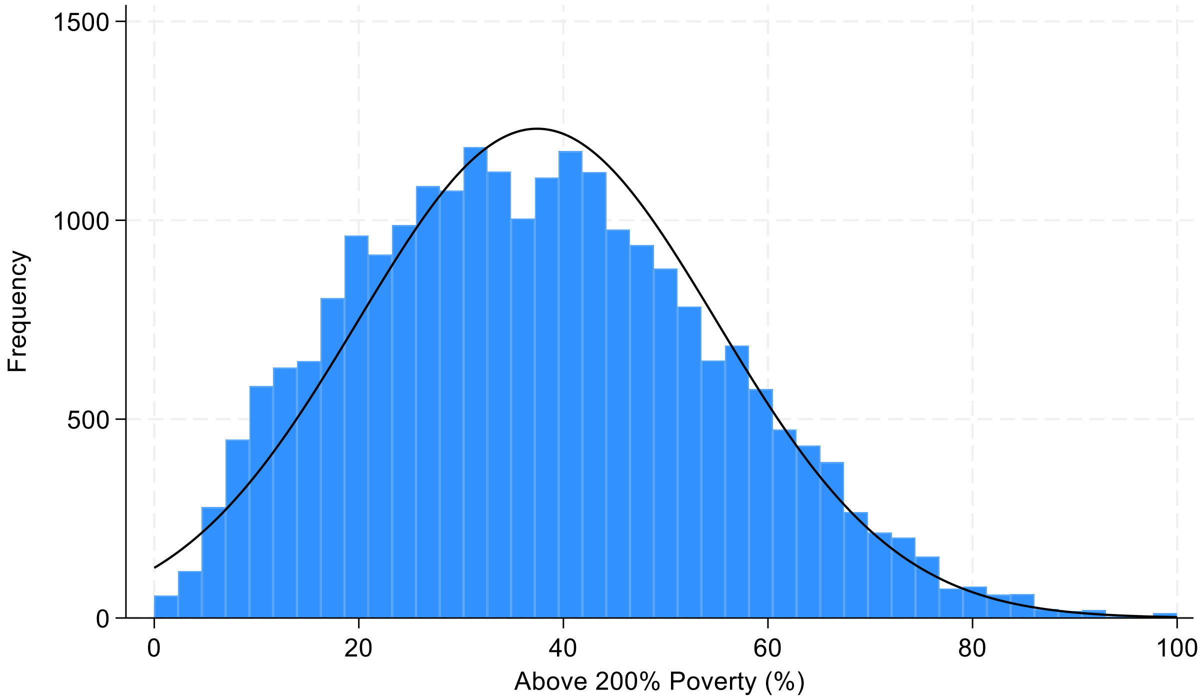

1.00
0.75
0.50
0.25
0.00
Normal F[(prop_area3-m)/s]
0.00
0.25
0.50
0.75
1.00
Empirical P[i] = i/(N+1)

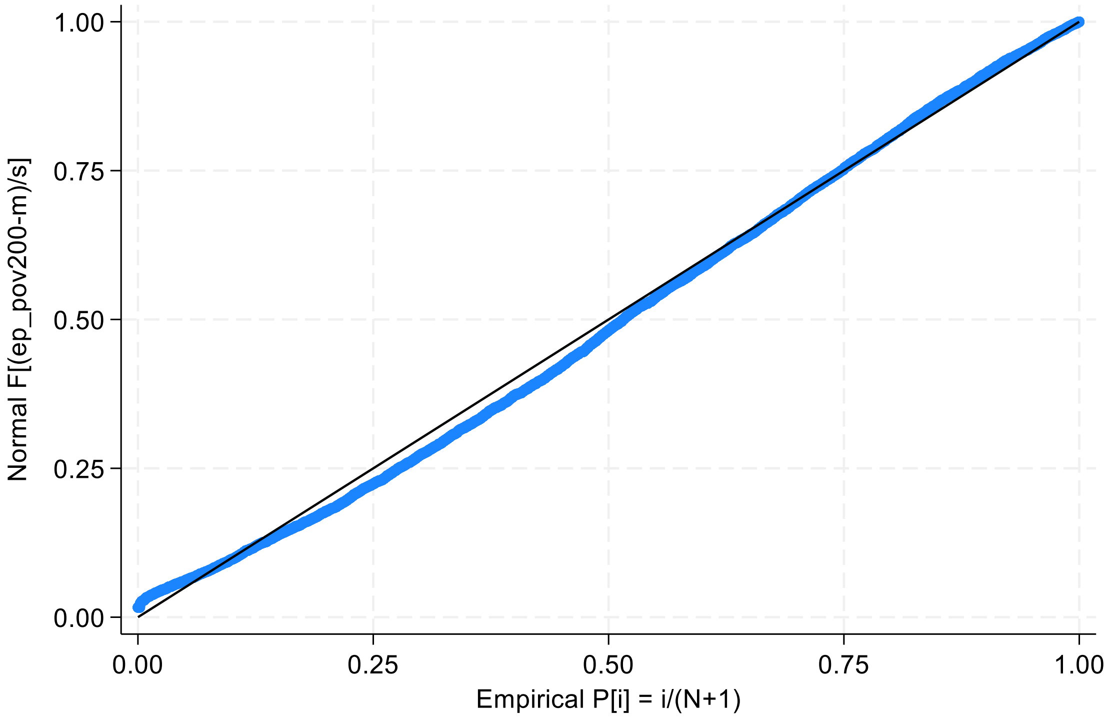

1.5e+04
1.0e+04
5000
0
Frequency
0
.2
.4
.6
.8
1
prop_area5

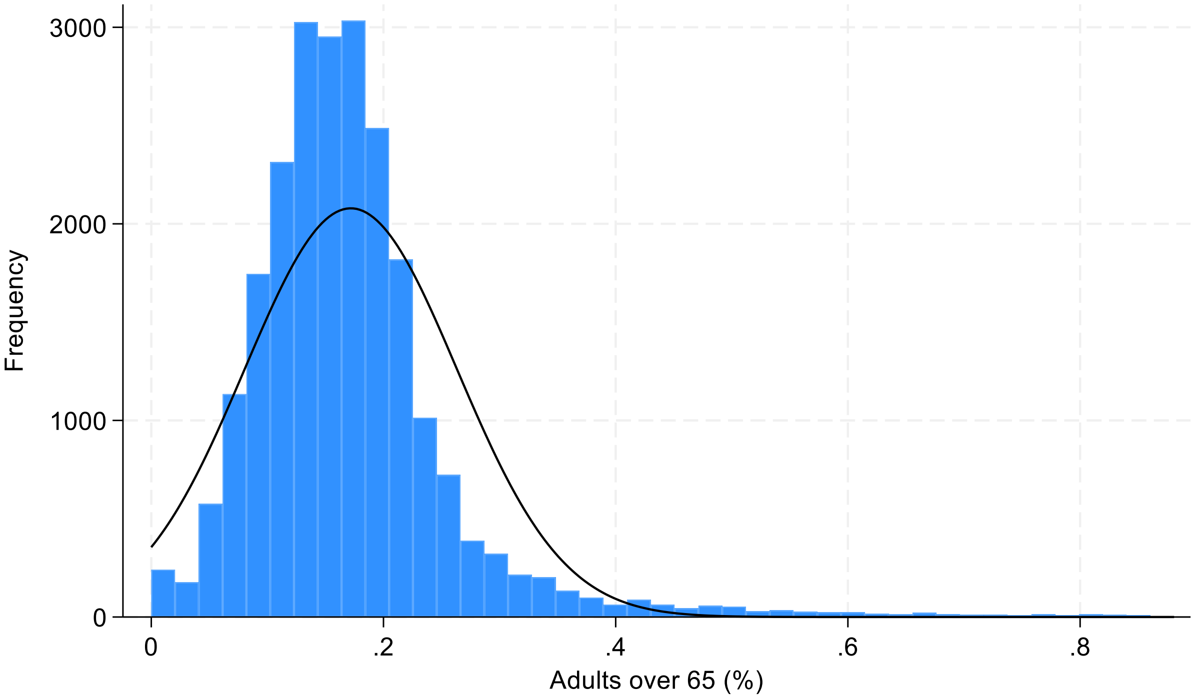

1.00
0.75
0.50
0.25
0.00
Normal F[(prop_area5-m)/s]
0.00
0.25
0.50
0.75
1.00
Empirical P[i] = i/(N+1)

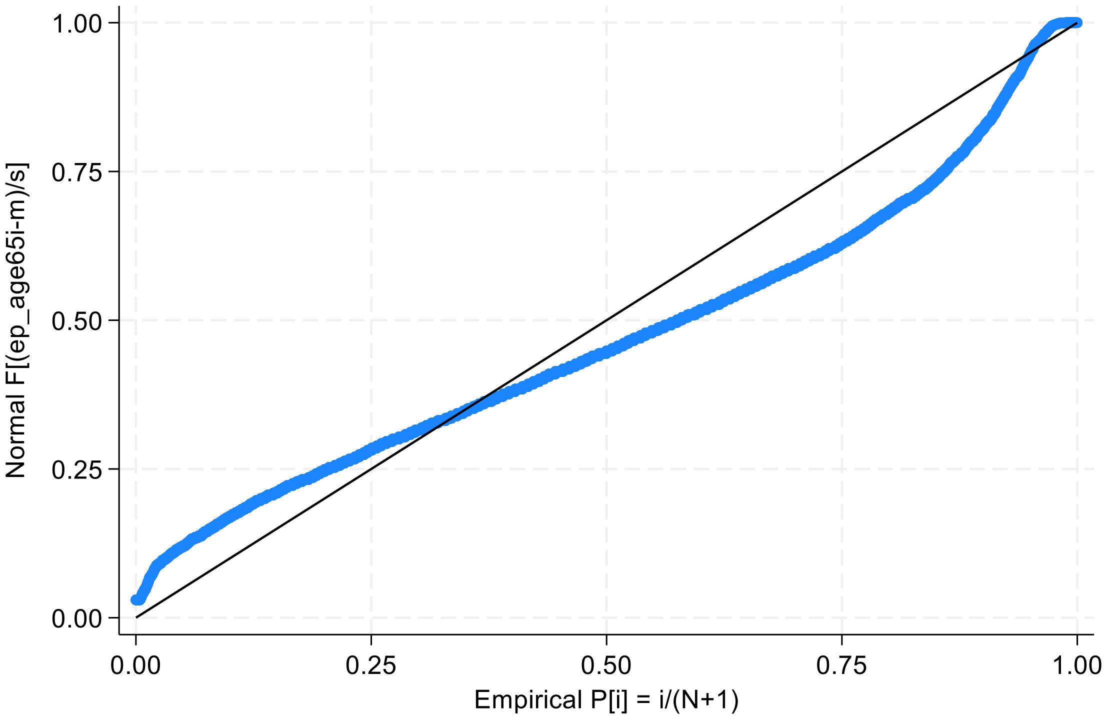
Appendix D

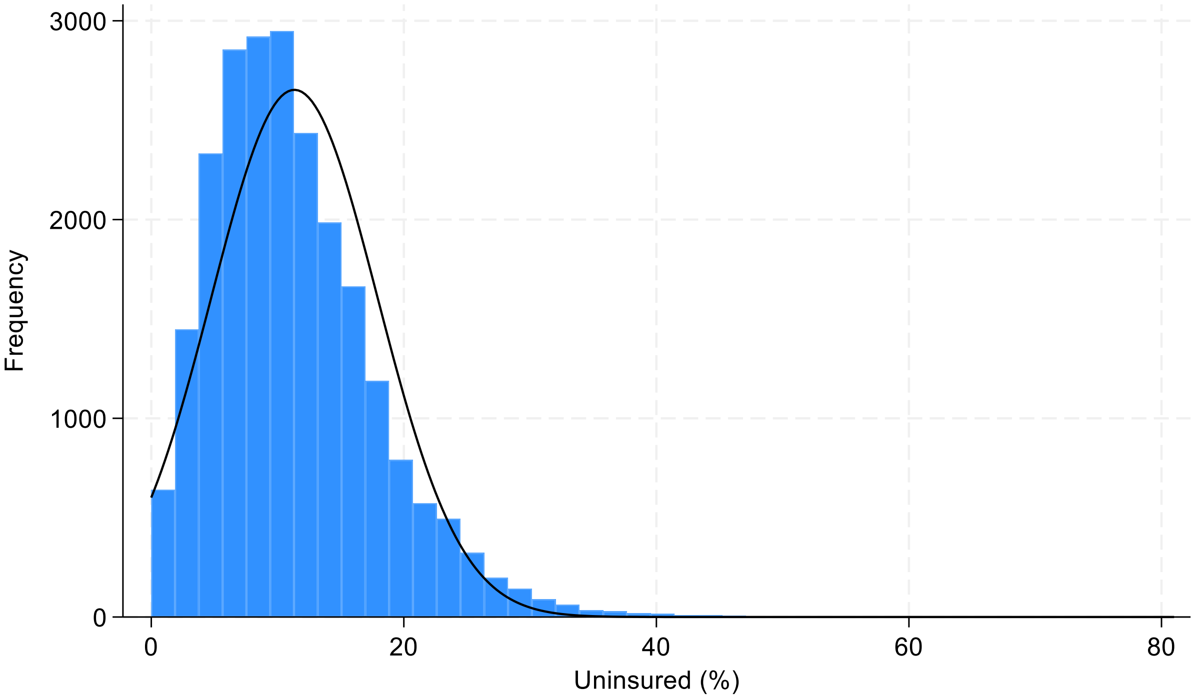
Adjustment Variables.

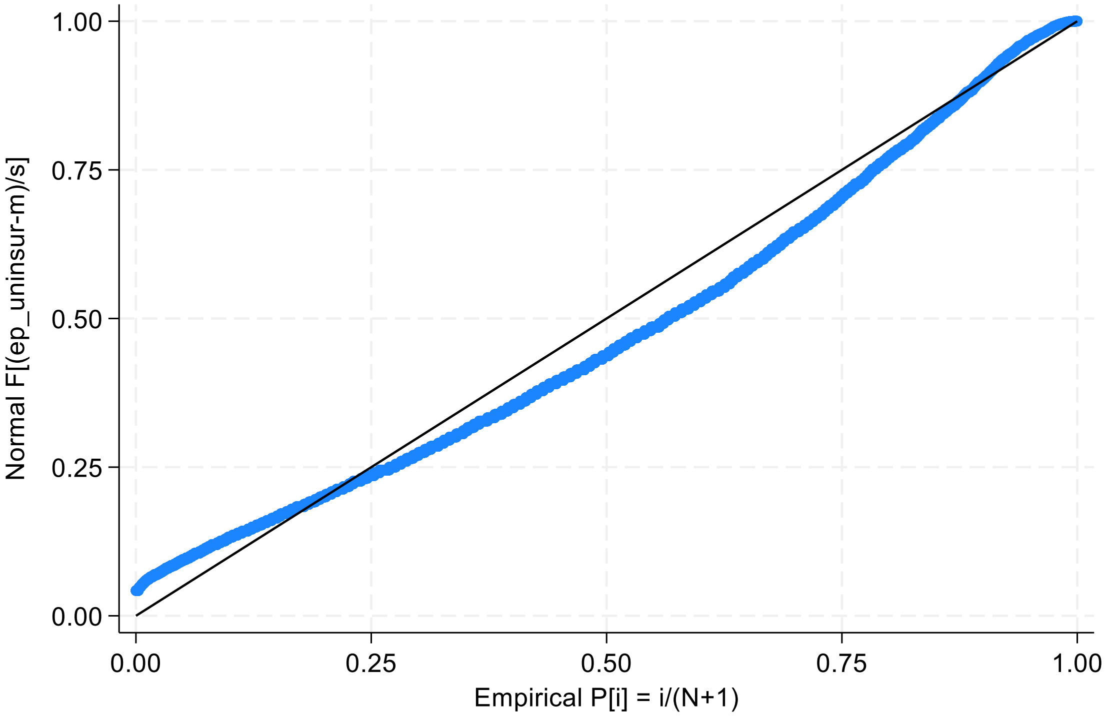





3000
2000
1000
0
Frequency
0
.2
.4
.6
.8
Adults over 65 (%)


1.00
0.75
0.50
0.25
0.00
Normal F[(ep_age65i-m)/s]
0.00
0.25
0.50
0.75
1.00
Empirical P[i] = i/(N+1)


Frequency
3000
2000
1000
0
0
20
40
60
80
Uninsured (%)


Normal F[(ep_uninsur-m)/s]
1.00
0.75
0.50
0.25
0.00
0.00
0.25
0.50
0.75
1.00
Empirical P[i] = i/(N+1)

```
. tab ruca3

   Rurality |      Freq.     Percent        Cum.
------------+-----------------------------------
      Metro |     19,188       82.51       82.51
      Micro |      2,406       10.35       92.85
      Rural |      1,662        7.15      100.00
------------+-----------------------------------
      Total |     23,256      100.00
```

Model using all adjustments in Multiple Linear Regression and AIC:

```
Akaike's information criterion and Bayesian information criterion

-----------------------------------------------------------------------------
       Model |          N   ll(null)  ll(model)      df        AIC        BIC
-------------+---------------------------------------------------------------
           . |     23,224  -43598.26  -31231.71       7   62477.43    62533.8
-----------------------------------------------------------------------------
Note: BIC uses N = number of observations. See [R] IC note.
```

Model using all adjustments a Generalized Linear Model with Gaussian Family and AIC:
Has lowest AIC and was chosen model and distribution for analysis.

```
Akaike's information criterion and Bayesian information criterion

-----------------------------------------------------------------------------
       Model |          N   ll(null)  ll(model)      df        AIC        BIC
-------------+---------------------------------------------------------------
           . |     23,224          .  -30846.51      14   61721.02   61833.76
-----------------------------------------------------------------------------
Note: BIC uses N = number of observations. See [R] IC note.
```

Model using all adjustments a Generalized Linear Model with Poisson Family and AIC:

```
Akaike's information criterion and Bayesian information criterion

-----------------------------------------------------------------------------
       Model |          N   ll(null)  ll(model)      df        AIC        BIC
-------------+---------------------------------------------------------------
           . |     23,224          .  -49042.44       7   98098.87   98155.24
-----------------------------------------------------------------------------
Note: BIC uses N = number of observations. See [R] IC note.
```